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Informatics in the Future

Proceedings of the 11th European Computer Science Summit (ECSS 2015), Vienna, October 2015

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Editors
Hannes Werthner
TU Wien
Wien, Austria

Frank van Harmelen
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

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Preface

This volume deals with the prospect and "evolution" of Computer Science, which has become the operating system of our society. From individual to collectives, economics, politics, and society, Computer Science influences all spheres of our life. Its pervasive nature lays the foundations to an overarching technological environment carrying an inherent unprecedented potential for change.

In the following, we use the terms Computer Science and Informatics—not being totally correct—synonymously. As we use Kristen Nygaard's definition from the 1980s (there are many more, and quite differing ones): "Informatics is the science that has as its domain information processes and related phenomena in artifacts, society and nature," Informatics (or Computer Science) is not anymore about a specific device, i.e., a computer, it is (or has become) a foundational discipline.

Today, we see Computer Science as *the* science of the information society. Its artifacts change the world, and its methods have an impact on how we think about and how we perceive the world. In classical terms, we refer to an "abstract" machine which can be instantiated by software to any concrete problem-solving machine, having the unique feature to change its behavior due to external and internal states (being self-reflective and exhibiting "intelligent" behavior). However, current phenomena such as the Web, cyber physical systems, or the Internet of Things (IoT) show us that we might already be beyond this idea, exemplifying a metamorphosis from a stand-alone calculator to the worldwide operating system of our society.

Computer Science relies on three methodological pillars: Mathematics/Logic (theory), Science (abstraction), and Engineering (design), with their different paradigms and methods. Combining these pillars—not always without conflicts—Computer Science shows two faces, which cannot be separated:

(a) Acting "from within," e.g., algorithm, design, information presentation, programming languages, distribution aspects, and complexity issues

(b) Acting "for others," being a tool or methodological approach in other sciences and application fields

However, the power of Computer Science and its impact can also be classified in a different way (extending the view of Tedre and Denning in this volume), showing that Computer Science is nearly interdisciplinary by nature—it has rich relationships with technical as well as social science and humanities:

(a) It has become a tool with power and versatility for scientific computing and simulation, changing how science is performed in practice.
(b) It has developed a completely new way of looking at natural and artificial phenomena, fundamentally changing how other fields see themselves and evolve their disciplines. The info-computational theory of science provides a new ontology, epistemology, methodology, and principles of scientific inquiry.
(c) Furthermore, Computer Science creates new things: Unlimited by physical constraints, we build systems that change the world yet are not limited by it.

However, while Informatics has the potential to solve human (not only technical or economic) problems, it is the source of critical issues (e.g., privacy). Taking these contradictory developments into consideration, we will not be able to tackle specific technological or methodological problems in the future without also approaching them on a more "meta-level." We need to fathom and work not only at the origins but as well at the consequences of the change.

As scientists we are driven by curiosity and a wish to understand the world; on the other hand, as engineers we change the world and solve problems with respect to specific objectives (defined by ourselves or somebody else). This often leads to conflicts. It is our responsibility—not only as scientists but also as citizens—to make the public aware of these dichotomies or dialectic relationships of Computer Science. This specific dialectic nature as well as its pervasiveness calls for an interdisciplinary and reflective approach. As we can see, despite its short history, Informatics has both enabled and pushed a substantial development. Computer Scientists will need to reconsider the foundations of our discipline to enable the full potential of our field.

The following presentations and the set of papers of the conference take a first step forward and reflect on these issues, from different perspectives. The broad spectrum of topics ranges from

- Informatics, or a discipline with a (short) history and a high impact
- Interdisciplinarity, or how to do research
- Ethics, or what is our responsibility
- Diversity, or why are so few women in Informatics
- Combining Informatics, History, and Art—a special contribution

In the following, we provide a brief overview of some of the summit's presentations, following the above structure.

Informatics, or A Discipline with Short History and High Impact

We start with the contribution of Matti Tedre and Peter J. Denning named "*Shifting Identities in Computing: From a Useful Tool to a New Method and Theory of Science*." They take a historic approach, showing the development of a discipline and its shifting identities. They show that almost every field—not just science and engineering, but also humanities—has embraced computing and developed its own computational branch. Computing became the most important player in science today (and not only science).

Stefano Ceri in his contribution "On the Big Impact of *Big Computer Science*" takes up the discussion of a new "paradigm" with the popular name *big science* or differently: a data-driven approach in contrast to formal model-driven approach in Computer Science. He observes that the "big science" approach brings unprecedented progress in many fundamental fields, such as biology and medicine. However, he also wonders whether this approach is in contrast with critical thinking and model-driven scientific methods. Finally, he discusses how the data-driven approach will impact our university curricula and education.

Interdisciplinarity, or How to Do Research

As already Stefano Ceri points at the issue of interdisciplinarity or cross-disciplinarity, this topic is further elaborated by Maarja Kruusmaa and her contribution "*On Informatics, Diamonds and T*." She reflects upon ICT and Informatics research, highlighting that it is per se an interdisciplinary endeavor. And, interdisciplinarity is inherently a team effort, requiring us to consider team work in a fundamentally different way. This puts emphasis on education as well as team building. The chapter uses robotics as an example of an interdisciplinary research area, heavily relying on ICT expertise but additionally on other disciplines such as biology, social sciences, and law.

In such an interdisciplinary setting, the issue becomes how to organize research, and one way is without doubt to show strong leadership. This is described—in the special case of a nonuniversity research setting—by Dunja Mladenić and Marko Grobelnik and their contribution "*Leadership and Balance in Research*." They provide several observations, based on their experience of many years. One is that leadership requires clear philosophical alignment and fundamentals shared between all the members. An important issue is the organization of the team, which should be preferably flat (but not too flat) with well-defined roles, but as fluid as possible. And not surprisingly, one of the major fundamentals is to develop trust between people and maintain good human relationships.

Ethics, or What Is Our Responsibility

Given the pervasiveness of Computer Science, both in its artifacts and its methods, the issue is how to deal with this development as a society as whole, but also as scientists being at the roots of these developments. In the first paper of this section, Bertrand Meyer classifies his contribution "*Rational ethics*" as an effort to refound ethics on the rules of logical reasoning, basing this approach on a few basic principles. In such a way he also provides hints for an "operationalization of ethics"; he argues that taking a reasoned approach to ethics, based on the careful application of a few well-defined principles in a strictly delimited scope, one can obtain guidance for some of the most difficult decisions humans have to make.

Also Jeroen van den Hoven treats ethical issues in his contribution "*Ethics for the digital age: where are the moral specs?—Value Sensitive Design and Responsible Innovation*," or how to do ethics of Informatics or IT today. He notes that our way of keeping tabs on technological developments (e.g., IT assessment or regulations) is no longer sufficient. These attempts are often too late or too slow. We are trying to regulate future technology with yesterday's legal regimes. Thus, "How should we make our ethics bear upon high impact and dynamical digital phenomena?"

A critical case in this respect is security, closely related to privacy and sovereignty. Reinhard Posch's contribution "*Digital Sovereignty and IT-Security for a Prosperous Society*" shows that Europe with its (hoped for) Digital Single Market, covering all 27 member states, makes substantial efforts with respect to legislation where IT security plays a vital role. But this is not only seen in a "protective" view, but it could also provide a chance for innovation and economic development. Here, he underlines the issue of European digital sovereignty.

Diversity, or Why So Few Women in Informatics

The next chapter deals with women in computing, presented by Britta Schinzel. Her contribution "*Women in Computing and the contingency of informatics cultures*" highlights that early programming was highly shaped by women, and when and why computing moved into the hands of men. Interestingly, women's participation is a cultural issue and mainly a problem of western and north-western countries in the world. She explains clearly that to increase women's participation requires structurally embedding measures into our work culture.

Combining Informatics, History, and Art: A Special Contribution

In this final chapter, Britta Schinzel gives an overview of an opera libretto dealing with "*Ada—poet of computing*." It is a combination of art, history, and computing and, given this unique combination, also an outlook into the future, demonstrating skills needed to shape the future (that is not technology alone). The libretto was written on the occasion of the 200th anniversary of Ada's birthday (Dec, 10th, 1815). Lady Ada Lovelace's—more correctly Augusta Ada King-Noel, Countess of Lovelace (daughter of Lord Byron)—notes on Charles Babbage's analytical engine are seen as the first algorithm which could be carried out by a machine. As such she is the first computer programmer. The libretto describes her life and work—with all the challenges to illustrate abstract mathematical abilities concepts; maybe art helps.

At the end of this preface, we would like to take the opportunity to express our gratitude to all who contributed to this volume. We acknowledge the authors' patience for waiting for this volume to be printed. Furthermore, we are grateful to Informatics Europe, in particular to their President Lynda Hardman and their Secretary General Cristina Pereira, for their support and for chasing belated authors as well as slow-acting editors. We also thank Springer for producing this volume.

Wien, Austria — Hannes Werthner
Amsterdam, The Netherlands — Frank van Harmelen

Contents

Chapter 1
Shifting Identities in Computing: From a Useful Tool to a New Method and Theory of Science

Matti Tedre and Peter J. Denning

Abstract Following a number of technological and theoretical breakthroughs in the 1930s, researchers in the nascent field of automatic computing started to develop a disciplinary identity independent from computing's progenitor fields, mainly electrical engineering and mathematical logic. As the technology matured in the next four decades, computing emerged as a field of great value to all of science and engineering. Computing's identity as an academic discipline was the subject of many spirited debates about areas of study, methods, curricula, and relations with other fields. Debates over the name of the field and its relations with older academic departments occupied many hours and journal pages. Yet, over time computing revolutionized practices, then principles, of science and engineering. Almost every field—not just science and engineering, but also humanities—embraced computing and developed its own computational branch. Computing triumphed over all the doubts and became the most important player in science today.

1.1 Introduction

Computing has come to pervade every sector of life. Everyday citizens want to know if it is really true that advanced automation will take their jobs, and whether some outcomes of computing research, such as artificial intelligence, are dangerous. Educators want to know what their curriculum should say about computing or what is meant by popular terms like "computational thinking". Researchers want to

M. Tedre (✉)
Department of Computer and Systems Sciences (DSV), Stockholm University, Borgarfjordsgatan 8, 164 07 Kista, Sweden

School of Computing, University of Eastern Finland, Joensuu, Finland
e-mail: matti.tedre@uef.fi

P.J. Denning
Department of Computer Science, Code CS, Cebrowski Institute, Naval Postgraduate School, 1411 Cunningham Rd GE-314, Monterey, CA 93943, USA
e-mail: pjd@nps.edu

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know whether computing can help solve problems in their fields and whether computer scientists who join their teams are peers or just programmers. Students want to know what they would study in computing and what kinds of jobs might be available to them. To give a context for any answer to these concerns, we propose to examine what is computing as a discipline and where it comes from.

Some of us might think that computing as an academic discipline began in the 1990s with the World Wide Web, or in the 1980s with personal computers and networks, or in the 1970s with the microchip and Internet, or in the 1960s with time shared operating systems. Others point to the automatic computing projects started in the 1940s by the military as the beginning, as well as the advances in mathematical logic in the 1930s. It is not easy to pinpoint an exact beginning for computing and computer science. In fact, computing in the sense of calculating numbers has been a human concern for thousands of years.

For millennia, merchants, engineers, and scientists have relied on mechanical instruments to calculate numbers. Tools like the abacus have been with us for as long as historians can see. Mathematicians have produced many clever methods (today called algorithms) for calculating numbers. Some methods eventually were embodied into machines. In an explosion of interest in the 1600s, Pascal invented a simple machine for calculating sums and differences, and Napier invented the logarithm for multiplying numbers fast. The Pascal machine was the first in a long line of machines that became ever better at helping merchants, leading up to marvels such as the Marchant calculator in the 1920s, which with many gears and levers could add, subtract, multiply, and divide. The Napier logarithm initiated a long line of slide rules that were the most popular computing instrument among engineers and scientists for the next 300 years—until 1972 when the Hewlett Packard pocket digital calculator made the slide rule obsolete.

In the middle of these ancient currents, Charles Babbage proposed to the British government in the 1820s that he could build a machine—the Difference Engine—that would calculate numerical tables error-free. He noted that many shipwrecks were the result of errors in hand-calculated navigation tables. Alas, his machine demanded greater precision in lathing the gears and levers than the technology of his day could achieve. Dissatisfied by his inability to produce a working machine, the government cut off his funding in the 1830s. In his frustration with the obstacles in getting the Difference Engine finished, he started designing the Analytical Engine, a new machine with fewer parts that would be programmable and more versatile than the Difference Engine. He collaborated with Lady Ada Lovelace, Lord Byron's daughter, who designed algorithms for the Analytical Engine. She became known to history as a "programmer" of the first general-purpose computer, albeit the machine was a hypothetical one. However, Babbage was unable to get much funding for the machine and the project died with him in 1871.

Development of all kinds of computing instruments continued. In the early 1900s the US government developed an interest in machines for fire control of weapons. It sponsored projects including Vannevar Bush's Differential Analyzer at MIT in the late 1920s for solving differential equations. In the 1930s governments in Germany, UK, and US developed sophisticated electronics for radar and networks of radars. Some of their engineers became interested in whether the electronics could be used to build machines that computed numbers, resurrecting Babbage's dream. Around 1940, the US Army commissioned a project at University of Pennsylvania to build an automatic computer, ENIAC, that would calculate ballistic tables for artillery. In those days the term "computer" named individuals whose profession was calculating numbers, and the "automatic computer" replaced slow error prone human computers. In 1945 a small group of computer designers led by electrical engineers Eckert and Mauchly and mathematician von Neumann, proposed a design for an electronic stored program computer. The first of these was working by the end of the 1940s and the computer industry was born in the 1950s. By then it had been 80 years since Babbage dreamed of a programmable computer.

One of the great ironies of the computer is that, owing to the complexity of computer systems, it is extremely difficult to ensure that a machine will, even in theory, compute its numbers correctly. Thus the machines Babbage dreamed about turned out to be prone to errors, like the human processes they were to replace. The biggest challenges in computing today continue to be the design of reliable and dependable computer hardware and software.

By 1960 computer science had become a common name for the new field of automatic computation, and academic departments were formed to gather faculty and educate students. In the early years universities resisted the formation of the new departments because computing looked like a technology field without a pedigree. There were endless arguments and debates over the years about whether computing is a legitimate field of science and engineering, and if so, what is its subject matter. Our purpose here is to explore some of these debates and show what identity has emerged in the 80 years since the first electronic digital computers were built. What has emerged is a strong, principled field, which some argue has the status of a new domain of science alongside the traditional domains of physical, life, and social sciences. Let us tell you this story.

1.2 The Birth of a Discipline

A major impetus to computing's emergence as a discipline was given in the late 1940s and early 1950s by a change in computing's status in universities. Many academic pioneers, who were not called computer scientists at the time because there was no such field yet, played important roles in technical innovation in computing. They included, for example, Bush at MIT, Atanasoff and Berry at Iowa State University, Aiken at Harvard, and Kilburn and Williams at University of Manchester (Aspray 2000). But after the World War II, hardware research and development moved quickly to private companies' laboratories; academic computing people were faced with increasing demands to train future computer programmers and engineers. Some universities started to offer courses and degrees in computing in the late 1950s. Still, computing pioneers had to justify their work as a new field that overlapped greatly with mathematics and electrical engineering and to withstand pressure from academic administrators who wanted computer science to be a branch in one of the existing departments.

Computing's place in the academic world was uncertain at the beginning. In its early days, computers were seen as tools for numerical calculation. A community of mathematicians called numerical analysts devised algorithms for mathematical functions that would not succumb to round-off errors from the machine's use of finite registers to represent real numbers. Engineers worked on making the machinery faster, smaller, more reliable, and cheaper. The job of software design was often left to the numerical analysts, who designed the bulk of software used for scientific and engineering computing. Some business schools also entered the fray with groups that designed software of use in companies such as accounting and tabulating systems.

For nearly four decades after the first electronic computers were built, the people involved were almost all primarily occupied with getting the technology of computers and networks to work well. Despite astounding progress with the technology, the academic field of computing remained an enigma to outsiders in established fields of science and engineering: depending on the observer, it looked much like applied mathematics, electrical engineering, industrial or business applications, or applied science (Denning and Martell 2015). From this diversity arose a perennial question: who should own computer science? The School of Science, which housed Mathematics, the School of Engineering, or even the School of Business? Even more, should computer science be a division of an existing department or a new department?

It is no surprise that the early discussions about organizing the new field were filled with debates about what to name the field (Tedre 2014). Some name suggestions (of which some were less serious than the others) emphasized the field's theoretical elements: Turology, comptology, algorithmics, hypology, and computing science. Others emphasized computing's technical aspects: Computer science, computerology, technetronics, and computics. Some names, like datalogy and informatics, called attention to the "material" that computers process. Others, like intellectronics, bionics, autonomics, cybernetics, and synnoetics, called attention to the field's interdisciplinary and societal nature. Yet others, such as Turingineering, attempted to combine theory and practice into one. Although names create strong impressions of a field's research agenda—its driving questions, research outputs, methodology, valid interpretations of results, and place among other disciplines—names never capture the richness of any field and many fields have evolved well beyond what their names suggest (Knuth 1985).

The intensity of interest in computing and of the debates about computing strongly motivated computing people to form societies and professional organizations early. In 1946 the American Institute for Electrical Engineers (AIEE) founded a society for computing professionals. The next year 78 people convened at Columbia University in New York to found the Eastern Association for Computing Machinery, today known as the ACM. In 1951 the Institute of Radio Engineers (IRE) started another professional group for computing, which after mergers between AIEE and IRE, became the IEEE Computer Society (Tedre 2014).

A division between engineering oriented members of AIEE, IRE, and IEEE and the more mathematically oriented members of ACM emerged early: the ACM focussed more on theoretical computer science and applications, while the engineering associations focussed more on standards, hardware, and technological issues. In addition, a variety of communities of different sizes and foci emerged at a rapid succession and in different countries, each providing to different groups of professionals and academics (Ensmenger 2010).

In the 1950s there was a broad realization of computing's value to science, engineering, business, and various other sectors (Akera 2007). Industry looked to academia to provide computing education for graduates who would be qualified for the rapidly-growing computing sector. Yet, despite generous support from private companies, universities were slow to start computing education (Ensmenger 2010). Many academic computing people, who worked in different departments, found themselves in weak positions: computing lacked independent student and staff quotas, faculty billets, budgets, computing centers, leverage in university politics, and representation in national or international boards (Tedre 2014). There were few directed grants for computing, and research funding agencies such as the National Science Foundation in the US had no computing-specific research programs. In short, computing had a very weak identity. And yet there was a growing desire for independence (Tedre 2014).

1.3 The Quest for Independence

Arguing for independence was a dilemma in its own right. Computing's original cornerstone ideas originated from insights by mathematicians, logicians, scientists, and electrical engineers. Mathematicians and scientists described numerical methods that solved differential equations in small, discrete steps, thus showing that computing opened new doors for scientific discovery based on simulation of mathematical models. Logicians contributed the ideas of representing data and algorithms as strings of symbols in languages; the idea of a universal system that could compute anything any other system of computation could; and the idea that data could be reinterpreted from representing numbers to representing algorithms. Electrical engineers contributed circuits that performed basic arithmetic and that sequenced the operations of an encoded algorithm; they provided means to combine these many circuits into full-blown computers; they discovered that binary representations were easy to generate and led to the most fault tolerant circuits; and they discovered how to use clocks to avoid the devastations of race conditions.

Because these insights originated in the expertise of different fields, arguing that computing was a new field was a tough challenge. Academic advocates of computer science found themselves in the unenviable position of arguing that while it shared aspects with mathematics, logic, science, and engineering, computing was not reducible to those fields. They also had to argue that computing was not merely technology—at the time technology departments were not well regarded in many academic institutions. The most well known example of an argument that tried to walk this tightrope came from Newell, Perlis, and Simon in 1967 who said that computer science studies phenomena surrounding computers (Newell et al. 1967). There were many critics of this argument, mostly around the belief that only studies of natural phenomena can be science, but computers were artifacts. This critique so irritated Herb Simon, a Nobel Laureate in Economics, that he wrote a book *Sciences of the Artificial* (Simon 1969), which demonstrated that many other established sciences already accepted human constructs as part of their phenomena.

For these reasons, early computing departments started in places of safe refuge in their universities. Those who were most interested in building and studying hardware did so within electrical engineering departments, sometimes forming a computing division of their departments and sometimes adding "computer" to their titles, as in the Electrical and Computer Engineering (ECE) departments that sprang up in the late 1960s. Those who were most interested in computational methods did so within a mathematics context. For example, Purdue founded the first computer science department in 1962 in the Division of Mathematical Sciences in its School of Science. Each university placed computer science in whatever existing school (engineering or science) would protect and nurture it. Within 20 years there were over a 100 Ph.D.-granting computer science departments in the United States and Canada. Yet, the founding of those departments was an intensely political process in the universities (Tedre 2014).

The process of placing new computer science departments in hospitable environments of their universities led, not surprisingly, to an intensification of the debates over the roles of the three roots (engineering, science, and mathematics) in the identity of the field. Some founders such as McCluskey at Princeton, Aiken at Harvard, and Wilkes at the University of Cambridge, believed that the primary work of the field was constructing hardware and software, which they regarded as an inherently engineering task. Some founders, such as Newell, Perlis, and Simon mentioned earlier (Newell et al. 1967), and Forsythe at Stanford (Forsythe 1968), argued that computer scientists should develop an empirical approach. Some, such as McCarthy (1962) and Hoare (1969), advocated a thoroughly reductionist view of computing that was like theoretical physics, where computing was reduced to axiomatic, mathematical, and purely deductive science.

In 1989 a committee of the ACM and IEEE, led by Peter Denning, sought to reconcile these three views by integrating them into a "theory–abstraction–design" model (Denning et al. 1989). The three historical roots of mathematics, science, and engineering contributed important paradigms to the way computing was done, and from their blend emerged the unique field of computing. They recommended using the term "computing" for the field rather than "computer science and engineering", and the name stuck. The Europeans had been using the term "informatics" in the same way and did not change from their established usage. The ACM/IEEE unified view helped, for its part, to pull the field back from two controversies—software engineering and computational science—that nearly split the field in the 1980s and 1990s. We will discuss these controversies shortly. About 20 years later, Denning and Freeman noted that the controversies had settled and they articulated a unique paradigm for computing that had emerged from the blend of the three root paradigms (Denning and Freeman 2009).

Paradoxically, even though academics tried to distance themselves from computing technology, it was the exponential advance of computing technology, captured by the statement of Moore's law, that opened the space of possibilities for computing to be accepted under its own identity. Every 10 years, chip makers accomplished the amazing feat of increasing the speeds of their chips by a factor of 30 with no increase of size or cost. That meant that computing kept expanding its reach as algorithm designers and engineers invented ingenious ways to automate tasks that only a decade before seemed impossible. On top of this, more and more things were converted into digital representations, meaning that computers came to be able to manipulate almost any information in the world. By the late 1990s, it was clear that computing is indeed a unique phenomenon and requires an independent discipline that aims to understand and harness that phenomenon.

1.4 Search for Disciplinary Identity

In search of the field's disciplinary identity, computing pioneers started to investigate their field's foundations. To start with, all academic fields of science and engineering like to define what they study with a pithy phrase. For example, physics studies the nature and properties of matter and energy. Chemistry studies the nature of substances and their interactions and bonding. Biology is the study of living organisms. What does computing study?

Some earliest proposals—especially that computer science studies computers—were rejected by many scientists who did not see computers as a natural phenomenon and who thought that technology developments in digital electronics did not merit an academic department. Similar, the argument that computer science is the study of phenomena surrounding computers (Newell et al. 1967), although widely quoted among people in computing, did not sell well with other academic departments.

A new argument that "computer science is the study of algorithms" began to emerge in the late 1960s. The idea was that programs are actualizations of algorithms to control machines. Even though the machines and executable programs are physical artifacts, algorithms are abstract mathematical objects that map inputs to outputs, and they can be analyzed formally, using the tools of mathematics. A strong impetus for this argument came from Donald Knuth, whose books *The Art of Computer Programming* developed rigorous analysis of algorithms and became very popular and influential. Another influence was Edsger Dijkstra, who coined the term "structured programming" for his methods of organizing programs (Dijkstra 1972). These pioneers articulated a vision of a programming as an elite, if not noble, calling that required great skill in mathematics, logic, proof, and design to formulate, analyze, and demonstrate great algorithms. They helped to put the algorithm at the center of computing.

Because pragmatic algorithm design most often involves programming, the algorithm-centric movement became known—right or wrong—to many as the “CS = programming” movement. Programming was seen to be the central activity of computer science, and the notion of mathematically oriented elite programmer became the educational goal of many computer science departments. But there were problems with this algorithms-oriented interpretation of the field, too. One was that it often ignored a large segment of the field that was involved in the architecture of computing machines and systems, such as instruction set design, operating systems, databases, graphics, and artificial intelligence. These specialties shared an engineering tradition whereby system builders and software developers constantly evaluate trade-offs in their search for systems that work. The idea of a trade-off did not fit with the idea that algorithms should have precise specifications and be provably correct.

Another problem with the algorithms-oriented interpretation was that, at least in the US, government labor departments did not understand it or agree with it. When they finally added the category “programmer” to their official lists of occupations, they defined a programmer as a fairly low level coder, someone who translates an algorithm design into a working machine code. The official public definition was a small subset of the noble view of programmers held by many pioneers of the field. Computer scientists argued against the programmer-as-coder view for years to no avail, meanwhile continuing to use the term programmer in the way that they wished it to be understood. This produced a large gap of misunderstanding between the general public and working computer scientists, which contributed to an identity crisis that strengthened around 1980 and took another two decades to resolve. That identity crisis surfaced in many ways and it fueled three crucial debates about computing—about experimental computer science, software engineering, and computational science.

Conflicts around experimental computer science became apparent in the late 1970s, and, for various reasons, they manifested first with issues with computing workforce (Feldman and Sutherland 1979). Many faculty members in computer science departments with systems expertise—such as computer architects, operating systems engineers, and graphics experts—were receiving lucrative offers from industry laboratories to join them. This created a “brain drain” that depleted systems faculty. It compounded the problem that many departments were strongly under the mathematics influence and looked to prolific publishing in theoretically oriented journals as a primary measure of academic impact. Systems developers, whose work involved a lot of experimental design and development, published fewer papers and their colleagues did not regard their design solutions and software as legitimate forms of publication. For many systems developers, who faced a hard time gaining tenure, the choice was easy when industry labs offered them positions at twice the salary.

This imbalance troubled many leaders of ACM, IEEE, and industry. They looked for the computer science departments to educate people in computing and prepare them for the workforce, but industry sought much more systems emphasis than the mathematically inclined departments were offering. Jerry Feldman of the

University of Rochester and his team published a report documenting what they called the "experimental computer science crisis." They called for help from the government, especially the US National Science Foundation (NSF) (Feldman and Sutherland 1979). Over the next 2 years the assembly of CS department chairs issued its own "Snowbird Report" on the crisis (Denning et al. 1981), and the ACM executive committee highlighted the crisis and discussed the nature of experimental computer science (Denning 1981; McCracken et al. 1979). The groundswell of community support around these reports led the NSF to create a program called CER (coordinated experimental research) and to fund a proposal to build the CSNET (the ARPANET-inspired network among all CS departments and research labs).

Although the crisis was readily acknowledged and actions taken, there were recurring issues with experimental computer science itself: What does experimental computer science, strictly speaking, mean? Although the mathematicians of the field would not be expected to have much interest in experimental methods, the engineers would. However, most of the engineers of the early days were so focused on getting technology working that they had a different notion of experimentation from traditional scientists. Engineers used the term more in the sense of "tinkering"—a search to find implementations of systems that worked. Traditional scientists think of experiments as means to confirm hypotheses by setting up an apparatus to generate data. These differences of terminology contributed to a sense of vagueness about what experimental computer science is (Tedre and Moisseinen 2014)—was it proof-of-concept, product testing, comparisons of implementations, or controlled experiments? Moreover, after the Feldman and Snowbird reports (Feldman and Sutherland 1979; Denning et al. 1981) the matter of experimental computer science got politicized, which further hindered its adoption (Tedre 2014). But despite terminological wrangling, the efforts to acknowledge computing's unique ways of working gradually produced a more tolerant attitude in academic tenure committees toward design-oriented experimental system research, and the experimental computer science crisis abated by the late 1980s.

Secondly, the software engineering aspects of computing's identity crisis were the outgrowth of a new movement begun in the late 1960s to establish a subfield called *software engineering*. A group of concerned experts from academia, government, and industry convened at a NATO conference in 1968 to decry the expanding "software crisis" and develop an engineering approach to contain it (Naur and Randell 1969). One aspect of the software crisis was that software systems were getting ever larger and more complex, and thus less reliable and dependable, creating many safety and economic hazards. The NATO group called for an engineering approach to developing software, arguing that engineers had mastered the reliability and safety issues in many other fields. This drew many academic departments into the work of defining the software engineering field and designing curricula to teach it.

Despite substantial progress in the next 20 years, software engineers had not tamed the "software crisis". In 1987 Brooks published a famous assessment of software engineering, "No silver bullet" (Brooks 1987). He claimed that a wide variety of technologies had been developed to help software developers—such as new languages, visualization methods, and version tracking systems—but these were addressing low-hanging fruit and not the hardest problem of all, which is to gain an intellectual grasp of the system and its components. Much software engineering research and education has since concentrated not only on tool development and use, but also on the intellectual disciplines needed to deal with the complexities of systems.

Software engineers soon clashed with the more traditional computer scientists who sought mathematical rigor. Some of these debates got so heated that frustrated software engineers such as David Parnas called for software engineers to split off from computer science and set up as a separate, new software engineering department in the School of Engineering (Parnas 1998). As software engineering matured and understanding of computing's constructive character developed, this controversy also settled down and most computer science departments took software engineers on board.

The third debate centered around computational science. It was much more challenging. Unlike the other two it was not an internal clash among computer scientists; it challenged the relationship between computer science and other sciences. In 1982, Ken Wilson, a theoretical physicist, was awarded the Nobel Prize for his work on a computational method he invented called "renormalization group", which yielded new discoveries about the nature of phase transitions in materials. He began to advocate that all of science could benefit from computational methods implemented by highly parallel supercomputers. He articulated "grand challenge problems" from different areas of science that would be cracked with sufficient computing power. He and others advocated that computation was a new method of doing science alongside the traditional theory and experimental methods. They challenged computer scientists to join with them to help build the systems and work out the methods that would solve grand challenge problems. They started a movement that accumulated considerable political momentum behind its focus on "big science" and was culminated in 1991 by the passage of the High Performance Computing and Communication (HPCC) Act of the US Congress. Many fields of science and engineering started to set up "computational" branches.

The computational science movement was a real challenge for computer scientists, many of whom were troubled with the idea that advances in science from supercomputers seemed to be more valued politically than advances in algorithms and computing theory. Some computer scientists stepped up to join grand challenge teams, only to find that the scientist team members viewed them mainly as programmers rather than full-fledged team members. Wilson and others became exasperated with the reluctance of computer scientists to participate and began calling on Deans of Science to establish new departments of computational science in their universities. Many computer science leaders saw that such a bifurcation would be a disastrous schism in computing and worked hard to avert it. The US NSF established a program in HPCC that enticed many computer scientists to join in computational science projects on the stipulation that they be part of cross disciplinary teams.

By the late 1990s these crises were past. Computer scientists had developed much more compelling articulations of what they do and how they could collaborate with other fields. Many others were taking the field much more seriously. The calls to "fold computer science back into the fields of its roots" faded.

1.5 Emergence of a Science

Just as the old controversies were settling a new challenge to computing's identity began to appear. There were a growing number of references to "natural computing", meaning computational processes in nature. One of the influential pioneers was Nobel laureate David Baltimore, who claimed that biology had become an information science (Baltimore 2002). Others argued similar things for economics, physics, chemistry, cognitive science, and other fields in the physical, life, and social sciences (Kari and Rozenberg 2008).

The rapid emergence and development of natural computing is an amazing turnaround from the 1960s, when Simon argued that computing is a science even if it studies artificial phenomena, and when many others believed that the field of computing is fully reducible to mathematics. Today scientists in other fields are saying that their fields include information processes that occur naturally. They are telling computer scientists, "We have information processes too!" This shift has led to a new definition of computing as a discipline as the study of information processes, both artificial and natural. This definition is important because it shifts the focus from the computer to information processes and their transformations. It is also a much more inclusive definition that allows for the computational branches of other fields, including the natural sciences.

This definition also accommodates the three intellectual traditions embedded in computing, which we mentioned earlier—theory, design, and abstraction. The theoretical tradition focuses on mathematical relationships and proofs. The design tradition focuses on the design and construction of computational circuits, machines, systems, and software. The abstraction tradition focuses on experimental work to test algorithms, validate software, find workable system configurations, and support design choices; it was advocated early (Feldman and Sutherland 1979; McCracken et al. 1979) but took many years to develop and earn a stature comparable to the theory and design methods. A combination of these three traditions gained wider currency in computing when other fields acknowledged computing as a third way of doing science and developed computational branches (Denning and Martell 2015).

The 1980s experimental computer science debates, which brought methodology to limelight, were supported in the mid-1990s by methodological meta-analyses, fashionable in many other fields. Many people and research groups analyzed journal articles and conference papers in computing and other fields in order to describe methodology in computing and compare computing research with research in other fields (Tedre 2014). Those meta-analyses found great methodological differences between computing's branches, but also revealed widespread disregard of methodological rigor in computing publications. For example, in a meta-analysis of software engineering literature, Walter Tichy found that only a small fraction of published papers performed experiments that would validate their claimed hypotheses (Tichy et al. 1995).

Meta-analysts urged their computer science colleagues to follow the example of other fields, especially physics, and strive to make computing similar to the older, more established fields. And indeed, by the end of the millennium natural sciences and computing were converging at a large scale—but mostly because natural sciences were becoming more like computing rather than computing becoming more like natural sciences (Denning and Martell 2015; Tedre 2014). Simulation started to compete in popularity with experiments in sciences and with prototyping in engineering (Wilson 1984). Following the success of computational sciences, national governments increased investments in high performance computing and in computing-intensive research to an extent that was called the "supercomputer race" between countries (Wilson 1984). Numerical analysts, having long felt being the "queer people in computer science departments" (Forsythe 1968) found themselves in the limelight again.

With the rise of computational science and penetration of computing into literally all areas of life in an increasing number of countries, computer scientists' disciplinary ways of thinking and practicing gained currency among educators, too. Those ways of thinking and practicing were called "algorithmizing" by Perlis in 1960 (Katz 1960), a "general-purpose thinking tool," by Forsythe in the late 1960s (Forsythe 1968), and "algorithmic thinking" in the 1970s and 1980s by, for instance, Knuth and Statz (Knuth 1985; Statz and Miller 1975). In the 1990s, with the computational science movement, the catchphrase became "computational thinking". Computational thinking was claimed as a valuable educational approach in the 1990s by Papert (1996) and was popularized as valuable for all children by Wing in the 2000s (Wing 2006). Educators gradually understood that in order to prepare students for the computing-pervaded work and world they will face in the future, it is crucial to familiarize them with computing's disciplinary ways of thinking and practicing.

This has raised a new question: where does computing fit in the firmament of all the sciences? There are three generally accepted domains, or families, of science: physical, life, and social sciences. Where does computing fit in? In 2004 Paul Rosenbloom examined the nature of the interactions between computing and other fields. He found that computing either influences or implements processes in virtually every field of science, engineering, and humanities (Rosenbloom 2004). He also found that these are two-way interactions, with the other fields influencing computing. There was no neat fit of computing into any of the three traditional domains. He made a bold claim that computing is a new domain, which he called the computing sciences, and is a peer of the three traditional domains.

The triumph of computing in sciences was evident by the beginning of the new millennium. The first computing revolution in science—the introduction of powerful tools for solving scientific problems—was largely complete. A look into any laboratory in natural sciences would show that computer simulations, numerical methods, and computational models had become standard tools for science, and many other fields in social sciences and humanities were developing computational branches, too. Computer proofs also led mathematicians to re-think the very idea of "proof" and computers became popular at all stages of mathematical discovery (Horgan 1993).

At the same time, a second computing revolution in sciences was well underway. An increasing number of researchers from natural sciences to humanities started to look at their fields through a computational lens, interpreting phenomena in their field as information processes. The new, info-computational model of science (Dodig-Crnkovic and Müller 2011) was greeted as "algorithmization of sciences," (Easton 2006) "the idiom of modern science," (Chazelle 2006) and "the age of computer simulation" (Winsberg 2010). These arguments harkened back to the 1980s, when computational scientists argued that the twin pillars of science—theory and experiment—were now joined by a third, equally important pillar—computing.

Today, computing's effectiveness in sciences has led to two versions of natural computing: the weak argument and the strong argument. "Weak" natural computing states that computers are a great tool for studying the world, and info-computational interpretations of phenomena are very useful abstractions. Few researchers today would disagree with that standpoint. But with the rise of info-computational interpretations of natural phenomena, various researchers started to advance "strong" natural computing—that calculation and interpretation are not enough, but computing plays a fundamental role in the naturally occurring processes of their domains. The strong argument for natural computing is one of the most exciting (and controversial) in the modern history of science: That argument suggests that there must be a reason for the amazing success of computing in predicting and modeling phenomena across all fields of science, and maybe that reason is that the world itself is an information processor. Maybe the world computes.

Over the years pioneers of computing have argued, on various levels and in different ways, for info-computational views of the world. Zuse argued in 1967 that the universe is a cellular automaton (Zuse 1970), Hillis wrote that molecules compute their spatial configurations (Hillis 1998), and Mitchell wrote that living organisms perform computations (Mitchell 2011). Wolfram wrote a whole book making the claim that computing is a new kind of science (Wolfram 2002). Chaitin wrote that the universe constantly computes its own future states from its current ones—"everything is made out of 0/1 bits, everything is digital software, and God is a computer programmer, not a mathematician!" (Chaitin 2006). Whereas Galilei's famous dictum was that the book of nature is written in mathematics, the proponents of weak natural computing would argue that the book of nature is written in algorithms, and the proponents of strong natural computing would argue, in the words of Dodig-Crnkovic, that the book of nature is an e-book: The book itself computes. And, in the minds of many, that makes computing not only *a* science, but *the* science.

1.6 Conclusions

As computing technology moved ever deeper into people's lives, people's perceptions about what computers are evolved and set a context in which the field's identity developed as discussed here.

The first stage of public understanding was computers as number and symbol crunchers. From the earliest days, computing was linked in the public mind to the brain and to intelligence, perhaps because the machines were doing computational tasks that everyone thought only humans could do. The news reports of the first commercial Univac computer in 1950 used the terms "thinking machines" and "electronic brains" (Martin 1993). The business world quickly embraced the computer revolution bringing its own long tradition of "symbolic data processing"—punched-card machines analyzed data such as gender, literacy, and occupation in the 1890 U.S. census and IBM built a strong business machines company in the 1920s. These traditions quickly shifted the interpretation of computers from crunchers of numbers to crunchers of arbitrary patterns of symbols (Hamming 1980).

The second stage of public understanding happened in the 1980s with the emergence of the Internet—computers were seen as communication machines rather than symbol crunchers. The modern cloud-mobile computing age, which realizes a 1960s dream of "computer utility", is a culmination of this way of seeing computing.

The third stage of public understanding started in the early 2000s with the claims that information processes are found through the natural sciences. This interpretation is supported by amazing developments throughout science, where computing blends with other technologies. It has also fostered anxieties about artificially intelligent machines automating most jobs out of existence and perhaps becoming an apocalypse for the world.

In the academic world, the first 40 years of computing focused a lot on developing the technology of computers and networks. Much of the content of curricula reflected the core technologies of computing. With the Internet in the 1980s and Web in 1990s, computing curricula began to adopt social dimensions that featured applications in and interactions with other fields. Today, with the rise of natural information processes, computing is now seen as fundamental in all the sciences and engineering and may even define a new scientific domain. Computing's development as a science and its integration into other areas of scientific inquiry is unrivalled.

Computing's self image has influenced and evolved with these larger changes. Gone are the defensive essays over whether computing is engineering, math, or science. Gone are the internal fights about how to deal with experimental science, software engineering, or computational science.

Computing has fostered two revolutions. The first was computing as a tool with unprecedented power and versatility for scientific computing and simulation, fundamentally changing how science was done in practice. The second was computing as a completely new way of looking at natural and artificial phenomena, fundamentally changing how other fields see themselves and do their work. The info-computational theory of science provides a new ontology, epistemology, methodology, and principles of scientific inquiry (Dodig-Crnkovic and Müller 2011).

The circle closed in the 2000s, when reductionist claims that computing was really other fields were flipped: now we see essays heralding a new era of science, explaining why all other sciences can be reduced to computing. Computing has begun its second revolution in science.

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Chapter 2
On the Big Impact of "Big Computer Science"

Stefano Ceri

Abstract Big science is bringing unprecedented progress in many fundamental fields, such as biology and medicine. While progress cannot be questioned, when looking at the foundations and models of big science one wonders if such new approach is in contrast with critical thinking and model-driven scientific methods—which has shaped for decades higher education in science, including computer science. In this paper, after a discussion on how big science is shaping drug discovery and modern biology, I trace the start of this new interest on data science as outcome of the "fourth paradigm" and I discuss how CS education is changing due to the impact of big science, and question where/how it will be hosted within universities and if Academia is a good fit for data scientists.

2.1 Introduction

"Big science" is a popular, perhaps abused term. It indicates not only that massive amounts of data are nowadays available in an unprecedented way, but also that the approach to science is shifting from being model-driven (where modeling and abstractions are foundational and data are just supportive of given initial hypotheses) to data-driven (where models can be directly extracted from data). A new figure of "data scientists" is emerging (and very much requested by the labor market), with strong computational and statistical background, that is particularly good at extracting domain-specific knowledge from big datasets.

The strength of a data driven approach is evident if one looks at the main players of the Computer Science Industry, such as Google and Facebook, whose business model relies on making profits out of data, the so-called "socially produced content". Google is a "data" company, as (a) its computational approach is data driven and heavily based in statistics and math (see the original competitive advantage upon other search companies based upon the "PageRank" algorithm, invented by the co-founders); and (b) it owns no data itself, but it converts user data

S. Ceri (✉)
Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Via Ponzio, 34/5, 20133 Milano, Italy
e-mail: stefano.ceri@polimi.it

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into information that is then provided essentially to the same users (in a sense, Google managed to convert steel into gold, as in many legends of ancient times).

In this paper, I start with a discussion of prototypical examples of big science in the medical and biological domains, which serves the purpose of introducing the data-driven approach in contrast to the model-driven approach; then I trace the start of the emphasis on “big data” to the so called “fourth paradigm” and recall some illuminating principles by Jim Gray, who first inspired the fourth paradigm revolution. Then I turn to discussing how big science should be taught, and whether big science experts can find a good fit in the current academic value system. I conclude with some considerations about the general relevance of multi-disciplinary and a problem-driven approach in computer science curricula, which go beyond the specific discussion on “big data”, although they fit well with the main theme of the paper.

2.2 Where “Big Science” Is Really Big: Pharma Industry and Genomics

The pharmaceutical industry has been impacted from a “big data approach” since a long time. We all remember the big discoveries in medicine in the last century due to scientists who had enlightening intuitions, driven by their acute observations; but now, the process of drug discovery is a highly standardized one, that has been described, e.g., by Bayer (2015), as a fixed sequence of 10 steps. In particular, the first two steps, called “DNA testing for target discovery” and “high-throughput screening”, consist of discovering the proteins that might be playing a significant role in the course of a disease, as drugs can either switch these proteins off or enhance their function. Once a target has been successfully identified, systematic test procedure is used to look for substances—known as lead candidates—which could be a suitable starting point for a new active ingredient. In this step, high throughput screening (HTS) applies an in-house compound library (currently containing over three million chemical substances) for suitable lead candidates. Robots fill thousands of microtiter plates on which up to 1536 tests can be performed simultaneously (see Fig. 2.1). In essence, drug discovery is now in most cases the outcome of massive screening, rather than being intuition-driven.

The drug discovery method described above seems to question the classic scientific method, built around testable hypotheses, or “models”. These models, for the most part, are systems visualized in the minds of scientists. The models are then tested, and experiments confirm or falsify theoretical models of how the world works. Scientists are trained to recognize that correlation is not causation, that no conclusion should be drawn simply on the basis of correlation between X and Y (it could just be a coincidence), that “data without a model is just noise.” However, the brute-force approach seems to require no a-priori model, or at least requires just a generic knowledge about the generic processes leading to the production of proteins and the mechanisms for compound screening. Generally speaking, faced with massive data, the classic approach to science—hypothesize, model, test—is

Fig. 2.1 High-throughput screening in the search for drug candidates, from Bayer (2015)

becoming obsolete. Data availability in the range of petabytes allows Chris Anderson, editor in chief of Wired, to say that: "Correlation is enough: We can stop looking for models. We can analyze the data without hypotheses about what it might show. We can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms find patterns where science cannot." In summary: is correlation without causation good enough when data sizes are big enough? This dilemma is current among computer scientists.

Another example of "big" approach is the construction of massive repositories of genomic data. Next Generation Sequencing is a technology for reading the DNA which is producing huge amounts of DNA sequences—at an exponentially decreasing cost and exponentially increasing processing speed, at a much faster pace than the Moore law for processors. Several worldwide consortia have been created in order to accumulate sequence data and make them available to the research community, through the combined efforts of hundreds of laboratories in the world. Among them, *1000 Genomes: Deep Catalog of Human Genetic Variation* (1000 Genomes Project Consortium et al. 2010), with the goal of finding most of the genetic variants that have frequencies of at least 1% in the populations; *the Cancer Genome Atlas* (Weinstein et al. 2013), which presents a comprehensive genomic characterization and analysis of several cancer types; the *100,000 Genomes Project*,[1] a UK project which will sequence 100,000 genomes from around 70,000 people, chosen amongst NHS patients with a rare disease or with cancer plus their families; and *ENCODE: Encyclopedia of DNA Element* (ENCODE Project Consortium 2012), with the goal to

[1] http://www.genomicsengland.co.uk/

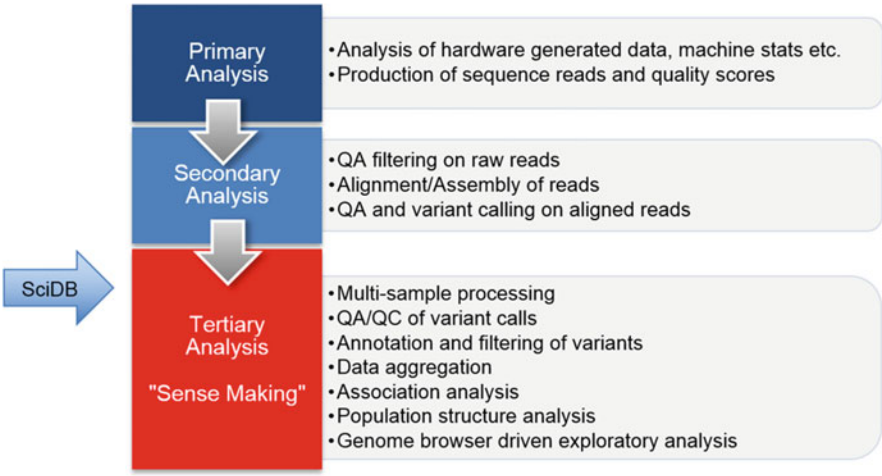

Fig. 2.2 Phases of genomic data analysis, taken from: http://blog.goldenhelix.com/grudy/a-hitchhiker%E2%80%99s-guide-to-next-generation-sequencing-part-2/

build a comprehensive parts list of functional elements in the human genome, including elements that act at the protein and RNA levels, and regulatory elements that control cells and circumstances in which a gene is active.

In recent years, I have become strongly interested in genomic data management. Figure 2.2, extracted from Paradigm 4 (2015), indicates the current state of genomic computing, where a lot of progress has been done in the so called "primary analysis" (essentially the reading of DNA) and "secondary analysis" (essentially, the alignment of DNA reads to a reference genome for each species, and the discovery of DNA features, such as mutations and peaks of expressions); my interest is on "tertiary analysis", i.e. making sense of datasets resulting from multiple, heterogeneous experiments. With my research team, I am currently working on a genomic data model and query language supporting querying of heterogeneous genomic datasets on the cloud, with a tight integration between genomic data (relative to the regions of the whole genome) and metadata (relative to the experiment preparation and sampling, including possibly the patient phenotype). In the near future, we expect genome sequencing to be a key to understanding many pathologies, and we forecast bridging genomics to personalized healthcare; this could be among the most interesting "big data" problems of mankind.

2.3 Where It All Started: "Fourth Paradigm"

The emphasis on "big data" in computer science can be traced back to the fundamental contribution of the "Fourth Paradigm" book (Hey et al. 2009), and to the legacy of Jim Gray (Fig. 2.3). The book's preface presents a historical view of computer science as separated into four phases, the first based upon empirical

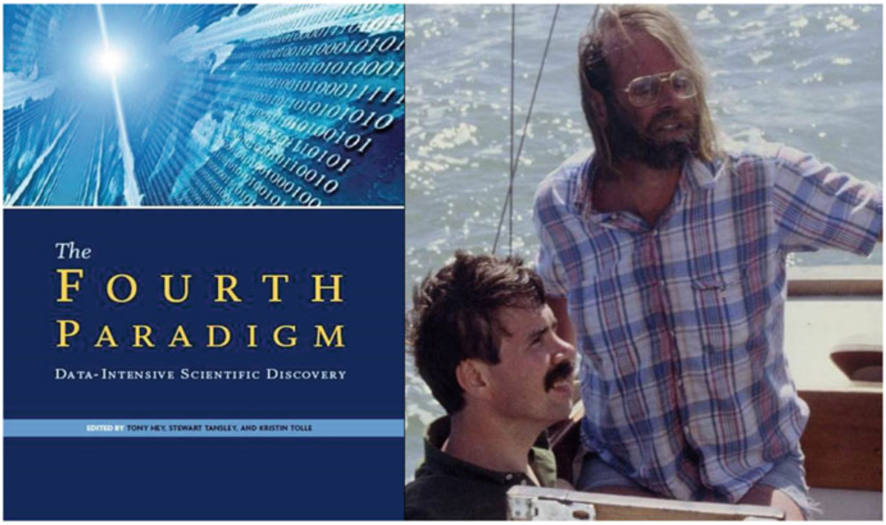

Fig. 2.3 "The fourth paradigm" book cover and an old photo of Jim and Stefano

science and observations, the second upon theoretical science and mathematically-driven insights, the third upon computational science and simulation-driven insights, the fourth upon data-driven insights of modern scientific research. Accordingly, we have entered the fourth phase, featuring the data-driven approach.

It is worthwhile to recall the words of Jim Gray about what makes "big data" amenable to effective processing. He claims the importance that all data being used, no matter how assembled, should be **self-describing** and should have a **schema**. In this way, it is possible to properly address content within a collection of information, e.g. by saying: "I want all the genes that have this property" or "I want all of the stars that have this property" or "I want all of the galaxies that have this property." Once a schema is well-defined, data can be indexed, aggregated, searched in parallel, and it is easier to build both ad-hoc queries and generic visualization tools. If instead big data are just a "bunch of files", it is not even possible to see the concept of gene, or star, or galaxy; and the data scientist has to understand the data content in each file, in a bottom-up and unstructured fashion. Essentially, these words are calling for a layer expressing data organization which should be separate from data content, in contrast to the current trend of just using data without any concern upon understanding their structure and quality.

The legacy of Jim Gray is huge, in this as in many other fields. I still remember when, about ten years ago, he was explaining to me his joint work with astronomers while at the same time I was looking into classic computer science problems, and I couldn't quite understand his enthusiasm. A posteriori, I was still trapped into a disciplinary silo, he had already moved towards interdisciplinary data science.

Scientific research more and more dependent on the careful analysis of large datasets, requiring a broad skill-set: scientists must be experts not only in their own domain, but in statistics, computing, algorithm building, and software design.

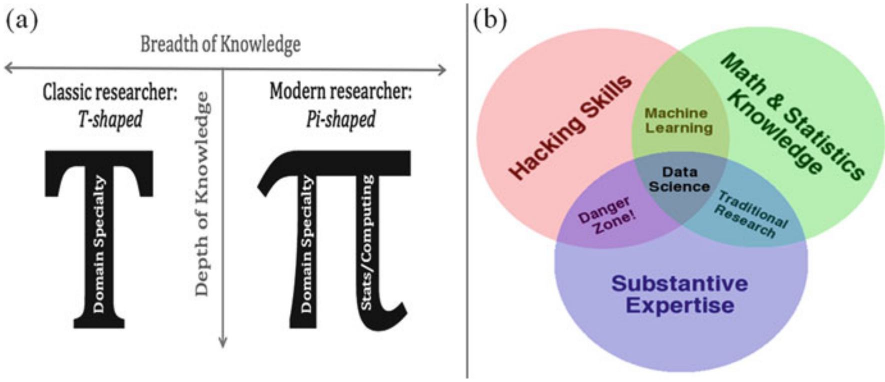

Fig. 2.4 Representations for data science research expertise: (**a**) "T" vs. "Pi-shaped" education and (**b**) multidisciplinary contributions to data science (from: DrewConway.com, retrieved 25/6/2015)

In order to understand the skills that we expect from a "next-generation data scientists", we refer to two popular diagrams, illustrated in Fig. 2.4. The first one shows the evolution from T-shaped to Pi-shaped models of knowledge: with the former model, a researcher had to provide both support domain specialization (on the vertical axis) with horizontal knowledge [i.e. general and cross-disciplinary competences: how to speak in public, participate to teams and become team leader, make decisions, approach and organize projects with appropriate methods, enhance creativity, see Banerjee and Ceri (2015)]. The new emerging model, denoted as Pi-shaped, adds another vertical competence, relative to the mathematical, statistical, and computational abilities which are required in order to deal with data science.

The second image of Fig. 2.4 illustrates the data science skills as currently available on the professionals market, where a first required ability is concerned with "hacking skills" (according to Drew Conway, "being able to manipulate text files at the command-line, understanding vector operations, thinking algorithmically"); then, appropriate math and statistics methods are needed to extract information from data (e.g., knowing what an ordinary least squares regression is and how to interpret it.) Combining hacking skills to math and statistics "only gets machine learning", whereas a substantive expertise in the application domain is needed as third dimension "which requires some motivating questions about the world and hypotheses that can be brought to data and tested with statistical methods." Interestingly, Drew Conway denotes those with hacking skills plus substantive expertise as a danger zone, as people in this area may be perfectly capable of extracting and structuring data, but they lack any understanding of what computation means. Fortunately, "it requires near willful ignorance to acquire hacking skills and substantive expertise without also learning some math and statistics along the way. As such, the danger zone is sparsely populated, however, it does not take many to produce a lot of damage."

2.4 Data Science and Academia: Issues and Opportunities

The push towards the creation of a new focus on data sciences in academic programs is very strong. Perhaps the most radical change is occurring at Berkeley University, where a new course **Foundations of Data Science**, jointly offered by the departments of statistics and of computer science, is currently being experimented with the goal of being offered to all the freshmen students in the near future (Data Sciences @ Berkeley 2015). The course will present key elements of introductory computational and inferential thinking in an integrated fashion, cementing conceptual understanding through direct experience with data (see the syllabus in Fig. 2.5).

Many universities are starting 1-year, intensive program the Master's level programs for creating data scientists. Among them, Harvard University offers a 1-year Master of Science in Computational Science and Engineering (CSE) (Fig. 2.6) targeted towards the construction of data scientists skills which seem to be inspired both by T and Pi-shaped education principles, reported in Fig. 2.4; note the emphasis on communicating across disciplines and collaborate with teams, which are typically regarded as horizontal skills, but note as well the emphasis on real-life problems. Other one-year master programs are spreading worldwide; among them, in Italy, three new programs offered by Cefriel (jointly with Politecnico di Milano), by the University of Pisa and of Bologna.

At Politecnico di Milano, we created a "Big Data" track in our regular Master Degree, which includes suitable CS courses (such as Advanced Data Management, Data Mining, Machine Learning), some application-oriented courses (e.g. in Computational Biology) and interdisciplinary contributions from the schools of Mathematics (Applied Statistics) and of Management (Business Intelligence). Small innovative experiments are ongoing, e.g. the Data-Shack program[2] jointly organized

> This introductory course in data science is built on three interrelated perspectives: inferential thinking, computational thinking, and real-world relevance. Given data arising from some real-world phenomenon, how does one analyze that data so as to understand that phenomenon? How does one collect data to answer questions that one is interested in? Inferential thinking refers to an ability to connect data to underlying phenomena and to the ability to think critically about the conclusions that are drawn from data analysis. Computational thinking refers to the ability to conceive of the abstractions and processes that allow inferential procedures to be embodied in computer programs, and to ensure that such programs are scalable, robust and understandable. In addition to teaching critical concepts and skills in computer programming and statistical inference, the course will involve the hands-on analysis of a variety of real-world datasets, including economic data, document collections, geographical data and social networks, and it will delve into social and legal issues surrounding data analysis, including issues of privacy and data ownership.

Fig. 2.5 Syllabus of the undergraduate course Foundations of Data Science, Berkeley University, from: http://databears.berkeley.edu/content/stat-94-cs-94-foundations-data-science

[2]datashack.deib.polimi.it

"What should a graduate of our CSE program be able to do?"

- Frame a real-world problem such that it can be addressed computationally
- Evaluate multiple computational approaches to a problem and choose the most appropriate one
- Produce a computational solution to a problem that can be comprehended and used by others
- Communicate across disciplines
- Collaborate within teams
- Model systems appropriately with consideration of efficiency, cost, and the available data
- Use computation for reproducible data analysis
- Leverage parallel and distributed computing
- Build software and computational artifacts that are robust, reliable, and maintainable
- Enable a breakthrough in a domain of inquiry

Fig. 2.6 Skills which are targeted by the Harvard: Master of Science in Computational Science and Engineering (CSE), retrieved from the program's Web pages

by Harvard's Institute for Applied Computational Science and by our Master schools of Computer Science and of Design, where students are exposed to hands-on data science problems.

The growing interest in academic courses and programs in data science seems not to be matched by offering of academic positions to the data science; according to Jake Vanderplas,[3] time spent developing high-quality reusable software for solving concrete problems translates to less time writing and publishing, which under the current system translates to little hope for academic career advancement. In particular, it is argued that industry may be a better fit for data scientist, due to a number of factors: salary, stability, opportunity for advancement, respect of peers, freedom from the burden of publishing and teaching, given that also in industry there is the opportunity to work on interesting projects and to contribute to open source software. In his blog, Jake Vanderplas calls for an increase of the pay of post-doctoral scientific research positions—so as to become more competitive with industry—and for a change of the Academic value system to defend the data scientists career, by pushing for a new standard for tenure-track evaluation criteria which emphasizes the importance of producing reproducible software and rewards the development of open, cross-disciplinary scientific software tools.

Another discussion (from 1) concerns where data science should be housed by Academia; five solutions are considered.

1. Data science is simply a label for a new skill-set, and **shouldn't be separated from the departments in which it is useful**. Departments across the university should simply incorporate relevant data science techniques into their normal curriculum.

[3] https://jakevdp.github.io/blog/2014/08/22/hacking-academia/

2. Data science might be organized as a **consulting service**, in a similar way to the IT infrastructures. We can't expect every scientist to be fluent in the statistical and computational methods required to work with large datasets, so these tasks would be outsourced to data science experts.
3. Data science could be seen as a**pplied branch of computer science or of statistics** which should give rise to a separate department, similarly to existing departments of "applied math" and "applied physics", which distinguish themselves from the non-applied version by employing the techniques of the field within practical rather than theoretical contexts.
4. Data science could be similar to an **evolution of library science**: as digitization is changing the role of libraries on university campuses, focus of a modern Library and Information Science departments could be moved from hosting printed books to *data curation*.
5. A middle ground to the above approaches may be to organize data science **within an interdisciplinary institute**, along a cross-departmental organization which is becoming common in Academia.

2.5 Assessment and Conclusions

Computer science is still a growing discipline, that has successfully overcome a decline (e.g. in enrollment) observed about 10 years ago. In these days, most of computer science schools around the words have lots of undergraduate and graduate applicants, typically of very high quality, and the job market offers good jobs to a potentially large mass of students exiting from our education systems, both at undergraduate and undergraduate level. Computer science schools as they stand could be self-referential, and stand on their models, methods and technologies; but computer science could be even more successful by opening to other fields. The creation of data science curricula within computer science is not only timely (it captures the "taste of time") but also strategic, as a means for outreaching to other scientific communities, given that data science is intrinsically interdisciplinary.

Compared with other foundational disciplines, such as mathematics, biology, physics and chemistry, computer science has a clear advantage in being immediately applicable to solve concrete problems. Therefore, computer science can be very much problem-driven, both in the case of a broad offer to undergraduate students and in the development of graduate curricula; the push towards data science is making this aspect even more evident. In the past, many openings of computer science to the multidisciplinary dimension from inside computer science have been quite difficult: such disciplines were considering computer scientists not much as "peer scientists", but rather as "service providers" who could offer their skills in order to solve disciplinary problems of the hosting discipline. A push towards data science will put our community in the position of driving the change towards a true multi-disciplinary approach, where data scientists with a strong computational background will be recognized as a key success factor for solving data-driven problems.

In conclusion, an educational model of big science is emerging, combining computational and inferential thinking in an integrated fashion, cementing conceptual understanding through direct experience with data (Data Sciences @ Berkeley 2015). This approach stems from a new emphasis on "big data", which can be traced back to the Fourth Paradigm book (Hey et al. 2009) and which is becoming more and more relevant with the growth and worldwide organization of big data repositories; I offered some examples of them in the biology sector. One big question which is left somehow opened is whether computing should be driven by models rather than by data; according to some opinion-makers and colleagues, traditional computer science models should be used when/if needed but no longer be the key foundational aspect of problem solving.

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Chapter 3
On Informatics, Diamonds and T

Maarja Kruusmaa

Abstract This chapter reflects upon Information and Communication Technologies (ICT, including informatics) research and education in the light of current technology trends. My key messages are that (1) ICT has become ubiquitous and therefore runs a risk of becoming understated and worse, underappreciated. (2) because of its widespread use ICT is evolving to be more involved in interdisciplinary research. I argue that interdisciplinarity itself is inherently a team effort, requiring an individual to consider team-work in a fundamentally different way. The conclusion which emerges from the previous statements is that researchers and engineers in ICT should be better prepared for working in interdisciplinary teams and understand that continuous, deliberate effort is required for successful team building.

In this chapter, robotics is given as an example of interdisciplinary research area, heavily relying on ICT expertise but also progressively on far interdisciplinarity (e.g. with biology, social sciences, law, etc.). Using the metaphor of T-shaped competences, a possible profile of an expert in this field is described and as a case-study, the development of Centre for Biorobotics, is analysed. I conclude with some personal experiences from working in and building interdisciplinary teams.

3.1 Setting the Scene

Current technology trends foreshadow the rapid advances in technologies, where informatics (or more generally ICT, information and communication technologies) play a leading or important role. Amongst them are the rapid development of mobile internet, knowledge automation, cloud services, as well as the Internet of Things and advanced robotics (Manyika et al. 2013). The amount of data created every day is increasing with a progressing rate and will reach nearly 45 ZB by 2020, according to Oracle's 2012 forecast. Managing this rapidly growing volume of data

M. Kruusmaa (✉)
Centre for Biorobotics, Tallinn University of Technology, Akadeemia tee 15-A, 12618 Tallinn, Estonia
e-mail: Maarja.Kruusmaa@ttu.ee

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needs new theories and new methods as well as allowing for new approaches to be rapidly applied.

Another rising trend is the emergence of physical and virtual worlds, in the so-called Internet of Things, where smart sensors and devices are connected to the Internet. Gartner, Inc. forecasts that 4.9 billion connected devices will be in use in 2015, up 30% from 2014, and will reach 25 billion by 2020. This would support total services spending of $69.5 billion in 2015 and $263 billion by 2020.

Robotics is another growing domain where ICT plays a major role. The growth in robotics is mainly expected to happen because of robots moving from its traditional application domain in industry into the service sector. In particular the amount of privately used service robots (such as vacuum cleaners or lawn mowers) is expected to increase most but also the service robots for professional use (for example for military use, in agriculture and transportation) is steadily increasing. It is estimated that by 2018 the total robotics market will reach 100 billion dollars whereas the service robots are behind 85% of this growth (IFR 2015). As a characteristic example we are witnessing today the arrival of consumer drones that are now available in every tech store at affordable prices. Their market share has risen from USD250 million to USD1800 million in 2 years (2013–2015) (Meeker 2014).

3.1.1 Robotics as an Interdisciplinary Area Involving ICT

The situation of ICT development bears a resemblance with the Water and Diamonds value paradox. If asked, everyone would first answer that diamonds are more valuable that water because diamonds are rare and precious but water is present everywhere and is cheap. However, one can very well live without diamonds but not without water. In that sense water is much more precious (ISTAG 2010–2012). ICT seems to be such a substance, diluted and embedded in almost every object and service, so that one ceases to appreciate its importance and starts taking it for granted. At the same time, in modern world it is almost impossible to survive without it. As such, ICT in one hand is highly in demand but most of all in its applied form. On the other hand, for a discipline to develop and advance, one needs highly specialized research to push the research frontier forward. Of course, it can be argued that the balance between applied research and development and basic research should be found in every discipline but the argument in this chapter is that ICT more than other disciplines runs a risk of getting diluted.

Robotics is a good example of an interdisciplinary research area that is heavily dependent on computer science and computer engineering. Even if we are used to thinking of robots as mechanical machines, most of the methods, skills knowledge and expertise in robotics is computer science and computer engineering related (Eu Robotics 2014).

Classically, a robot is a mechanical machine, which is electrically controlled, whereas the control is implemented on digital computers and may also include (and nowadays usually does) high level planning and decision-making affordances. Thus classical robotics already is an interdisciplinary field comprised of mechanical engineering, electrical engineering, control engineering, computer engineering and computer science. Here expertise of close disciplines (e.g. mechanical and electrical engineering) or specialties within the same discipline are emerged (e.g. electrical engineering and computer engineering).

The above-described emerging trend of consumer robotics is pushed by and pulls specific research areas in informatics and other disciplines so that robots would be able to reliably function in real world environments. Whereas traditionally industrial robots where working in almost static well-defined industrial environments on pre-programmed specific tasks (e.g. point welding in car industry), consumer robots work and interact with humans in their natural environments which are dynamic and on tasks that vary. This in turn requires a number of new functionalities. The robot now perceives the world around it with a variety of sensors. The sensor information has to be processed, analysed and perhaps fused together with information from different kinds of sensors (sensor fusion). Information from other different sources (e.g. online databases, other robots) can be used to detected the changes in the environment and interact with it. Then the robot has to make plans and take decision under circumstances where data is often noisy and almost always incomplete. Finally, if these robots are connected to the internet and receive or upload information to the cloud, they become part of the Internet of Things. As such, robots can be viewed as mobile data collecting machines.

On the research front, modern roboticists also work on paradigm shifting robotics technologies that could possibly provide entirely new kinds of ways for designing robots. Among those is for example material science, where roboticists hope to find new ways of building robots from e.g. lightweight, soft and sometimes active materials. Also bio-robotics is a rapidly emerging research trend which seeks to apply principles of biological systems developed by evolution in robot design. This may involve new types of bio-inspired locomotion, bio-inspired sensors or sensing principles as well as new ideas to build reliable control methods based on analogy with neurocircuitry of animals. In addition, many ideas of cognitive science are entering robotics and form a so-called subspecialty of cognitive robotics. Cooperation with developmental psychologists provides ideas how to build self developing and learning robots. The whole subfield of human robot interaction heavily relies on cooperation with social sciences in order to develop most efficient methods for interacting and cooperating with the robot as well as predicting how humans would adapt those kinds of new technologies.

The above given examples of advanced robotics are examples of far interdiciplinarity where engineering disciplines and computer scientists cooperate with biologists, material- and social scientists.

Moreover, moving closer to our everyday world robotics is faced for the first time with Ethical, Legal and Societal (ELS) issues. Would people accept a robot taking care of their children or elderly, who will be responsible if a surgical robot damages a patient or what happens to people who's jobs will disappear because of the rise of robots. These are just a few examples of a myriad of problems that roboticists, traditionally been educated as engineers, seriously face for the first time.

3.1.2 Specialty Profiles and Interdisciplinary Research

The challenge facing ICT research and education is thus how to keep a balance between increasingly widespread demand of applied research and engineering while still maintaining sufficient depth to push the frontiers of its field. Obviously, there is no interdisciplinarity without disciplinarity. Therefore this chapter argues that interdisciplinarity should preferably be achieved on the level of a team rather than of the individual. A suitable metaphor, originally used in business management, for describing a preferable width and depth ratio is the concept of T-shaped profile (Hansen and Von Oetinger 2001).

This competence building paradigm has also made it to the academic world and has been considered as a desirable outcome of university education (Rip 2004; Uhlenbrook and Jong 2012; Heinemann 2009). And certainly, this approach lends itself easily to various interpretations. A skills profile that someone considers as vertical, may occur flat, without sufficient depth and therefore mainly horizontal for another. However, I suggest that T-shape profile is still a valuable metaphor in order to assess, envision and plan the competence development.

Essentially, the T-shaped profile means that a person (or on a system level, an organization, team, etc.), has a strong specialization in one specific area, comprising the vertical bar of letter T. The horizontal bar then is comprised of various skills that are acquired rather superficially but let the person to easily interact with another person with a different competence. Depending on interpretation, the horizontal bar may include communication skills, creative thinking, team-working skills, project management skills etc. Science and technology development seem to need progressively more individuals competent in ELS Issues. The horizontal bar can also comprise knowledge in other scientific and engineering disciplines (e.g. statistics, biology, arts, etc.) but the main idea is that the extent of those skills is not comparable with the competence in the vertical bar. I have found a good indicator that the vertical is in place if the person can answer: "*I am an expert in ….*". If the person cannot name his/her area of expertise or names several, the knowledge is not T-shaped.

Such a T-shaped competence profile suggests that the interdisciplinarity is reached not on the level of a person but by a team of professionals. Comprising an interdisciplinary team then becomes quite obvious, the team is glued together by matching horizontal bars of team-working skills and secondary expertise whereas every individual remains responsible for providing deep knowledge in his or her area of expertise.

Of course such a shape of a T can describe the competence on the level of an organization. Some examples are a company with a core competence to make it competitive in a global market niche (Nordström et al. 2000), a research team specializing in a narrow area of research, an university curriculum with a goal to educate experts in a certain area. The challenge again becomes to identify its core expertise and to maintain horizontal competences for cooperation on more challenging interdisciplinary tasks.

Certainly, this is a dynamic challenge, expertise can be developed and changed and indeed, should change in response of the changes in the environment (market needs, job availabilities, technology trends and developments in science). From the perspective of the individual it becomes important to match the individual competences to the needs of the environment. One can bring an analogy with an evolution of biological systems. If the environment is very stable, species can afford becoming more specialized and maximizing its likelihood of survival in a narrow range of possible conditions. On the other hand, if the environment is unstable, generalists tend to do better. The technology forecast in the opening section of this chapter offers some insight into the specialization areas that add most value in the future.

3.2 Shaping Centre for Biorobotics: A Case Study

This subsection gives an overview of the development of Centre for Biorobotics in Tallinn University of Technology, Estonia which I founded in 2008 and discusses the challenge of building a team through the rough-hewn prism of personal experience. As the name of the research centre indicates, it already focuses on interdisciplinary research however, as it becomes evident by the end of this section, even interdisciplinary teams benefit from specialization and focus.

Biorobotics, being a subfield of biomimetics (or bionics) is a research area that discovers and uses principles from natural systems to create physical models, and engineering systems. Biomimetic and bioinspired robots include for example flying robots inspired by insect flight (Floreano et al. 2009), terrestrial robots using principles of snake locomotion (Transeth et al. 2009), sensors and sensor information processing methods inspired by bat echolocation (Peremans et al. 2000), or other so far overlooked sensor modalities such as active touch (Prescott et al. 2011) or flow sensing (Salumäe and Kruusmaa 2013). It may also be motivated by working principles of neural circuitry to achieve reliable control (Ijspeert et al. 2007). As it can be seen, the variety of possible research themes is so wide that for a small research team (10–20) people some further specialization is absolutely necessary.

Furthermore, the funding opportunities for research in Estonia are limited and highly competitive. While in European countries in general about 50% of funding is project based, in Estonia the competitive project based funding constitutes about 80% or more of research funding and is in most of cases highly competitive. That situation in turn sets limits to the size of the research team, been basically determined by the ability of the principal investigator (PI) and other senior staff to attract funding. Therefore, further specialization was necessary to achieve the competence in some area that is able to deliver cutting edge research results.

Table 3.1 Competence profile of Centre for Biorobotics

Year	Research competences	Supporting engineering skills	Collaborations (far field interdiciplinarity)
2008	Mobile robotics, robot learning, Smart materials, underwater robots	Electronic engineering, computer engineering, computer science	Material scientists
2009	Mobile robotics, active textiles, underwater robots, underwater sensing, smart materials	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Applied arts, material scientists
2010	Mobile robotics, active textiles, underwater robotics, underwater sensing, soft body modeling, soft robotics	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Fish biologists, radiologists, surgeons
2011	Underwater robotics, flow sensing, soft body modeling, active textiles, soft robotics, flow sensing, medical imaging	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Fish biologists, radiologists, surgeons
2012	Underwater robotics, active textiles, flow sensing, soft robotics, experimental fluid dynamics, medical imaging	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Fish biologists, radiologists, surgeons, underwater archaeologists
2013	Underwater robotics, flow sensing, soft robotics, experimental fluid dynamics	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, medical imaging mechatronics	Underwater archaeologists, fish biologists, hydraulic engineers, control engineers
2014	Underwater robotics, flow sensing, soft robotics, experimental fluid dynamics, ecohydraulics, hydraulics	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Fish biologists, hydraulic engineers, Oceanographers, optical engineers, control engineers
2015	Underwater robotics, flow sensing, soft robotics, experimental fluid dynamics, ecohydraulics, hydraulics	Electronic engineering, computer engineering, computer science, underwater engineering, sensor technique, mechatronics	Underwater archaeologists, fish biologists, hydraulic engineers, oceanographers, optical engineers

Table 3.1 summarizes the changing focus of the research group since its establishment in 2008. All the areas listed in the "research competences" have lead to at last one Ph.D. thesis from the lab. The starting years reflect the uncertainty of the strategic goals, but also uncertainty about funding possibilities and preferences and previous areas of research of the PI and its members. Various possibilities are considered, and every funding opportunity is used. Over the years, the focus of the

group gets more and more narrow, converging around underwater robotics, and underwater engineering.

Underwater robotics, and underwater engineering in general, are one of the areas of technology that are more than average costly and time consuming, involving much of so called "invisible work", mostly technical work for keeping devices watertight that by itself are not a subject of research but still requires highly skilled support engineers and technicians. Fluid dynamics experiments in terms of test tanks, special measuring and flow visualization equipment require certified personnel. Field-testing is another activity that, been dependent on weather, cost and availability of vessels, and other environmental and human factors, requires specific knowledge, skills and equipment. Learning here happens to a great extent by trial and error and over a long time period. It is therefore natural that, after getting over the entry barrier, one would decide to leverage on the accumulated knowledge and skills that also becomes a strategic asset of the team. Good results in turn lead to more research opportunities and new interesting collaboration in new but similar topics.

Besides the support engineering skills it should be pointed out that the team of Centre for Biorobotics also comprises one assistant to the manager who is responsible for all the administrative and financial matters, including EU project administration.

The last column of Table 3.1 lists our main collaborators. To be observed here is that over the years, also more computer engineering competence gets outsourced. It turned out to be more efficient to keep our narrow and unique competence and instead, collaborate with other individuals and groups that are distinguished experts in their field. The first outsourcing questions we asked ourselves in the beginning was if Centre for Biorobotics should develop expertise in both of the involved disciplines, biology and robotics. After flirting for a short while with the idea of hiring fish biologists, building facilities for animal housing and acquiring licenses for animal experiments we rather quickly decided that for the resources available its more feasible to cooperate with already established experts in this field. Retrospectively, this appears to be a very feasible decision. In a similar vein (Nordström et al. 2000), argues for what they call "hollow companies" in business management. Those companies would outsource everything but their core competences and be competitive in a relatively narrow, but a global niche.

3.3 Lessons Learned

Globally, interdisciplinarity is on the rise. Since 1980, research papers have increasingly cited work outside their own discipline (Van Noorden 2015). I suggest that because of global technology trends, IT research will be more widespread and part of almost every new technology and technical solution thus increasingly interdisciplinary. Obviously there is no interdisciplinarity without disciplinarity. But because of the extent of research and application areas an ICT expert would need extra training and show readiness to work in interdisciplinary teams, while still maintaining their T-shaped competences.

Mainly based on personal experiences, I am in favor for interdisciplinarity on a team level, rather than on a personal level. It has proven over the years that most interesting, fruitful and mutually beneficial collaborations happen between experts in different fields with good team-working and interpersonal skills. Deepening your own specific competence while staying serendipitous and open to new viewpoints has the potential to tackle new interesting problems.

Below are listed the most important personal lessons I have learned by trial and error (and mostly error) from leading and participating in international and interdisciplinary teams:

– **Find a common goal**. The common goal should be something that is related to the general problem statement and goes beyond what is considered as an achievement in a specific field of science or engineering. For example, I found computer scientists and computer engineers in medical engineering finding a common goal in improving patient care, contradictory to the wide misconception of that "computer nerds" don't care of those things. In another project, BONUS FISHVIEW, where we study water flow in fishpasses using signal and image analysis, novel sensors and computer simulations we first defined a naïve-sounding goal of "making fish happy". However, everybody in the team found they easily relate to it and the concern about environment would make them better work together. In my opinion writing good publications is not the best common goal because they are on different topics in every field and every researcher has personal interest to publish in their favorite journals. Rather a publication could be viewed as a formalization of results, while the result is something more general. Especially when working with companies, who are not concerned about publishing but making profit, this goal is not motivating.
– **Search until you find right (T-shaped) people**. Communication problems in interdisciplinary teams are quite common, especially if the common goal is lacking. As a consequence, everybody pulls in his/her own direction (perhaps publish her own papers). Not all good experts obviously are good team workers. It makes sense to put some effort in finding a good person for interdisciplinary work instead of later struggling to make people work on a common goal they are not interested in.
– **Listen**. It takes time and willingness from all team members to understand the interests and personal goals of others as well as some understanding what methods, equipment and other resources they have. Usually people are quite willing to talk about their work, the tricky part is listening and finding overlaps and complementarities. Not understanding what methods, equipment and technical approaches others are using often leads to bad planning and missed opportunities to solve really significant problems.
– **Accept that interdisciplinary work takes more time**. Defining a common goal, finding right type of people, understanding the way the business is done in other areas, establishing common vocabulary, common work routines and

communication channels take more time if people come from diverse backgrounds. For unusual combinations of interdisciplinary work there is often no standard test equipment, no commonly accepted methods and even agreement over what can be considered as a result. All those things need to get established before the project delivers. Therefore some more ramp-up time is necessary to be planned in interdisciplinary projects.

– **Respect the standards and culture in other disciplines**. Different disciplines differ not only because of their methods, problem definitions and technical approaches but also by their working culture, ways of communication, and what is considered to be result or success. It is also not entirely unusual that we underestimate the effort other groups and people put into solving a common task because we are not entirely familiar with their work procedure and cannot fairly estimate their contribution. It is worthwhile spending time on building a common culture that everybody agrees on.

In Brown et al. (2015) authors give a complementary but rather similar list of recommendations for building interdisciplinary teams. It differs by more general recommendations on shaping adequate financial, institutional and policy instruments to support interdisciplinary work.

3.4 Summary and Conclusions

This chapter gives a brief overview of current technology trends and investigates one of the emerging technologies, advanced robotics, as an example. It argues that informatics and other information and communication technologies will be the core part of almost every emerging technology megatrend. Therefore there is a risk for ICT research and engineering to get diluted because of value paradox (it is not given sufficient value because it is ever-present, hidden and often taken for granted). Because of its wide applicability this risk is larger than in other disciplines and the challenge to find balance between broad and wide expertise, theory and applications is more severe. T-shaped competences are discussed as a metaphor for educating experts able to cooperate over a great variety of domains whereas it is argued that the T-shape is favorable both on the level of an individual as well as of an organization (research team, company, etc.). It described as a case study a short history of establishing and developing Centre for Biorobotics in Tallinn University of Technology, Estonia and finally gives some personal experience-based recommendations for creating and working in interdisciplinary projects.

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Chapter 4
Leadership and Balance in Research

Dunja Mladenić and Marko Grobelnik

Abstract Leadership and balance are challenges relevant for scientific work as well as in business, politics and also in daily activities of individuals. Here we share our reflections based on the experience of building and leading a research group of over 40 people at a national research institute. Our first observation is that leadership of a research group towards success requires clear philosophical alignment, fundamentals shared between all the members. This includes maintaining a common vision and high enthusiasm towards achieving results (no nonsense rule). In order be sustainable on the longer run, we have to maintain the flow of: (a) knowledge/experience, (b) social network of partners, and (c) constant funding. Organization of the team should be preferably flat (but not too flat) with well-defined roles, but also as fluid as possible (no rigidness rule) facilitating personal and group progress. One of the fundamentals is to develop trust between people and maintain good human relationships within the team (no fighting rule).

4.1 Introduction

Everyone is a leader in something, the question is to what extent we recognize and accept that leadership role and how we live it out in our daily life. Actually, to live already is an experience of leading your life. Implicit leadership is also very evident in the nature of research work, where we lead ourselves in forming research vision and goals, planning the path for fulfilling the goals, setting scientific hypotheses, conducting the needed research, planning presentations for sharing our research results. We apply our leadership skills not only when relating to ourselves but also in collaboration with others, regardless whether we have implicit or explicit role of a leader being responsible for organizing a meeting, coordinating research work or taking care of leading family life.

D. Mladenić (✉) • M. Grobelnik
Artificial Intelligence Laboratory, J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia
e-mail: dunja.mladenic@ijs.si; marko.grobelnik@ijs.si

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Research work often involves also advising others that is a leadership more or less limited in time and scope and has its own specifics. For instance, advising Ph.D. students requires leadership on several levels within a limited time frame and with a well-defined goal of the student growing professionally and personally towards obtaining a formal recognition in the form of a Ph.D. degree. Regardless of the kind and scope of the leadership role one may have, successful leadership requires certain behavior and skills. As suggested in Singh and Mladenic (2016) "***In order to be able to lead others, a leader must be authentic and experienced in leading himself or herself by combining both intuition and intelligence***. *In other words, to be an authentic leader, you should be who you are without pretending to be what you are not. Recognize your qualities and abilities, as well as your weaknesses and limitations, then accept and use them all*."

In research, as well as in life in general, we want to be successful, we want to be happy and prosperous. This means balancing different aspects of life including expressing our talents and qualities. Related to leadership of a research group, balance of the group to cover research of different nature (ranging from interdisciplinary basic research to research applications) brings stability by breadth of the research. On the other hand, it is also important to cover some research topics in depth and several application areas or business scenarios. For instance, our research group currently focuses on big data analytics of text data, social networks and sensor networks applying the research results in media monitoring and modeling complex data.

Through our own experience of leading a larger research group for over a decade hopefully gaining some wisdom on the way, we have identified several dimensions that we consider important for a successful leadership of such a group. If one would summarize our experience of leadership, it is mostly about inducing improvement to bring to realization a vision involving and motivating other people, so we are all gaining as individuals, as a group and, contributing to the society.

> *Our intelligence, our sophistication, is the key to our living! We must understand that our life is for expansion and that it will expand up to death whether we use it or not. If we use our life it will expand beautifully, benefit us beautifully and make us comfortable. You cannot stop expansion! Old age without wisdom, youth without success and childhood without smiles are worthless* (Bhajan 2001).

The rest of this chapter reflects on these dimensions we have identified, expressing subjective views and sharing our insides in dynamics of gradually developing a research group from scratch.

4.2 Group Alignment

Successful leadership of a group requires clear philosophical fundamentals shared between the group members. The alignment inside the group makes the work smooth, reduces the need for too frequent meetings and supports efficiency and effectiveness of work. That is especially important for a core team that ensures keeping the fundamentals pure and strong enabling flexibility. This includes maintaining a common vision and high enthusiasm towards achieving the results.

4.2.1 Common Vision

The common vision should be elaborated on different levels including long-term vision giving high-level directions, a midterm vision taking care of synchronizing separate projects with the long-term vision and a short term vision enabling fulfilling goals of specific projects. For instance, a long-term vision of our group has been advances in artificial intelligence, text understanding, analysis of global social dynamics, sensor analytics. Our midterm vision is currently working on research involving multi-modal big data analytics and advising students, while our short term vision relates to the specific projects we have at the moment and their specific research hypotheses.

In addition we should take care that the form supports the content, meaning that the research topics, tools and methods should support solving the research problems we are addressing and not vice versa. Namely, it is easy to get trapped in looking for the data or problems that will fit your tools or your favorite technological solution. In the same line, any investment of resources—time and energy should bring some kind of profit. It does not mean that we suppress inspiration for pursuing unknown areas of high risk research, as the profit can also be seen on a long-term gaining experience and opening new areas. On the contrary, to ensure balance and stability we want to have a healthy proportion of investing in emerging technologies going in depth of the current research activities of the group and opening new research directions.

To ensure healthy research dynamics it is crucial to stick with no corruption in the very base of the group philosophy. Meaning we do not allow corruption on the whole spectrum of research activities, ranging from ownership of ideas, development of approaches, collaboration, honesty in reporting the research results, fairness in distributing the obtained funding. This is crucial to maintain a common vision and enthusiasm. No corruption on the group level assumes also individuals that have character to lead themselves over personal short-term gain to long-term gain on all levels including personal, group and society.

4.2.2 Common Approach to Leadership

Taking a wider understanding of leadership, all members of the group are leaders in some way, starting form leading themselves and planning their time for research activities. We want to support each other not only in performing research in a balanced way but also in developing our leadership skills.

Each research project is a chance to enhance our assets being it in the form of knowledge and experiences, the developed algorithms and tools, written publications, social network of collaborators or something else. With each project we would like to ensure a better starting position for the future. Sometimes collaborations or just research projects themselves turn out not to be what we were expecting. Still we want to recognize their potential benefits for our long-term vision and turn them into success. If we are putting our time and resources into something, we should do it honestly rather than minimizing the efforts needed to fulfill the requirements or just ensuring a few more months or years of funding for the people. We want to reach the goal with people improving in knowledge/experience, consciousness, happiness, richness. After finishing a research project people should have more individually and as a group.

Similarly as in any business collaboration, also in research we should keep going until everybody walks away feeling good—we achieve a win-win situation, everyone wins and there are long-term benefits. This may take efforts, especially as there is often a limited time frame, but that is where the true leadership takes place. In any relationships, it is good to be kind, show gratitude, acknowledge contributions and thank people for their contribution whatever it is. We all like when our contribution is recognized, even if we do not work for that recognition. When we express our gratitude people are inspired to keep collaborating and contribute even more.

To be successful in what we are doing we look at merging our goal and our life while keeping a good balance and no separation of all the ingredients. We know from our own experience as researchers that our research is with us all the time and often some of the best ideas we get outside the office hours. As suggested by Mladenic in an interview (Brodnik et al. 2006) "*being a scientist is more a way of life than occupation*".

4.3 Maintain the Flow

Sustaining a research group requires a continuous flow, as in life in general where we have an internal flow of life forces, the flow established through communication with others and the flow in relation with the environment that provides resources to support us.

In a research group we want to ensure and maintain a healthy flow of knowledge and experience, social network of partners and continuous funding. Inside a research group we should ensure that the whole group and the individual members are growing in knowledge and experience. Leading should bring people not only to knowledge but also the capability to do things themselves. "*…becomes personal, it becomes individual. As it does so, we will move closer to a situation in which we not only produce students who know stuff but also students who can do stuff too*" (Casse 2012). With each project we should gain and enrich our personal and group assets. This is very difficult without the previously mentioned group alignment where everyone understand that we are on the same ground, fighting for the same cause and that everyone is given a chance to contribute and harvest the results.

As researchers integrated in a research community, we want to build and maintain a social network of partners that we collaborate with. As our interests and ideas change and evolve, our social network should follow and sometimes even lead, as meeting new people may trigger new directions in our research. In any case, we need a flow of exchange with our social network of partners. Exchange of ideas and knowledge, exchange via publications, sharing of program code, sharing via presentations and teaching, sharing via people visiting.

In order to ensure conditions for performing research, we need stable funding possibly spread over different kind of sources. This requires good skills in developing research ideas in a way that is suitable for funding agencies, often approaching it in a collaborative way to apply for joint projects. As the priorities in funding agencies regularly shift, we also need flexibility to recognize opportunities for our research potential under different funding umbrellas.

4.4 Flexible Internal Organization

Organization of the team should be flexible to support dynamic nature of research work and enable handling unexpected situations. It should be changing to accommodate current projects, responsibilities/workload. Despite the flexibility, the roles of individuals should be well-defined at any moment with clear responsibilities and their time span.

Some roles are predefined and needed to make it all function smoothly, such as project manager or secretary. Based on theory and practice we can identify demand for people of different profiles/talents to fit that predefined roles, e.g., a project manager with good research and programming skills. We also need to ensure condition to support people in their work, e.g., appropriate space and equipment. With the progress and expansion of the group, new roles may be articulated (e.g., separate financial issues from secretarial). We can get demand for new roles due to the change in nature of work (e.g., project logistics to be handled separately from project management) or approach (e.g., need for programming sensor platforms).

The internal organization should be preferably almost flat facilitating personal and group progress. Any hierarchy should emerge naturally based on contributions that individuals have to the group and different aspects related to supporting the group, such as coordinating work of students, managing research projects, ensuring funding.

There are different ways for a successful research group to grow. We have experience of organically growing a group out of enthusiasm for programming, research and sharing with others. We were lucky to get support from several established researchers when we were still students, several years before we got into shaping our own group.

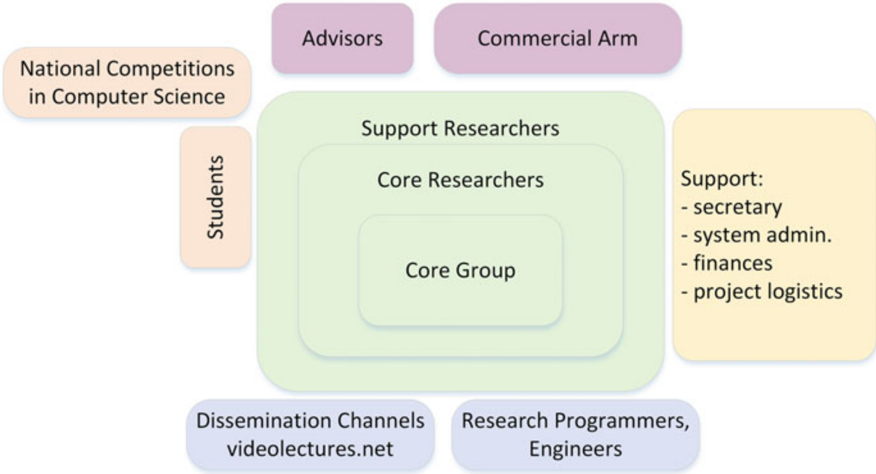

Fig. 4.1 Internal organization grown organically over a decade

The group was organically growing attracting enthusiastic students, greatly supported by our involvement in Computer Science National Competition. The core group holding the vision expanded with researchers and Ph.D. students, the number of international projects was growing. We shaped our dissemination channels (videolectures.net public portal) initially as a part of dissemination activity on collaborative research projects supported by European Commission. With the growing group size and the growing number of project, the support team initially covering secretarial work and system administration extended by financial manager and project logistics. International interest and long-term collaboration naturally resulted with an informal advisory board and a formal commercial arm, supported by research programmers and engineers, as shown in Fig. 4.1.

Despite the fact that there is a well-defined organizational structure of a group, one should keep it open and as fluid as possible. Namely, it is in the nature of research that at the same point in time a person can have different roles depending on the context. For instance, one may lead a project, while also working on another project and providing occasional support to students.

4.5 Profile of Group Members

Leadership in research naturally involves managing human resources, where trust is one of the fundamentals of a successful communication. We all know importance of trust in life and how the lack of trust can inhibit our capabilities to express and successfully relate.

4.5.1 Trust

First, we trust ourselves and our own values so we can express our ideas, our talents and share with others. This also means that we know ourselves, we understand our inner dynamics and trust that we can consciously go through challenging situations not being a victim of our own little goals that would jeopardize our overall long-term goal. When we trust ourselves, we are in a position to trust others. For a smooth running of a research group, high trust between people in the group is fundamental. This means transparency in communication and absolutely no space for gossiping. To maintain the trust and a creative flow, we need early conflict detection and prompt conflict resolution. Moreover, to make an honest progress in research we have to be honest in what we are doing, in what we know and what we do not know. Thus there can be no tolerance on scientific "bluffing". There is no need to pretend to be what you are not, it is clearly visible when someone is pretending and that if fact shows disrespect to intelligence of others. Instead of pretending, rather work on strengthening your talents and elevating your weaknesses.

Good human relationships are fundamental for good collaborations. Especially inside a group, everyone has to understand the game. You want to ensure transparent leadership and open sharing of knowledge/experience. Tight inner collaboration, where people share working as well as some private time, contributes a lot to well-functioning of the group.

4.5.2 Excellence

All the group members should recognize that we are on the same boat, so we support each other. We share a common vision with priority on the group interests. At the same time, carrying for each other and making individual interests priority on a long run, working towards enabling individual growth in addition to the group growth.

When talking about excellence, it is important for a leader to understand what the preferred profile of a group member is. For instance, it can be a researcher having vertical skills with experience in programming and mathematics, great enthusiasm for research and capable of gradually developing some management skills.

Science to be excellent relies on excellent people. As stated in Singh Avenali (2012) there are several steps to excellence, several characteristics that we can develop to support us in achieving excellence in something. First we want to decide what is that 'something' that we want to be excellent at. That we recognize intuitively by having a vision and shaping it in a goal that is bigger than us, a goal that is worth our time and efforts. Soon we will find out that for pursuing such a goal we need courage and enthusiasm for following the vision crossing the limits of known as needed. Following the vision means also to stick with the goal and be ready to work hard—what Sadhana Singh in (2012) is referring to as have grit. While we are progressing we need an open mind and humility to listen to criticism and suggestions. Furthermore, we need knowledge. Every research is based on some knowledge of the subject and the related work. As difficulties approach, we need to trust the initial vision and the process, while we also need some healthy openness for taking risks. One can say that we need faculties of prayer and grace in handling difficulties. We do not want to lose time and energy fighting, rather we take the challenges with grace and with great determination make the best out of them. Starting from the vision and going through all the process we make a decision to go for winning and not for losing. This means that you put all of you in it, you merge your vision/aim and your life. For more on merging your aim and life see (Singh and Mladenic 2016).

4.6 External Collaboration

External collaboration makes research more fun and brings new opportunities. Maintaining high standards of the group is crucial for a successful long-term collaboration. This means that you should have good performance also on a short-term when for instance, working on a single task or a project deliverable. Additionally you want to contribute to the overall success of the project you are working on. On a long-term you want to develop technology and alliances beyond a single project which includes working on complex solutions and maintaining the already developed prototypes and products.

Leadership and balance in research include keeping operational links with others alive, having joint projects and/or providing technology. There are at least three stake-holders you want to target. One is academia, where it is advisable to have operational links to academic hubs. For instance, letting you collaboration result in working together on a shared codebase, or on sharing services resulting from joint research efforts or maybe sharing dissemination channels. Academia is your target for research collaboration on projects and developing your research network.

Businesses on the other hand can offer opportunities for collaboration on challenging projects, where there is no off-the-shelf product. The idea is that operational links with businesses result in innovative and challenging researcher. Additionally, collaboration with research labs can lead to joint research projects, student internships and joint organization of research events.

Government funding agencies on national and European level are very important stake-holders where you want to be at least informed about the forthcoming funding opportunities. Depending on your research profile, you may be even able to establish collaboration where your research is providing some practical value for them, as for instance developing tools for analytics of funded projects or monitoring public opinion regarding research policies.

4.7 Conclusions

Leadership in science should support excellence of individuals, excellence of the group and excellence of science itself. We would like to support the involved people growing professionally and personally, gaining experience and growing in consciousness. There are certain characteristics that a leader should have to ensure a successful leadership.

4.7.1 Characteristics of a Leader

Research is often about dealing with negative results, the results that were not expected or simply show that your hypothesis was not right. In such a situation, it is important not to be attached to research results fulfilling our expectations. We want to see beyond the immediate situation, to have a long term vision. Negative result may lead to new discoveries. We also want to be flexible and adjust to new situations (new research findings, new funding schemas, new problems, new technology), see opportunity in every situation and learn from experience. To be successful in leadership and also in life in general, you should know your strengths and your weaknesses and use them all, be authentic. You should do the same with others, understand their strengths and weaknesses and support their talents. As said by Yogi Bhajan (2001) "*. . .you will only be appreciated if you appreciate the good side of your students. If you want to tell someone they are rotten, just appreciate their good side instead. They will fully realize how rotten their other side is*."

Successful leadership revolves around having and maintaining a common vision over time, which is challenging. The initial vision came intuitively, but then it requires conscious effort to maintain it and develop a strategy for achieving it. One of a great tools for keeping the alignment of the whole group with the common vision is to organize regular research retreats taking a few days to reflect on the past research and plan for the new research directions.

Leadership requires combining intuition and intelligence. Already the vision of our overall goal, the vision of goals of future projects should be obtained by intuitively. Then we elaborate on it intellectually developing a strategy to manifest it. "*There is no question that the use of gut feelings and intuition can help leaders make quick and (sometimes) accurate diagnosis. . .ability to read between the lines and to see what many people do not see. Then it is the gift to seeing the big picture and to connect the pieces together so that the meaning of the entire situation is now different. And finally, is to have a vision in terms of how the situation is (or can) evolve or become*" (Casse 2012).

As we know, good work speaks for itself. As a leader you should work on maintaining high quality standards, before, during and after performing the work. High standards should be a part of your group code of conduct. With success and expansion it is easy to lose your anchor, your original vision. You should ensure to regularly get some quiet time for yourself and for getting together with the core group.

One of big challenges of leaders is being overloaded with work. Keeping too many roles on yourself leads to wasting your time for things that others can do and thus only partially utilizing your own talent. It is crucial to learn how to delegate work. A very simple rule is to check if something can be done by someone else in the group and if so, delegate. When delegating clearly specify what needs to be done and provide support and supervision as needed. Delegating is not just about getting some workload off you, maybe even more importantly it is about trusting others and giving them a chance to take more responsibility.

You lead by example. Handle difficult situations gracefully. Find a way to be calm, open minded and kind no matter what. In challenging situations you can help yourself with conscious breathing, changing the view angle and looking for opportunities in challenges.

4.7.2 Successful Leadership

Successful leading of a research group means that the whole group is successful, including people being happy and prosperous. Namely, if it comes to the situation that goals of a project are fulfilled but at the end the involved people are, for instance, exhausted, it is only a partial success. To lead the whole group towards success, you have to develop a strategy how to realize your vision on micro and macro level. You should also know in advance the possible consequences of success (e.g., group expansion requires more office space, as a leader you become a multi-threaded person—multiple tasks, multiple worries, multiple responsibilities). You have to understand the needed energy/resource in advance (e.g., getting good quality people, your own time investment), consider possible problems and develop a plan "B" (e.g., reduced funding opportunities, shift in research topics).

Successful leaders are experienced in leading themselves. They are clear enough to understand what is happening around and they are in control of their mind, meaning they do not react on situations but rather consciously act. As a leader you should have self-respect, so that others can respect you. This means that you recognize who you are, your qualities and weaknesses and use them. You use discipline to hold your intention alive, to notice opportunities and use challenges to gain experience. The leader is flexible on all levels: mental, physical and spiritual. She has capacity to hold the situation and encourage others, she has a personal code of conduct (e.g., no blame, no complain, no compare, no gossip).

Your own success as a leader is measured by the success of the people you are leading. Leaders recognize talents of others and support them, as the only way to maintain your own success is to make others successful.

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Chapter 5
Rational Ethics

Bertrand Meyer

Abstract An effort, originating from an invited talk on "ethics and computers", to re-found ethics on the rules of logical reasoning, from three concrete principles (Goodness, Truth, Fairness) and two meta-principles (Restraint and Importance).

5.1 Introduction

In the attempt to address the assigned theme for this contribution, ethics and computers, it became clear that while the second term is well defined the first is not. What kind of behavior qualifies as ethical? The established works on ethics, from Aristotle to Spinoza, Kant and modern moral philosophers, lack precise definitions of the concepts they discuss. They bring to mind C.P. Snow's *Two Cultures* thesis that instead of berating scientists for not reading Dickens we might ask writers and philosophers to explain the second law of thermodynamics.

Of the two cultures, the humanities indeed have as much to learn from science and technology as the other way around. The latter's advantage comes from three fundamental characteristics of scientific discussions. First, they devote great care to defining precisely the concepts under consideration. Second, to draw conclusions from principles, they use simple and firmly grounded laws of reasoning, rather than appeals to emotion or authority. Third, all their propositions are subject to refutation through objective criteria (of which the most practical is that a *single* counter-example suffices to refute a proposition of the universally quantified kind, such as "all French women are red-haired").

Ethics is one of the parts of the humanities that has the most to gain from the scientific method of reasoning. The present article proposes a rational basis for ethics.

B. Meyer (✉)
Politecnico di Milano (professore associato)

Chair of Excellence (2016–2017), IRIT, Université de Toulouse

Professor of Software Engineering (emeritus), ETH Zurich

Chair of Software Engineering, UNG-F14, Universitätstrasse 19, 8092 ETH Zentrum, Switzerland
e-mail: Bertrand.Meyer@inf.ethz.ch

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After discussion and polishing, it could serve as a basis for a second part addressing the original theme of ethics and computers.

The proposed basis for ethics consists of five principles. Three are concrete rules of behavior:

- Principle of Goodness: help the weak; in particular, do not harm.
- Principle of Truth: do not lie.
- Principle of Fairness: treat others fairly.

The others are meta-principles, governing the application of the first three:

- Principle of Restraint: only apply ethical considerations to cases of a demonstrably ethical nature.
- Principle of Importance: if concrete principles lead to conflicting conclusions, rank their relevance.

Section 5.2 briefly reviews why some classical approaches to ethics do not help. Section 5.3 distinguishes ethics from other forms of behavior prescription: religion, law, politics and reason. The next five sections, complemented by one on the fundamentals of rational thinking and another on the concept of relativism, detail the proposed principles of ethics. The last section is a short conclusion.

5.2 Classical Ethics

In trying to derive laws of ethics, the prestigious traditional contributions are of little practical use. Kant, for example, is famous for the "categorical imperative" which, in a simplified version, states that one should make each decision through a rule that could become universal. The immediate objection is that such a principle solves no problem of ethics, but simply pushes the problem: how are we to know that a rule is universally applicable? There is an even more fundamental impossibility: any non-trivial case admits no single generalization. Difficult ethical situations are difficult precisely because they are specific.

A recent, much publicized legal case provides an illustration. A wife killed her husband; was that right? The categorical imperative tells us that it is not. But wait, he had abused her for 30 years! Is not self-defense acceptable? Yes, it is permitted to kill in self-defense.[1] But wait, he was not threatening her at that particular moment; she killed him in cold blood. Then it was not permissible. But wait: was it not self-defense after all, given all these years of beating and humiliation? Self-defense does not necessarily mean an immediate threat if the victim knows the threats are going to start again. But wait... And so on. Any proper discussion leads to restricting the context repeatedly until it comes to encompass only the case at

[1]The categorical imperative does not rule out all cases of killing, as evidenced by Kant's acceptance of the death penalty and even of the "annihilation" of bastard children.

hand; then one is left where one started, with no other guides than generalities and preconceived ideas. Surely we are entitled to expect more from ethical theories.

The Categorical Imperative can lead to such absurd conclusions (such as the injunction not to lie to a would-be murderer) that it is better to consider it as an elegant intellectual exercise on Kant's part, rather than a rule intended for practical use.

Also disturbing to someone trained in scientific reasoning is the Kantian use of intentions to judge the morality of actions. Rational thinking needs objectively assessable criteria. Results are subject to objective assessment; intentions are not.

A traditional idea often proposed as the key to ethics is the "Golden Rule": treat others the way you would wish them to treat you. While useful, it is clearly insufficient, and not always applicable. For a soldier who sees an enemy taking aim, making sure to shoot first is not unethical, but contradicts the golden rule since he most likely does not *wish* the other soldier to do the same unto him. More fundamentally, the rule's naïve assumption of symmetry does not hold in most cases and leads to hypocrisy. A man discussing the ethics of abortion cannot possibly understand the procedure's potential effect on *him*, and would be dishonest if he pretended otherwise; ditto for a young adult discussing the ethics of policies for the old, or a billionaire discussing the ethics of unemployment compensation.

Another example of traditional approaches to ethics is Spinoza's treatise. It deserves praise for its emphasis on human freedom and for attempting mathematical-style deductions—mathematical, however, in style only.

A satisfactory system of ethics requires fresh thinking.

5.3 Distinctions

It seems to be a universal feature of human societies that they consider some behaviors, aside from the immediate benefit or harm they cause, as inherently "good" or "bad". The role of ethics is to codify this innate sentiment into rules of conduct.

To develop sound principles of ethics, the first task is one of delimitation from other endeavors which also seek to regulate behavior: religion; law; politics; reason.

Religion is often mentioned in connection with ethics and played a role in the progress of ethical values in European history. If, however, we take a contemporary perspective, no discernible connotation exists between ethics and religion. There is no evidence, for example, that religious people behave more ethically, or less, than agnostics and atheists. If we wanted to run an experiment that *might* evidence some correlation, we could immerse a country for a sufficiently long time in a religious culture with ethical ambitions, then see how it reacts to an ethical challenge. The country might be France; the sufficiently long time could be a millennium; the ethical challenge could be whether to take a stand about a crime of unprecedented proportions against humanity; and the people we test could be the dignitaries of the religion that had dominated the country for those 1000 years. We do not need to run the experiment, it ran itself: out of about a 100 French bishops in World War II, six

(six heroes, some of whom paid dearly) took a public stance against the treatment of the Jews. Such an example suffices to dispel any hope of correlating religion with ethics.

A connection with *law* exists, but it is indirect. Not all that is legal is ethical; you can take advantage of what your mother taught you about how she runs her business to start your own competing company and drive her to bankruptcy, all within the framework of the law, but hardly ethical. Not all that is ethical is legal, as in the case of people helping illegal immigrants against the law but out of ethical concerns. The more tyrannical the regime, the more examples there will be of ethical behaviors that are illegal. A definition of the ideal democracy might be that it is the place where every ethical behavior is legal.

The relationship with law is interesting in two more respects, leading to both of the meta-principles, Importance and Restraint. First, law gives us useful terms to *talk* about ethics. We mock lawyers and their "on the one hand, on the other hand" style of reasoning, but many legal modes of thinking are effective for ethics, for example the practice of assessing which is the lesser of two evils. Often in ethics as in law there is no perfect solution, but we have to choose the least bad, as expressed by the Principle of Importance. Second, ethics can benefit from more law. In many debates, partisans of one of the two sides unfairly tilt the discussion by asserting that they are defending good against evil. Handing over the decision to rules of law simplifies the discussion and lessens the role of emotions. A typical example is prostitution, which is not an ethical matter once we remove confusion by not commingling it with issues of child abuse and human trafficking, on which all sides agree; if it were an ethical issue, countries with a similar ethical culture, such as Canada and the US, would not treat it in opposite ways, regulation versus interdiction. Ethical considerations bring little to the debate. Better to resolve it through legislation after a pragmatic discussion of the benefits and disadvantages of both approaches. (In 2008 the governor of the state of New York, elected in part because of his staunch moral crusade against prostitution, was exposed as a valued customer of a high-class prostitution ring. He might have avoided having to resign in shame if he had earlier stated his position through arguments of public policy rather than proclamations of his high-minded ethics.)

Producing legislation is the work of *politics*. The actual role of ethics in politics is tenuous. Most politicians would have us believe otherwise, draping their ambitions in ethical clothes, with the usual heart-rending declarations of devoting oneself to the good of one's country. Such ethical motives do exist, but only as an adjunct to the politician's primary drive, the drive for power. (Witness the ever-repeated saga of the heroic freedom fighter who, the minute he topples the previous regime, becomes the new tyrant.) Desiring power is not unethical, but it would be refreshing to see a candidate proclaiming: "vote for me because I badly, badly want the decision power and the limousine and the deference of office-seekers and the TV crews outside my house eagerly awaiting my next pronouncement".[2] This drive

[2]Brilliantly expressed by Don Magnifico's aria "*Già mi par che questo e quello*" in *La Cenerentola*.

is always present, and often dominant, in the mindset of *every* candidate; *no* candidate ever states it. From the Principle of Truth, the first one who did would, on purely ethical grounds, deserve our vote.

In a stable democratic regime, most political decisions are of a pragmatic rather than ethical nature. Is it better to route landing airplanes through the Western or Southern route? Fuel costs being the same, the question is whether to harm Jürg in the Western suburbs or Hans on the South side; neither solution is more ethical than the other, and the question will simply be which of the two camps has more political clout. The presence of a strong ethical component in a political decision is usually a sign of crisis, for example when a people rises against a tyrannical power, or in times of peace when the president and congress of the USA collude to take away health care from the country's entire lower class, in clear violation of the Principle of Goodness.

The last concept against which to assess the role of ethics is *reason*, in the sense of rational processes for solving problems, as used in science and engineering. Rational thinking is indeed at the basis of the approach to ethics developed in this discussion. But rational thinking alone does not suffice. In countries that do have a universal health care system, a strictly rational policy would be to stop health care benefits at, say, 65, since older people account for a disproportionate share of health costs. Deficits gone, financial problem solved! The argument for not following this route is entirely ethical. The constraints of reason are not sufficient to guide ethical decisions. The concept of good and bad is the driver.

This observation is worth emphasizing, if only to avoid misunderstanding the term "rational ethics" as implying that ethics should entirely follow from reason. The confusion is all the more possible that reason does go a long way to justify ethical rules. The ethical injunction not to kill is a good example of a principle that one can sustain through rational arguments: if we could all kill each other without restraint, humankind would either not last long, or, for those few of its members that survived, not lead pleasant lives. While such a rational argument supports the corresponding ethical principle, it does not constitute all of it. It does not, for example, rule out the death penalty, which in normal circumstances has no quantitatively significant population consequences; and yet civilized people have come to reject that practice as unethical. Something else than pure reason is at play: an independent notion of distinguishing between good and bad.

While not sufficient, the constraints of reason on ethics are necessary. The corresponding principles of rational thinking deserve a few more comments in the following section.

5.4 Rules of Reason

The logical method of reasoning is the basis for mathematics, science, technology and much of the progress in human history. (A common retort is that logic is not everything or, in Pascal's terms, "the heart has its reasons, to reason unknown". All well and good, but to broadcast such appeals to emotion, for example from your smartphone, you are taking advantage of centuries of advances in mathematics, physics, electronics and computer science. Astrologists need YouTube just as much as astronomers do. A politician's most rousing appeals to instinct reach no one without correctly modulated electrical signals. Even back then in the savannah, the most mystical of our ancestors needed logical thinking to keep the predators at bay.)

Section 5.1 listed three fundamental rules of reasoning: precise definitions of the terms of any discussion; reliance on a small number of precisely defined schemes of logical deduction; and a simple technique for disproving universal ("for all") statements through exhibiting a single counter-example. (In epistemology this second rule is known as falsifiability; in computer science it corresponds to the fundamental rule of software testing, expressed in Dijkstra's famous pronouncement.)

Two other rules of rational thinking are also essential: proof by contradiction, and limits on the reach of theories.

The first is (like falsifiability) a technique for *disproving* propositions.[3] It encourages us to examine the consequences of an assumption with the specific intent of reaching a contradiction. If we succeed, then we can reject the assumption. Tolstoy's *Kreutzer Sonata* provides an example in ethics. After a dissolute youth, the novelist decided that carnal love was evil and should be renounced. To people who pointed out that following this principle would soon put an end to the existence of humans, he replied that he was only prescribing it as an ideal behavior and that not everyone would apply it. Even ignoring the strangeness of the immediate consequences in this specific case (is it desirable to restrict future generations to the progeny of the *unethical* members of current humankind?), it makes no sense to promote an ethical theory subject to the condition that that not everyone will follow it. *Reductio ad absurdum* is as useful a reasoning technique in ethics as elsewhere. It does make discussions more messy, by taking us away from the comfort of pondering grand principles, such as "thou shalt not kill", purely in the abstract. Sound reasoning, however, requires that we consider their consequences. As with an experiment in science and a test in software development, a positive result only provides a minute increment of trust, but a negative result forces us to change our assumptions.[4] It also helps us, in applying the Principle of Importance, to assess the respective merits of other principles: the flight attendant's injunction to "put on your own oxygen mask before that of children traveling with you" only seems to contradict the Principle of Goodness until we consider the consequences of not applying it. (If you are unconscious, you cannot do much good for your child.)

[3]The scientific method has a distinct Mephistophelic ("*ich bin der Geist, der stets verneint*") component.

[4]An example is an illustration, a counter-example is a disproof. This observation imposes a strict intellectual discipline (which the present article strives to apply) on the use of examples and counter-examples to support arguments.

The other rule, which we may call "acceptance of inherent limits", is one of the major discoveries of twentieth-century science. Incompleteness and undecidability results in logic, mathematics and computer science force us to accept that for sufficiently complex problems no complete theory can even exist. They have echoes in other disciplines, physics in particular with the uncertainties of quantum mechanics, and even in the humanities with Isaiah Berlin's emphasis on favoring local, specific political solutions over all-encompassing schemes. The echo in ethics is the realization that not all dilemmas have a satisfactory solution. The fashion in moral philosophy in the past few decades has been to brood over the trolley problem[5] and other riddles of that kind. The likely answer in such cases is that a satisfactory solution is as impossible as Russell's barber, or a definition of "heterological" in the Grelling-Nelson paradox, or a C compiler that guarantees termination of the generated code. More important than these intellectual games are the many cases, arising every day in the world around us, of clearly right and clearly wrong actions, which moral philosophers should delineate for the rest of us.

Giving logical reasoning the central role in discussions of ethics has another benefit: it decreases their *ad hominem* component. We cannot completely discard that component; it is natural in particular to take a skeptical view of ethical exhortations proffered by a scoundrel. The more serious risk arises in the opposite situation: being taken in by holier-than-thou types who proclaim their own perfection, using the pretense of ethics as a cover for the advancement of their own goals. The US population seems to be a particularly frequent prey for televangelists who build a business empire by hectoring sinners, until some mishap reveals them as abusers and crooks. (An advantage of having gone to school in France is that around the age of twelve you go through *Tartuffe*, where a self-advertised saint spends five acts berating everyone else until officers of the King come onto the stage and arrest him for fraud and racketeering. This early vaccination makes people wary of grandiose proclamations. Real saints do not typically go around advertising their own sainthood.) Setting aside the extreme examples of scoundrels and saints, we should try as readers to separate the message from the messenger. As authors we are correspondingly permitted to write about ethics as we would write about any other topic deserving rational discussion, without making any claim of moral superiority, or any personal claim of morality at all. "Do as I say, not as I do" is hypocrisy, but a condition of sane discussions is to focus on what we say, not what we do.

[5] A cable car is running into five people; do you pull the switch to divert it to a track where it will kill just one person?

5.5 The Principle of Restraint

We start our review of the five principles by one that *limits* the use of ethics. The Principle of Restraint states that we should only apply ethical criteria to issues of a demonstrably ethical nature, defined as issues of deciding between good and evil.

Ethics is about serious, often difficult cases of such decisions. It is inappropriate—and may occasionally be unethical—to appeal to ethical considerations in cases that do not justify it.

Sometimes such overreach is harmless. Many professional organizations have "codes of ethics" which are really rules of serious professional behavior, only some of which have an ethical character. In the IFIP codes of conduct for authors and referees,[6] the injunction not to submit a scientific paper simultaneously to two different conferences or journals is not a matter of good and evil, simply a way to make the publication system efficient. Purely rational considerations suffice here; we do not need to devalue ethics by invoking ethical principles unnecessarily.

More harmful effects arise when people artificially bring ethics into a discussion to make their side look good and the other side look bad. We saw an example in the case of prostitution. Another one, from information technology, is the attempt to position open-source software as a moral crusade. As illustrated in my 2000 article *The Ethics of Free Software*,[7] the leaders of the movement, self-proclaimed saviors of humankind, switch to savage attack mode the minute they feel one of their colleagues is taking undue credit for their contributions. (For a while, the creator of GNU, unhappy that Linux, which used many GNU tools, was getting all the credit, lobbied to have the system renamed "Lignux".) This observation removes nothing from the value of open-source software—it simply shows that these brilliant programmers are also normal humans—but does suggest staying away from ethical considerations when discussing such matters as the respective merits of commercial versus open-source software. The article's conclusion was that open source is not an ethical stance but a business model. Pretending otherwise is hypocrisy.

A similar confusion, with worse consequences, has now arisen in the world of scientific publication. Riding on the popularity of open-source software, many publishing companies have embraced *open-access* publishing. Open-source software is, at least, "free" in the economic sense: you can get it at no cost (paying only for associated services). While some open-access journals (such as the Journal of Object Technology, jot.fm) are indeed free to both authors and readers, the more common "gold" model of open access simply means that authors pay to publish, rather than readers to read. Not only is the move to such a model based on economic rather than ethical considerations, but the ethical implications are actually onerous, since a number of disreputable publishers have taken advantage of the new fashion

[6] bit.ly/2j18Lby and bit.ly/2j18ghD; I was the main author of these documents. Another important example is the carefully designed ACM code of ethics.

[7] *Software Development*, vol. 8, no. 2, pages 32–36, se.ethz.ch/~meyer/publications/softdev/ethics.pdf

to swindle naïve authors. (See the many descriptions of the phenomenon such as bit.ly/2iwGTQ5 in *The Scientist*.) Predatory publishers take advantage of ethical arguments to achieve purely selfish aims. Ethically, their behavior is all the more repulsive that it breaches the Principle of Goodness by preying on the weak.

Pretexting ethical reasons to further one's own interests is the precise definition of hypocrisy. Overuse of ethics always raises its danger. The Principle of Restraint decreases this danger by enjoining us to restrict the application of ethics to cases of an undisputed ethical character: decisions that demand a crucial distinction between good and evil. For everything else, use any arguments that you think will work, but keep the ethical pretense out.

5.6 The Principle of Importance

Many ethical fallacies arise when someone considers a problem according to a single criterion, ignoring others that are more important. The danger already exists in Aristotle's list of virtues including "temperance" (moderation) and "courage" (the ability to face danger with thoughtful deliberation) with the implication that they are at a comparable level of importance. The famous Milgram experiments suggest that temperance has an unfortunate tendency to supersede courage. When applied to making practical decisions, these principles often lead to different directions; the conflict arises most vividly for people facing tyrannical regimes, when temperance suggests conforming and courage suggests revolt.

The Principle of Importance states that we must recognize such conflicts between different ethical criteria, and resolve them by attaching weights to each. (The alternative would be to pretend pretending that a single criterion, such as a categorical imperative, suffices to produce all the answers in all cases.)

This is one of the areas where ethics benefits from law (Sect. 5.3): it is standard practice in legal reasoning to weigh the respective importance of several criteria. Someone who rushes into the street to help an accident victim should not be charged with jaywalking. The legal concept of "extenuating circumstance" is a more general example of the multi-criterion approach of judicial decisions.

Neglecting the Principle of Importance is the specialty of single-issue advocates, who subordinate everything to their favorite concern. The *Ethics of Free Software* article cited this extract of a lecture on free software by Richard Stallman:

> *[...] scientists used sometimes to be able to cooperate even when their countries were at war. I read that once American soldiers who landed on an island of the Pacific Ocean, during World War II, found a building with a note saying: 'To American soldiers. This building is a marine biology laboratory. We put all our samples and reports in order so that US scientists can go on with our work." Because, for them, they were working only for humanity. Not only for Japan. They wanted their work to be useful for humanity, regardless of the outcome of the war. But today we live in a state of civil war between small groups, in every country. In which every group acts to stop the others, hinder the others, hamper the others. It's sad.*

Obsession with a single issue (academic openness) led the author to lose his ethical perspective. Reading his plea, one might believe that willingness to share marine research was the salient feature of Japanese troops in WW2, rather than the unprovoked attack of democratic countries and the devastation of Asia; and that marine biology was the salient feature of Japanese research, rather than horrendous experiments on humans (en.wikipedia.org/wiki/Unit_731).

For another example of distorted ethical priorities, here is an extract (in my translation at from the French at bertrandmeyer.com/2012/11/04/souvenirs-of-a-dark-time/) from the memoirs of my mother, who during the war was placing Jewish children in homes and convents:

> *I also have to evoke that other Mother Superior, stern and dry, who after making me languish for several days while asking for the approval of her supervisors finally consented to see four or five little girls. I arrived with five of my charges, whom my neighbor had brought to me after their parents were arrested on that very morning. I can still see the high-ceilinged parlor, the crucifix on the wall, the freshly waxed and shining floor, the carefully polished furniture and a tiny figure with curly brown hair, all trembling: the eldest girl, who at the point of entering stepped back and burst into tears. "One does not enter crying the house of the Holy Virgin Mary", pronounced the Mother Superior, who had me take my little flock back to Grenoble, without further concerning herself with its fate.*

If in today's peaceful France a little girl starts crying loudly in a church, you might order her to behave: to conform to temperance. The Mother Superior understood that Aristotelian virtue. Courage is what she lacked. In such examples, we cannot make an ethical decision without deciding on the respective importance of the criteria at play. Here is an extreme case from Timothy Snyder's *Bloodlands*, about the Holodomor (the Ukrainian famine expressly caused by Soviet authorities):

> *Survival was a moral as well as a physical struggle. A woman doctor wrote to a friend in June 1933 that she had not yet become a cannibal, but was "not sure that I shall not be one by the time my letter reaches you." The good people died first. Those who refused to steal or to prostitute themselves died. Those who gave food to others died. Those who refused to eat corpses died. Those who refused to kill their fellow man died. Parents who resisted cannibalism died before their children did. Ukraine in 1933 was full of orphans, and sometimes people took them in. Yet without food there was little that even the kindest of strangers could do for such children. The boys and girls lay about on sheets and blankets, eating their own excrement, waiting for death.*

Such extreme circumstances are a challenge to any system of ethics—no moralist would defend cannibalism, or leaving children without food—but the passage again illustrates the necessity of weighing criteria against one another.

One hardly needs to argue for the Principle of Importance with a person who has had the privilege of living or working with an uncontested hero. "There are no heroes to their valets." Petty offenses in everyday behavior do not, however, annul the heroism.

The Principle of Importance does not justify the ethical fallacy, sometimes known as "false moral equivalence", of pretexting of an ethical violation to justify another, as in "how can you accuse me of Y given that you did X?" Unless Y is a demonstrable consequence of X, they are worthless. Yet such arguments are a favorite of propaganda in foreign policy, as if a country could invoke another's past military follies as a permission to invade its own defenseless neighbor. The Principle of Importance does not involve comparing different cases but comparing competing criteria in one case.

A criticism of the Principle of Importance is that it does not include rules for assessing the respective weight of conflicting criteria. This question may indeed need further work. In many practical cases, however, the more difficult step is to accept that more than one criterion may be at play; after that, the assessment is not so hard. Carelessness in managing your email server may be bad; but as an ethical violation, it cannot possibly measure up against repeated lying, shady financial dealings, boasting of sexual assault, and insulting people because of their handicap or national origin.

5.7 Relativism

The Principle of Importance does not imply "moral relativism". This term denotes arguments (often used by apologists for dictators) justifying unethical behaviors through cultural differences. Relativism is generally unfounded. We may, for example, respect "Asian values", but they cannot not justify violations of universal rules of ethics. Asians require freedom, respect and safety as much as everyone else.

The Principle of Importance can justify moral relativism in diachronic rather than synchronic comparisons (history rather than geography). At a given time (synchrony), the same general norms apply everywhere, with some fine-tuning to local nuances. We need, however, some flexibility in assessing *past* practices, and must recognize that all human discourse is influenced by the author's times. Otherwise we would reject almost all the classics: Kant, as noted, condoned cases of infanticide, and Voltaire was an anti-Semite. While we may and should remain shocked by some of their ideas (as anyone reading us in two hundred years will undoubtedly be by some of ours), we must accept that some of them simply followed from the authors' cultural context and focus on their contributions of eternal value.

Examples abound, here is a Japanese one (Fig. 5.1).

Hard to imagine today. As another Japanese example, if only from the Japan of Western fantasy, the story in *Madama Butterfly* involved an ethical scandal[8] at the time of its creation and still does. But the nature of the scandal has entirely changed. The scandal then was a child conceived out of wedlock (even from an arranged union with a cynical American officer). The scandal for the modern mind is the story's reliance on what we would call child sex tourism, a practice that the libretto treats with not even a hint of disapproval.

[8]One may safely combine at most two of: supercilious moral principles; a love of opera; understanding of Italian.

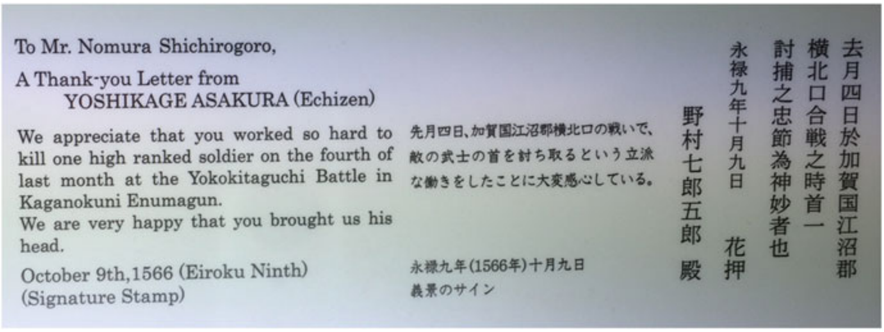

Fig. 5.1 An Exhibit from the Nomura Samurai House Museum in Kanazawa

Ethical principles do evolve, but at a given time, while we should be tolerant of cultural differences, the key rules of ethics are universal.

5.8 The Principle of Goodness

The Principle of Goodness states that we should help people who are weaker than we are. This idea, also known as altruism, may be the source of all ethics.

We cannot restrict Goodness to cases in which it helps our self-interest, such as protecting our children (members of other animal species do so too) and the rest of our families. The true test of altruism is whether we can do good even we do not stand to benefit other than, possibly, from the pleasurable sense of having acted right. The principle's definition contains, however, another restriction: helping *weaker* people. Without this qualification, goodness might suggest that you should give $100 to Warren Buffett if he asks. That is not the idea.

The principle bears in itself a contradiction: altruism cannot be absolute without becoming self-defeating. If you gave all your food to the hungry, or even just (as the principle more exactly suggests) to those hungrier than you are, you would lead a wretched life and become unable to help anyone at all. Even the most saintly people must, like airline passengers with their oxygen masks, take some care of themselves. Saint Martin, of Catholic legend, wisely gave the beggar *half* of his coat.

More generally, any of us can only ever help a minuscule subset of those who need it. This inherent limitation separates Goodness from other ethical principles, making it inherently non-absolute. It is in fact so far from the possibility of absolute application that it can only be viewed as a general advice, what scientists call a heuristics: help weaker people "as much possible".

If we are not happy with this vagueness and search for a possibly more limited but firm rule, we may deduce from the Principle of Goodness the Principle of No Harm: do not harm needlessly. This rule is indeed a logical consequence of Goodness since someone that you can harm is by definition weaker. As always, we should be careful about careless generalization, hence the restriction to "needless" harm, recognizing that harming someone may be needed; you may be defending yourself against him, or protecting him from greater harm (as when brutally throwing him to the side because a car is rushing his way). But even just by itself the Principle of No Harm goes a long way towards addressing the core goals of ethics. If there is indeed is a "Golden Rule" of ethics, this must be it. If everyone consistently applied this principle, the world would be a much better place.

Goodness manifests itself in portentous questions but also in small matters. Traveling, known as a way to enhance appreciation of others' values, can also trigger a realization of the merits of one's own culture. A good experience is to spend a week in the traffic of Shanghai or Bombay, exposed daily to road traffic. No driver of truck or car or motorcycle or rickshaw *ever* yields any advantage, not even a centimeter: all that counts when two rivals could move is who would suffer more from a clash (inevitably the pedestrian, if he is one of the two), and it is *always* the other who moves. Coming back to the streets of Paris or Milan or Los Angeles, you realize what you have been missing: the little, casual horizontal hand gesture, unknown in many parts of the world but an unsung component of polite society, with which a driver whisks off a pedestrian or other driver, with or without a smile, but *without any necessity*—other than Goodness and perhaps the common-sense desire to help smooth the flow of traffic.

The varieties of driving mores may seem a trivial concern, at most a question of temperance, in light of the giant challenges of ethics. But they are revealing, and have ethical consequences. To be convinced, it suffices to have seen a frail old lady caught in the vociferous pandemonium of Hanoi, having attempted to cross a street; transfixed in terror, she seemed to have been standing there for hours, an incessant flow of cars rushing past her left and right, none ever slowing down. "Asian Values", with their supposed focus on honoring the elderly, were not in evidence.

European drivers generally will honk, Southern California drivers generally will not, but in both places there will soon come a driver who stops. While goodness in everyday behavior does not guarantee goodness in the life-and-death cases of ethics, it is difficult to imagine that societies that condone callous everyday behavior will naturally resort to goodness in matters of greater import.

This seemingly anecdotal example is indeed (perhaps better than intellectual puzzles of the Trolley kind) a crucible for ethical values. We can only argue for the obviously appropriate behavior (stop and let the pedestrian go, even at the risk of losing thirty seconds of your precious time or, supreme shame, let a less considerate driver overtake you) on ethical arguments. If we used law, we would argue that jaywalking is illegal (presumably in Vietnam too). If we used pure reason, we would argue that stopping many vehicles and delaying their occupants, for the sake of one person, is an affront to traffic efficiency. Only through the Principle of Goodness can we justify the decision.

Because the Principle of Goodness is at best partially applicable, we must often resort to its more restrictive but absolute corollary, the Principle of No Harm. It does the job here: we do not just try to be good to the jaywalking lady; if we were, we might as well propose to remove red lights, pedestrian crossings and all rules on pedestrians (who are, by construction, “weaker” than vehicles as required by the Principle of Goodness). That decision, as other extreme applications of Goodness, would have unacceptable consequences. No Harm tells us, however, that when we see the occasional jaywalker ethics should drive us to compassion. To avoid harming her, we push the brake pedal.

The supreme form of harm is killing. Many stern moralists of the past had no qualms about condoning some cases of killing. It should be a cornerstone of any modern system of ethics that killing stands apart from all other disapproved forms of behavior. Any acceptance of killing humans after birth should be restricted by the most stringent and exceptional conditions. This rule, the Principle of Life, is another quasi-absolute corollary of the Principle of Goodness: before all, preserve human life.

The Principle of Life explains, for example, that while we think regrettable to separate a child from his teacher we recoil with horror at the idea of separating him from his parents. The reason is that life is the most important of all human goals, and harming people’s life, especially the life of the weak, is the worst possible kind of harm.

5.9 The Principle of Fairness

The Principle of Fairness states that, under equal conditions, we must treat people equally. A concern for fairness, or at least some concern, seems, like Goodness, to be a key part of the very notion of ethics.

Fairness was one of Aristotle’s principles. He defined it as fairness to enemies. Being fair to friends is easy. More significant is how you deal with your foes.

Fairness and Goodness may come into conflict. Fairness can prevent us from according an advantage to someone who from pure concerns of Goodness might seem to merit it. On the waiting list for a heart transplant, a rich child is ahead of a poor child. When a heart becomes available, goodness might entice us to move the poor child ahead: is he not “weaker”? But fairness tells us otherwise. For the relevant criterion (the need for a heart), they are equally weak.

Fairness is in general, more than other principles, subject to qualification. In particular, fairness does not imply absolute equality. That chimera has been tried (by such principled ethicists as the Khmer Rouge), with results that no one wants to experience again. We want fairness, but not too much of it, because we recognize that conditions are seldom entirely equal.

One practical, actionable consequence of the Principle of Fairness is the Principle of Respect: show tolerance towards the diversity of humans. Here too we have to be careful, applying the Principle of Importance and avoiding the pitfall of moral relativism. The Principle of Respect directs us to accept other cultures; but if someone tells us that his culture justifies keeping women inferior, we should treat this remonstrance as the nonsense it is. Giving every person a chance to develop to his or her fullness, justified by the principles of Goodness and particularly No Harm, has overwhelming priority, and is indeed the very idea of Fairness.

5.10 The Principle of Truth

The last principle states that we should tell the truth.

Like Goodness, the Principle of Truth has a weak positive form and a stronger negative form,[9] as reflected in the standard instruction to jurors in a trial. "Tell all the truth" is the positive rule; "tell only the truth" is the negative one since it is equivalent to "do not lie".[10]

The positive form is not an absolute principle. When you describe yourself in your CV, or in declarations to a girl you court, you seldom tell the full truth. That does not make you depraved. Telling actual lies, however, is a different matter. The negative variant, "Do Not Lie", is indeed closer to an absolute rule.

Yet again, even the Do Not Lie principle has exceptions. To the object of your heart's desire you should not lie, but few people in love have ethical qualms lying to their rivals. The Principle of No Harm justifies that doctors lie to terminally ill children. The Principle of Restraint justifies that companies and sports team lie to their competitors (because such cases generally do not involve any compelling ethical element).

It is significant that these examples include a justification through other ethical principles. The existence of exceptions to Do Not Lie does not mean that we should take lying lightly. Most ethical behaviors are also truthful behaviors. Departures from the principle, that is to say, lies, create a heavy burden of justification.

The Principle of Truth seems related to a commonly accepted rule: the keeping of promises. Hold Your Promise is, however, not a separate ethical principle. It relates to the Principle of Truth only marginally: at the time of making a promise, if you already do not intend to hold it, you are lying. At any subsequent time, however, any ethical argument for keeping the promise has to come from the Do Not Harm principle. Such an argument can only exist if breaching the promise would harm someone weaker. If I promise to you on December 31st that I will eat less next year, and do not stick to that resolution, your opinion of me may sink, but I have not done anything ethically wrong unless your well-being depends on my slenderness. Keeping a promise can in fact be gravely unethical. If you have promised to send a child to a summer camp, and discover that the camp's leader has had a conviction for child abuse, reneging on your promise is the ethical solution.

What is the basis for the Do Not Lie principle and more generally for the Principle of Truth? To some extent, they can find a rationale on the sole basis of

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[9]The two forms were, for Goodness, "help the weak" and "do not harm" (Sect. 5.8).

[10]Technically, "do not lie" is a trifle weaker than "tell only the truth" since it also allows proffering statements that you not know to be true or false.

reason and logic. If everyone lied all of the time, or many people much of the time, it would be very hard for society to function. This matter provides an illustration of the Snow *Two Cultures* thesis: computer scientists trying to address fault tolerance and safeguard computer networks have made considerable progress towards understanding how a system can work correctly even when some or possibly many of its components, consistently or occasionally, deliver wrong information. Every ethicist should have read the Paxos paper.

On the other hand, the most obvious lesson, once you have learned from such work how to deal with systems that lie, is that if there is a choice truth always wins. We deal with lies because the world is imperfect and TCP/IP loses the odd packet or two, but things would be so much easier if Alice could always trust Bob.

The rational arguments are not enough; truthfulness in human affairs is in the end an ethical issue. What better evidence could there be, for the last example of a discussion arising from an informatics conference, than the titanic Volkswagen lie of 2015? The software engineers, and their managers, and most likely the managers of their managers, apparently thought that results-faking software would gain VW a few points of market share. The company will, it seems, recover; but only after providing, through its egregious violation of the Principle of Truth, a textbook-quality example of unethical behavior, sure to serve many generations of future ethicists.

5.11 Conclusion

Ethics affects some of the most crucial aspects of the human condition and of our ability to live in a society. These matters are far too fateful to allow for the interference of prejudices, superstition, or the overreach of ethics into questions that trivialize its value.

By taking a reasoned approach to ethics, based on the careful application of a small number of well-defined principles in a strictly delimited scope, we can obtain guidance for some of the most difficult decisions humans have to make.

Chapter 6
Ethics for the Digital Age: Where Are the Moral Specs?

Value Sensitive Design and Responsible Innovation

Jeroen van den Hoven

Abstract In the middle of the twentieth century scholars in the social sciences and humanities have reflected on how the telegraph, the telephone and TV have shaped our societies (A good example is the work of Ithiel de Sola Pool in the mid twentieth century. See for example *Politics in Wired Nations, Selected Writings*, Transaction Publishers, London/New York.). In the last 30 years, researchers in a variety of disciplines such as technology assessment, computer ethics, information and library science, science and technology studies and cultural and media studies have conducted research into the way new media, computers and mobile phones have turned a wired society into a full-fledged digital society. In the last 10 years we have entered a new phase of the digital shaping of society. We are trying to come to grips with artificial intelligence, big data, social media, smart phones, robotics, the Internet of Things, apps and bots, self-driving cars, deep learning and brain interfaces. New digital technologies have now given rise to a hyper-connected society. IT is not only getting in between people, but it is also getting under our skin and into our heads—often literally. Our standard ways of keeping tabs on technology by means of information technology assessment, tech policy and regulation, soft law, ethical codes for IT professionals, ethical review boards (ERBs) for computer science research, standards and software maturity models and combinations thereof, are no longer sufficient to lead us to a responsible digital future. Our attempts to shape our technologies are often too late and too slow (e.g. by means of black letter law) or too little or too weak (e.g. codes of conduct). The field of privacy and data protection is an example of both. Data protection lawyers are constantly trying to catch up with the latest in big data analysis, the Internet of things, deep learning and sensor and cloud technology. On any given day, we often find ourselves trying to regulate the technology of tomorrow with legal regimes of yesterday. This gives rise to the question 'How should we make our ethics bear upon high impact and dynamical digital phenomena?'

J. van den Hoven (✉)
TU Delft, Room number: B4.270, Jaffalaan 5, 2628 BX Delft, The Netherlands
e-mail: M.J.vandenHoven@tudelft.nl

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6.1 Introduction, or How to Do Ethics of IT Now?

The first thing we need to realize is that the technologies we end up using are consolidated sets of choices that were made in their design, development and implementation. These choices are about e.g. interfaces, infrastructures, algorithms, ontologies, code, protocols, integrity constraints, architectures, governance arrangements, identity management systems, authorization matrices, procedures, regulations, incentive structures, monitoring and inspection and quality control regimes. We build a social world that is shaped by the algorithms that determine how far our messages reach into our networks, what is recommended to us on the basis of what the system has learned about our search history and preferences, what is filtered out and how our reputation is built. We inhabit parametrized life worlds with properties and dynamics that we are mostly unaware of, or that we hardly understand, in case we are aware of them. Digital technology determines how we interact with each other, what we end up seeing and what we end up thinking. The filter bubbles described by Eli Pariser (2011) and Epstein and Robertson's description of Search Engine Manipulation effects (2015) provide examples. The technology that we are using is thus not neutral, since its design is informed by the world views and values of its makers. Once their ideas, values and assumptions have been embedded or expressed in digital artefacts, they start to influence the options, behavior and thinking of users. The digital technologies, our tablets, laptops, and smart phones with their software, apps, user interfaces and default settings form our 'choice architectures' (Thaler and Sunstein 2008) and our 'extended minds' (Clark and Chalmers 1998). The dilemma's and ethical problems we confront are a function of the programs that are running.

Recent thinking about ethics of IT and computer science has therefore focused on how to develop pragmatic methodologies and frameworks that assist us in making moral and ethical values integral parts of research and development and innovation processes at a stage in which they can still make a difference. These approaches seek to broaden the criteria for judging the quality of information technology to include a range of moral and human values and ethical considerations. Moral values and moral considerations are construed as requirements for design. This interest for the ethical design of IT arises at a point in time where we are at a cross roads of two developments: first, "a value turn in engineering design" and on the other hand "a design turn in thinking about values".[1]

First, when the computer was introduced around the middle of the twentieth century, scholarly attention was mainly focused on the technology itself. The computer was developed without too much thought about (1) the use and application in real life, or (2) the social, organizational and political changes it would require to function properly or the impact it would have on society. Computers were a new and fascinating technology: solutions looking for problems. The technology

[1] This draws on my "ICT and Value Sensitive Design", IFIP Int. Fed. For Info. Processing, 233 Nov 2006, DOI 10.1007/978-0-387-72381-5_8

initially appeared to be 'context-free', 'context-independent' and neutral. In the seventies and eighties, attention was increasingly drawn to the context of the technology, i.e. real organizations, (human) user needs and requirements, work conditions, etc. The social and behavioral sciences became increasingly involved with information technology (IT) in the form of (i) human-computer interaction, (ii) participatory design and (iii) social informatics. However, these efforts and commitments were initially mainly focused on a limited set of values, such as user-friendliness and worker-safety. Furthermore, the social and organizational context was often taken into account only as a way to identify potential barriers to the successful implementation of systems and to prevent failed investments. In the first decade of the twenty-first century, the successful application of information technology is increasingly seen as being dependent on its capacity to accommodate human values. Human beings, whether in their role as employers, consumers, citizens, or patients, have moral values, moral preferences and moral ideals. Information technology cannot and ought not to be at odds with them, and preferably should support and express them. In every society, there are ongoing moral and public debates about liability, equality, property, privacy, autonomy and accountability. Successful implementation is more and more construed in terms of how and to what extent values are taken into account in the design and architecture of systems. Values may even become driving factors in the development of IT instead of being an impediment in the design of information technology. We seem to have entered a third phase in the development of IT that we would like to refer to as "The Value Turn in IT", where the needs and values of human users, as citizens, or patients, are considered in their own right and not simply as a side constraint on successful implementation.

Secondly, simultaneous to the development of the views on technology and society, a development in ethics occurred during the course of the last century. From a predominantly meta-ethical enterprise in the beginning of the twentieth century, where the focus was on questions concerning the meaning of ethical terms such as "good" and "ought" and on the cognitive content and truth of moral propositions, the philosophical climate changed in the sixties and ethics witnessed an "Applied Turn". Moral philosophers started to study problems and practices in the professions, issues in public policy and public debate. In the USA, especially, a notable development took place, as philosophers gradually started to realize that philosophy could contribute to social and political debates by clarifying terms and structuring arguments, e.g. concerning the Vietnam War and civil rights, abortion, environmental issues, animal rights, and euthanasia. The focus at this point was on the application of normative ethical theory, utilitarianism or Kantianism, for instance, to practical problems. There often remained a considerable gap with the real world between the prescriptions derived from general theories and the results of the prescriptions in the world of policy making and the professional practice. However, in the last decade, applied ethics has developed into an even more practical discipline as emphasis is now being placed by some authors on the design of institutions, infrastructure and technology, as the shaping factors in our lives and in society.

If ethics wants (to help or to contribute to) real and desirable moral changes in a digital world then digital systems, institutions, infrastructures and applications themselves need to be designed to be demonstrably in accordance with our shared moral values. This design perspective does not only apply to digital technology, but also to other fields of engineering and other sectors in society. Ethicist will have to devote a good part of their attention to design in order to be relevant in the twenty-first century. This notable shift in perspective in practical ethics might be termed "The Design Turn in Applied Ethics" (Van den Hoven et al. 2017).

This has given rise to a different and pragmatic approach to ethics of IT; that goes by different names, but focuses on design and design for values as moral requirements early in the development of new functionality.

6.2 Value Sensitive Design

As a strong proponent of private transport, famous architect and urban planner Robert Moses designed low overpasses on New York parkways, so that cars could easily access e.g. Jones Beach, while at the same time preventing buses to pass under. This turned out to have severe social and political implications, as Langdon Winner (1980) pointed out, as the poor and (mainly) colored population—who are largely dependent on public transport—were prevented from accessing Jones Beach. Indirectly, the overpass functioned as a border-mechanism separating the wealthy from the poor with respect to the area that lies behind. Even if it is still contested whether Moses' design was consciously intended to have the implication of 'natural' or even racial selection as it did, according to Winner it is nevertheless a clear-cut illustration of the political dimensions that artifacts may have. With his account of "The Politics of Artifacts", he was one of the first to point to the political and social ideologies, values and biases our technologies have embedded in them.

Other studies into the philosophy and sociology of technology have also revealed numerous illustrations of the fact that social and political biases and values are incorporated in technical artifacts, systems and infrastructures (see, for example, Cowan 1985; Lansing 1991; Latour 1992; Mumford 1964). The examples in these studies illustrate how technologies tend to promote certain ideologies, while obscuring others. Batya Friedman, Helen Nissenbaum, Jeff Bowker and other scholars in ethics of information technology have extended this research into questions of how information technologies specifically can carry values and contain biases. The presumption here is that technology is not neutral with respect to values. Value-Sensitive Design (VSD) recognizes that the design of technologies bears "directly and systematically on the realization, or suppression, of particular configurations of social, ethical, and political values" (Flanagan et al. 2008).

The idea of making social and moral values central to the design and development of new technology originated at Stanford in the 1970s, where it was a central subject of study in Computer Science. It has now been adopted by many research groups and is often referred to as Value-Sensitive Design (VSD). Various groups in the world are now working on this theme. Batya Friedman (1997, 2002, 2004) was one of the first to formulate this idea of VSD, others have followed with similar approaches, e.g. 'Values in Design' at University of California (Bowker; Gregory) at Irvine and NYU (Nissenbaum 2001) and 'Values for Design' (Van den Hoven 2007a, b; Brey 2001; Friedman 1999; Friedman et al. 2002; Camp 2003; Flanagan et al. 2005, 2008; van der Hoven and Manders-Huits 2009; van den Hoven et al. 2015).[2]

These approaches share the following features:

First, there is the claim that values can be expressed and embedded in technology. In the way that Moses' racist preferences were expressed in the low hanging overpasses.[3] Values and moral considerations can, through their incorporation in technology, shape the space of action of future users, i.e. they can affect the set of affordances and constraints of users. A road from A to B allows one to drive to B, but not to C. Large concrete walls without doors make it necessary to take a detour. Architects and town planners have known this for quite some time. If values can be imparted to technology and shape the space of actions of human beings, then we need to learn to explicitly and transparently incorporate and express shared values in the things we design and make. And what is more we need to accept accountability for the process to all who are directly or indirectly affected (Fig. 6.1).

Secondly, values and choice made by some will have real effects (often not obvious) on those who are directly or indirectly affected. A good example of how this works can be found in the recent work of Cass Sunstein entitled *Nudge*, which construes the task of applied ethicists and public policy makers as a matter of 'choice architecture' (Thaler and Sunstein 2008; Van den Hoven et al. 2017). Think for example of the person who arranges the food in your university lunch room. That person is your choice architect insofar as he is arranges the things from which you can choose, and by doing so makes some of your choice more likely than others. For example by placing the deep fried stuff almost beyond reach and the healthy fruit and veggies in front, the consumer is invited (not forced) to go for the healthy stuff (the nudge). Speed bumps and the 'fly' in men's urinals are other examples of persuasion and nudging by technology. Digital technologies, in the form of computer interfaces, apps, menu's, webpages, search engines provide paradigm cases of choice architectures that have real impact on how people choose, act and think.

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[2]See for an overview (Alina Huldtgren's overview, Design for values in IT) in Van den Hoven, Vermaas and Van de Poel, Springer, 2015). In 2015 an international workshop was held to map out the challenges of Value Sensitive Design in the next decade, see https://www.researchgate.net/publication/283435670_Charting_the_Next_Decade_for_Value_Sensitive_Design

In 2016 A follow up international Lorentz workshop is held https://www.lorentzcenter.nl/lc/web/2016/852/description.php3?wsid=852&venue=Oort

[3]There is some controversy over the true motives of Robert Moses, but Winner's example has become paradigmatic in this context and there are a panoply of examples to the same effect.

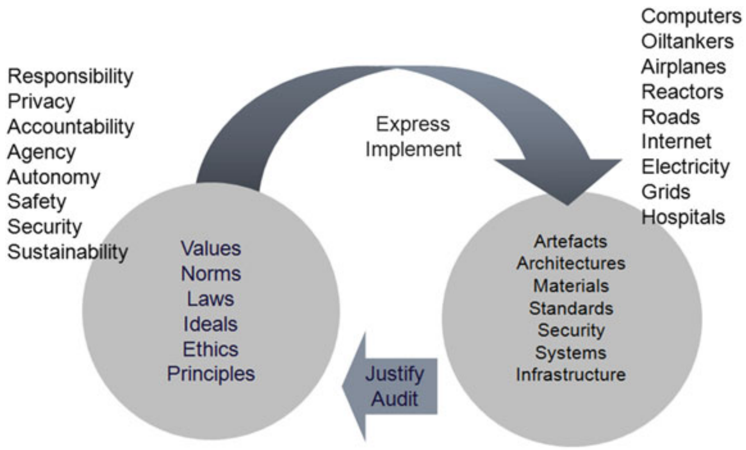

Fig. 6.1 Key problem twenty-first century: value sensitive design

Thirdly, there is the claim that conscious and explicit thinking about the values that are imparted to our inventions is morally significant. Churchill famously observed in front of the House of Commons: "first we shape our dwellings and then our dwellings start to shape us". Technology and innovation are formidable shapers of human lives and society. It is therefore very important to think about what we are doing to ourselves and to each other by means of technology.

A final feature of the value-design approach is that moral considerations need to be articulated early on in the process, at the moment of the design and development, when value considerations can still make a difference. This sounds easier than it in fact is. This desideratum runs into the so-called 'Collingridge dilemma', which states that early in the process of development of a technology, the degrees of freedom for design are significant, but information that could inform design is relatively scarce, while later on in the development of the technology, as information starts to become available, the degrees of freedom in design have diminished.

According to this design approach to ethics of technology ethical analysis and moral deliberation should not be construed as abstract and relatively isolated exercises resulting in considerations situated at a great distance from science and technology, but that instead they should be utilized at the early stages of the research and development. Moreover, they should be construed as non-functional or supra-functional requirements on a par with functional requirements that are used in design. Moral considerations deriving form fundamental moral values (e.g. equity, justice, privacy, security, responsibility) should be decomposed to the point that they can be used alongside other functional requirements to inform design at an early stage. The gradual functional decomposition of supra functional requirements results in the moral specifications (see Fig. 6.2).

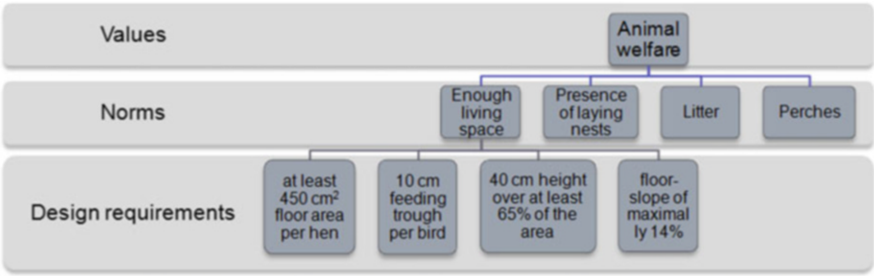

Fig. 6.2 Example of values hierarchy. Courtesy: Ibo van de Poel

6.3 Responsible Innovation[4]

The division of Google concerned with innovations, Google X, has worked on Google Glass which they tested in 2014 and they stopped as a project in 2015. The glasses allowed one to have voice controlled internet access and augmented reality features. Although Google promised not to make face recognition features available for this wearable platform, there were many privacy, safety and security concerns. The idea that large numbers of people would be looking at each other through the lens of a Google device and that people would constantly be checking out things and other people in fairly inconspicuous ways, while surreptitiously taking pictures and capturing data, met with too much public resistance to continue the innovation project. Assuming that Google did not expect upfront to be out of touch with the ethics of society, this seems like an example of an innovation that was discontinued as a result of a failure to deal with the relevant moral considerations.

The Netherlands has learned similar interesting lessons about ethics and digital innovation in the first decade of the twenty-first century. A first instructive case was the attempt to introduce smart electricity meters nationwide. In order to make the electricity grids more efficient and meet the EU CO_2 reduction targets by 2020, every household in The Netherlands would have to be transformed into an intelligent node in the electricity network. Each household could thus provide detailed information about electricity consumption and help electricity companies to predict peaks and learn how to "shave off" the peaks in consumption patterns. After some years of R&D, a plan to equip every Dutch household with a smart meter was proposed to parliament. In the meantime however, opposition to the proposal by privacy groups had gradually increased over the years (AlAbdulkarim and Lukszo 2011). The meter was now seen as a 'spying device' and a threat to the personal sphere of life, because it could take snapshots of electricity consumption every 7 seconds, store data in a database of the electricity companies for data mining, and provide the most wonderful information about what was going on inside the homes

[4]This draws upon my discussion of the relation between Responsible Innovation and Value Sensitive Design in Richard Owen's Responsible Innovation (2013).

of Dutch citizens. With some effort, it could even help to tell which movie someone had been watching on a given night. By the time the proposal was brought to the upper house of the Dutch parliament for approval, public concern about the privacy aspects had become very prominent and the upper house rejected the plan on data protection grounds. The European Commission, being devoted to the development of smart electricity grids in its member states, feared that the Dutch reaction to this type of innovation would set an example for other countries and would jeopardize the EU wide adoption of sustainable and energy saving solutions in an EU market for electricity (Al Abdulkarim and Lukszo 2009).

Another story—not very different from that of the smart meter—is the introduction of a nation-wide electronic patient record system in The Netherlands. After 10 years of R&D and preparations, lobbying, stakeholder consultation and debates—and last but not least an estimated investment of 300 million euros—the proposal was rejected by the upper house in parliament on the basis of privacy and security considerations (Tange 2008; Van Twist 2010).

Clearly these innovations in the electricity system and health care system could have helped The Netherlands to achieve cost reduction, greater efficiency, sustainability goals, and in the case of the electronic Patient Record System, higher levels of patient safety. In both cases, however, privacy considerations were not sufficiently incorporated in the plans so as to make them acceptable. If the engineers had taken privacy more seriously right from the start and if they had made greater efforts to incorporate and express the value of privacy into the architecture at all levels of the system, transparently and demonstrably, then these problems would probably not have arisen.

The important lesson to learn from these cases is that values and moral considerations (i.e. privacy considerations) should have been taken into account as “non-functional requirements” at a very early stage of the development of the system, alongside the functional requirements, e.g. storage capacity, speed, bandwidth, compliance with technical standards and protocols. A real innovative design for an Electronic Patient Record System or a truly smart electricity meter, would thus have anticipated or pre-empted the main moral concerns and accommodated them into its design, reconciling efficiency, privacy, sustainability and safety. Value-sensitive thinking at the early stages of development at least might have helped engineers to do a better job in this respect. There is a range of fine-grained design features that could have been considered and that could have been presented as choices for consumers. A smart meter is not a given, it is to a large extent what we design and make it to be. Respect for privacy can be built in (Garcia and Jacobs 2011; Jawurek et al. 2011). There are several objections against this suggestion. The first is that of moralism, another is that of relativism. Should values be built-in at all and if so which values should be ‘built-in’ and with which justification? There seem to such a great variety of values. Empirical research even seems to indicate that there is no coherent and stable set of European values, let alone global values. Both objections, it seems, can be addressed satisfactorily. No technology is ever value neutral (Van den Hoven 2012). It is always possible that a particular technology, application or service, favors or accommodates a particular conception of the good life, at the expense of another, whether this was intended or not. There is therefore virtue in making particular values at play explicit and evaluate how their implementations works out in practice and adjust our thinking accordingly. By being overly impressed in the field of technology by objections of moralism and relativism and as a result abstaining from working with values in an explicit and reflective way, we would run the risk that commercial forces, routine, bad intentions would reign free and infuse technology with values that were not discussed and reflected upon by relevant parties.

Serious attention to moral considerations in design and R&D may not only have good moral outcomes, but may also lead to good economic outcomes. Consider the case of so-called 'privacy enhancing technologies'. The emphasis on data protection and the protection of the personal sphere of life is reflected in demanding EU data protection laws and regulation. The rest of the world has always considered the preoccupation with privacy as a typically European political issue. As a result of the sustained and systematic attention to data protection and privacy, Europe has become an important cradle of new products and services in the field of Privacy by Design or Privacy Enhancing Technologies. Now, the Big Data society is on our doorstep and many computer users—also outside of Europe—are starting to appreciate products and services that can accommodate user preferences and values concerning privacy, security and identity, Europe has a competitive advantage and is turning out to be an important commercial player in this branch of the IT industry.

Innovation can thus take the shape of (engineering) design solutions to situations of moral overload (Van den Hoven et al. 2012). One is morally overloaded when one is burdened by conflicting obligations or conflicting values, which cannot be realized at the same time. But as we saw above, conflicts of privacy and national security seem amenable to resolution by design and innovation in the form of privacy enhancing technologies. Conflicts between economic growth and sustainability were resolved by sustainability technology. Some think of these solutions as mere "technical fixes" and do not construe them as genuine solutions to moral problems. I do not take a stance on this issue here. I just want to point out that in such cases it seems to me that we have an obligation to bring about the required change by design or innovation (Ibidem). The principle that seems to be operative can be formulated as follows: 'If a contingent state of the world at time t1 does not allow us to satisfy two or more of our moral values or moral obligations at the same time, but we can bring about change by innovation in the world at t1 that allows us to satisfy them all together at a later time t2, then we have a moral obligation at t1 to innovate' (Van den Hoven 2013).

This is an important part of what responsibility implies in the context of innovation. It construes innovation as a second order moral obligation: the obligation to bring about a change in the world that allows us to make more of our first order moral obligations (e.g. for security and privacy, for economic growth and sustainability, safety and security) than we could have done without the innovation. Normally, the principle that 'ought' implies 'can' holds, but a noteworthy feature of this second-order obligation to innovate is that it does not imply 'can'. This means that we may be under the obligation to come up with an innovation that solves our problem, although success is not guaranteed.

It may seem fairly obvious to claim that we have a higher order moral obligation to innovate when it leads to moral progress, but it requires a considerable shift in our thinking about innovation. We need to learn to think—as argued above—of ethical considerations and moral values in terms of requirements in design and research and development at an early stage. Value discourse should therefore not be left on an abstract level, but needs to be operationalized or 'functionally decomposed', as is often done with high level and abstract requirements in engineering and design work. The process of functional decomposition eventually leads to a level of detail that points to quite specific design features of the system, the 'moral specs'. This requires engineers to be value-focused in their thinking and capable of articulating the values at play with different stakeholders (Pommeranz 2012).

If some innovative organization or process would be praised in virtue of its being "responsible", this would imply, among other things, that those who initiated it and were involved in it must have been accommodated as moral and responsible agents, i.e. they must have been enabled:

(A) To obtain—as much was possible—the relevant knowledge on (I) the consequences of the outcomes of their actions and on (II) the range of options open to them and

(B) To evaluate both outcomes and options effectively in terms of relevant moral values (including, but not limited to wellbeing, justice, equality, privacy, autonomy, safety, security, sustainability, accountability, democracy and efficiency).

In light of (I) and (II) above, I suggest that another implication of the notion of Responsible Innovation is the capability of relevant moral agents

(C) To use these considerations (under A and B) as requirements for design and development of new technology, products and services leading to moral improvement.

On the basis of this characterization of innovation and the implications (A), (B) and (C) we may characterize Responsible Innovation in summary as follows:

(III) Responsible Innovation is an activity or process which may give rise to previously unknown designs either pertaining to the physical world (e.g. designs of buildings and infrastructure), the conceptual world (e.g. conceptual frameworks, mathematics, logic, theory, software), the institutional world (social and legal institutions, procedures and organization) or combinations of these, which—when implemented—expand the set of relevant feasible options regarding solving a set of moral problems.

6.4 Conclusion

If were given a choice we would prefer a situation where only those digital technologies would gain social acceptance that were morally acceptable. We would prefer a situation where technologies deemed morally unacceptable would also not be socially accepted and gain currency for precisely that reason. In order to bring about this ideal situation, it would be helpful if the digital products and services, our systems and software, could be made to wear the index of moral acceptability on their sleeves and could be made in such a way that they send honest signals to users about their moral quality and the values that have been used to shape them. In order to achieve this level of accountability and transparency Ethics of IT in the twenty-first century will have to be developed along design lines sketched out here.

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Chapter 7
Digital Sovereignty and IT-Security for a Prosperous Society

Reinhard Posch

Abstract With the Digital Single Market and the supporting programs H2020, CEF, ISA2 and other instruments Europe is making a big effort to shape up its ICT. This is also supported by legislation where IT-security plays an excelling role. Not only is the eIDaS regulation as an example offering a seamless legal framework for all 28 member states also it is a unique chance for Europe to show its ICT-strength with its open and innovative approach to attract European industry as a provider and businesses as major enablers. IT-security and data protection need to enable digital sovereignty and at the same time are fields where Europe has developed renowned expertise in the past and could develop further strength in the future.

7.1 Introduction

As the incompatibility of US and European legislation (US Government 2001) as well as the impact of US legislation on data stored in Europe came under discussion, digital sovereignty has gained an increasingly attention also in the open public (Nojeim 2014).

In general, digital sovereignty can be defined as the ability to have full knowledge and control by the individual or by the society about who can access ones data and where ones data are transferred. The latter is of high importance as different jurisdictions have quite different regulations about data protection and data security. While in general, the perception is that cyber space has its own rules it is clear that the same laws apply as in the physical world unless explicitly regulated otherwise. The only remaining problem is that the enforcement of legal regulation differs in practice. This fact makes it even more important that appropriate precautions are in place.

Looking into daily practice and incidents, we observe that digital sovereignty is endangered not only theoretically, but also in practice. Many of these situations are only marginally observed by the public or even by professionals (Fig. 7.1).

R. Posch (✉)
A-SIT Zentrum für sichere Informationstechnologie, Seidlgasse 22/Top 9, 1030 Wien, Austria
e-mail: reinhard.posch@iaik.tugraz.at

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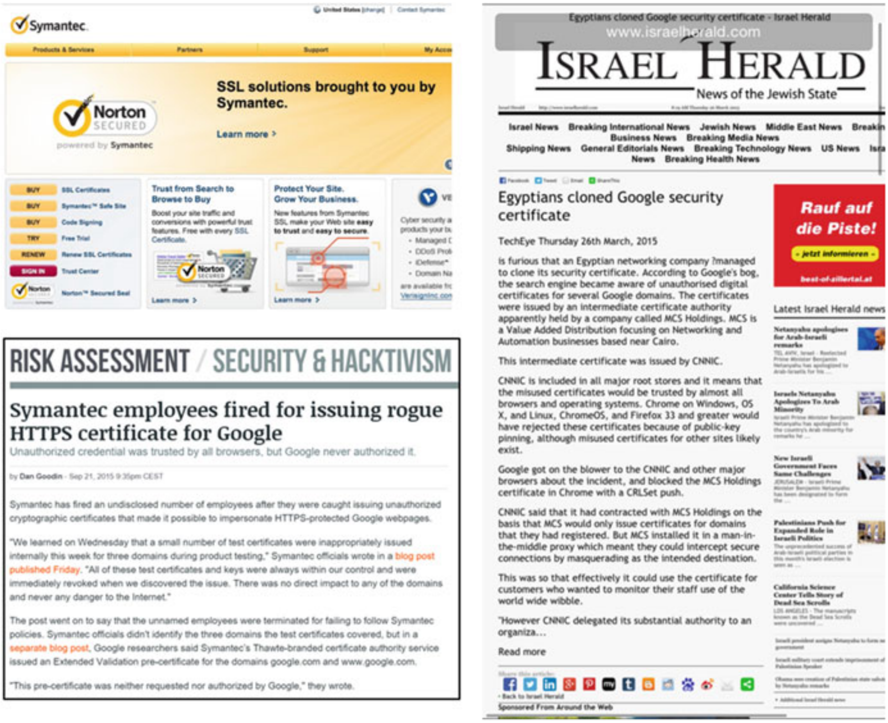

Fig. 7.1 Digital sovereignty in public press

The above notice that "test certificates for Google" have been issued by employees of a major security company like Symantec (Budington 2015) was rarely echoed in the press. There have been similar attempts by third parties as also shown above, however, this new one shows that such activity is capable of impersonating any company, administration or private person—no matter whether this entity ever had a relation to the rogue certificate issuer.

Only this very recent issue which made it to the public shows that the infrastructure and the capabilities have to be revisited in the light of digital sovereignty, trust and security.

We have opened up our communications perimeter in a generous way but have not understood the impact and are using communications infrastructures as if they were under control. Measures that would make these assumptions valid even if available are not widely used by the majority or by companies at least up to a certain size.

The following chapters flash out some areas where digital sovereignty has quite some room for improvement and at the same time shows potential avenues to approach the goal.

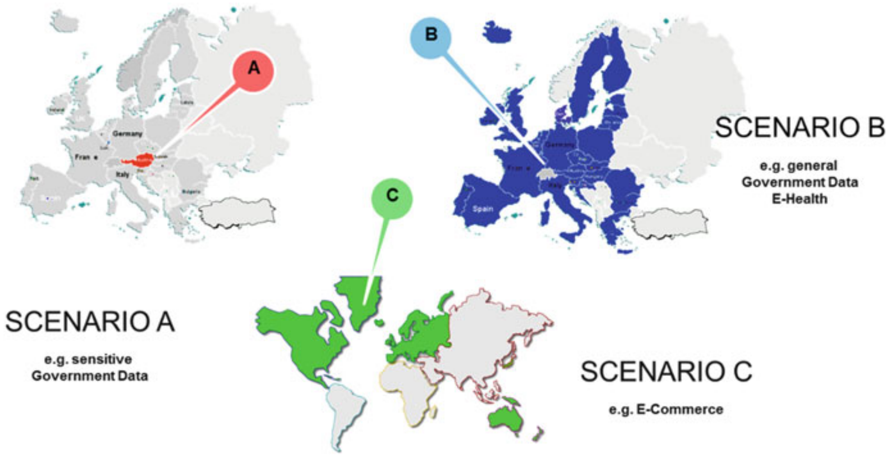

Fig. 7.2 Scenarios of interest clustering

7.2 Jurisdiction Aware IT and Communications

There is a need to make it easier for the everyday user private or professional to allow for a higher level of prevention from being subject of malicious attempts. The focus in practice is too much oriented towards observing what has happened and not on how to enable tools and infrastructures to prevent in a better way. The press also fosters this attitude, as it is easier to report on incidents than to contribute to general education and awareness.

Security-wise and trust-wise the internet is still single level unstructured. While there is broad discussion about bandwidth dedication as there is a commercial interest, the consumers and general public interest in trust is not well enough reflected (Fig. 7.2).

It is about protecting interests. In this context the above figure shows a realistic scenario of interest clustering: The actual clustering in the E-Commerce scenario “C” is arbitrary. This basically illustrates that there is a very small amount of information that allows identifying the relevant context in terms of applicable jurisdictions. For a general government data scenario “B” that may include personal data, data protection regulation asks for adequate protection that is to be assumed in the EU/EEA. And there is a sensitive government data scenario “A” where organisational or national borders are the perimeter.

As with many other trust issues we have pieces that could help to improve situations, but we lack a framework transparent to the user and to the service so that it can be efficiently applied. Concerning the applicable jurisdictions we could use DNSSEC (IETF 1999) and client certificates to ensure end to end trust. There are however some stumbling stones with this:

(a) DNS and DNSSEC address the domain but not the jurisdiction the domain is in
(b) DNS only addresses the endpoint not the route the communication flows

(c) Client certificates are rarely used and impose quite some complication in terms of organization

This points only to technical issues. Moreover some countries and organizations would not even favour such situation as communication relaying including scanning for malicious elements is in place and would contradict the above. This already makes clear that we need to concentrate on a framework.

Having in mind that the information to identify the jurisdictional context is very small, it could be handled even with two or three bits in the packets of existing communications which—if properly applied—could be asserted in a responsible manner by the communications provider.

The following is to give an example for feasibility:

11 communications within own legislation
10 communications within area (e.g. Europe)
01 communications among “cooperating countries”
00 unknown source
Optionally the travelling of the packets could be flagged
xx1 xx applies to source and transit of communications
xx0 xx applies to source of communications

If such scheme would be agreed by cooperating providers in a transitive way the user and the services would receive trusted information, if their own provider was offering this service. As any cooperating service provider would only inherit or generate such information, if the communication came from a provider cooperating in the scheme, the service provider is also subscribing to responsibility.

7.3 Switching Mobile Connections: Floating Cross-Jurisdiction to Reduce Cost

It should be considered to introduce identity management for carriers with roaming and reconfiguration and to add this to device management to enable efficient control by the user. Also the present practice leaves quite some questions open in the context of data protection and person related data.

The availability of mobile switching capacities exceeds by far the need and this results in a situation where switching of mobile communications might be done in a far away country with very different legal provisions. This may well also apply to communications where source and destination are in the same country irrespective of the provider.

The crypto protection over the air does not help in this case and interception—even if not legal in the country or countries of the source and destination of the communications—can never be fully excluded. Neither as concerns the metadata nor the content. Since communications can cross the mobile/landline border the provider and the switching provider must be able to handle the encryption and, therefore, the over the air encryption cannot be seen as a hindering aspect for legal interception.

The situation becomes even more complicated in case of roaming or pretended roaming. The whole system builds upon fully trusted carriers. That might have been the case when there had been only a few and within landlines, but is no longer a realistic assumption at this point in time. Moreover the technically and cryptographically supported identification of a provider towards other providers and especially towards the user is certainly insufficiently in place to support the need of sovereignty in a transparent way.

This is essential since roaming means reconfiguring the device on the communications level. This is triggered with “huge SMSes” that are interpreted by mobile device as commands. This makes evident that the identification and security measures with this reconfiguration process has a significant importance. As an example for this important “feature” it has to be mentioned that at this level the encryption of the traffic over the air can also be configured.

7.4 Push Notification: Always on a Short Leash

Like many of the technologies that are widely used push notification came out of consumer devices and have not been adjusted after being scrutinized in the context of sovereignty and use cross jurisdictions.

The convenience of being reached basically at zero cost at the level of applications results in the situation where all mobile devices that are online have an open connection to the communications hub of the manufacturer (Google, Apple, Microsoft, Blackberry) depending on the operating system of the smartphone (Hafizji 2013).

Depending on the system settings and the operating system, this mechanism can be used to assist updates of APPs and operating systems. The average user is unable to control these capabilities.

As we have already a hand full of manufactures and this mechanism works cross such manufacturers (e.g. WHATSAPP to give an example that is widely used) there is no barrier to change this to be compatible with legal requirements. E.g., installing such hub by a European trust provider rather than with the manufacturer would not need conceptual changes. In many ways these push notifications carry personal data subject to data protection regulation putting in scene an additional need beyond sovereignty. The general question in this context is the societal approach returning more powers to international companies than to national governments where the latter in many cases are at least democratically elected.

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NY judge: US warrant can reach Microsoft email in Ireland

U.S. law enforcement can force Microsoft Corp. to turn over emails it stores in Ireland, a judge ruled in a case that technology companies have rallied around as they pursue billions of dollars in data storage business abroad.

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Fig. 7.3 Microsoft's Ireland case

7.5 Cloud Storage: Do We Have to Fear About IPR

Like with data protection that has popped up recently, in many ways it is about incompatibility of legal systems. This aspect has already been addressed with the jurisdiction aware communications. However, this turns out to get even more complex in case legislations ask for applicability outside national borders. That this is the case not only in the cyber sphere but also with physical storage has been brought to visibility by the "Ireland Case" where Microsoft (Nojeim 2014) is asked to hand over data from Ireland to the US according to US legislation (Fig. 7.3).

The big conflict remains with the companies. If such company is US based the decision has to be made not to offer services outside US or to remain silent about the truth and the legal obligations towards its customers as set out in US law.

While US law at least does not allow to use intercepted data for competitive advantage of private sector players, this is not even generally the case in all countries. When it comes to Cloud and sensitive data—be it governments or industry—we need improvement on this situation before we can fully profit from Cloud.

If it is about storage, only encryption might be a tool from the practical demands giving a high level of assurance. Still there is quite some clarifications open in the context of data protection:

- Encrypted data is data that can relate indirectly to a person. In such case trans-border communications would require specific precautions not possible in most cloud settings.
- If encrypted data separated from keys is not yet person related, what about deleting data? Unless we come to a legal opinion that deleting keys is equivalent to deleting data, in the data protection context this leaves open questions.
- Still encryption only solves storage demands for time being and only if encryption happens external to the service in a "trusted" environment. After all we need

also to process—search, sort, etc.—data and there is very limited remedy in sight for these aspects.

With this regard Europe is in a dilemma. Not making full usage and taking advantage of the Cloud will be a competitive disadvantage. Like with environmental issues and a labour-related legislation this might be a further asset Europe would not like to give in and then will notice that some of the business is not realistic. With the "safe harbor case" this has clearly demonstrated its international and global dimension.

7.6 Document Collaboration: In the Cloud as You Type

Cloud, mobile devices and many others—we observe an increasing level of complexity reducing the number of players to multinational companies or even to a monopoly. With operating systems and large multipurpose packages companies offering both conventional and as a service approaches have a clear handle to set the directions by their pricing policies.

In a few years it is most likely that the majority of document editing also will be done online offering the option of collaboration. In fact this is starting already now despite of all problems that would have needed to be considered from the data protection perspective. Decreasing budgets for government IT will at least partly force them also to join this trend (Fig. 7.4).

The evolution is introduced silently, but has a huge impact.

- Any change of a document is immediately available over the internet
- Users have no knowledge of the "software" that is used for generating/editing documents
- The "software" can even without the user noticing change even temporarily at any point in time as it comes online in a browser-like way or even through the browser

Fig. 7.4 Documents in the cloud

- As for the time being user driven encryption is not possible
- Identification methods are according to the provider not according to the demands of the users

In the public sector this might even be seen as incompliant with the eIDaS regulation—or the levels substantial and high of eID, with the web server authentication etc. At least there is a substantial gap before we get there.

From a sovereignty viewpoint the basic needs would be:

- **eID as a basis**: Access to remote data (Cloud/Mail/Calendar) shall be configurable in a way that the user can determine availability of services only through eID (according to the eIDaS requirements). It should be possible that the owner of data can set the level of requirement (eID only). Consequently all internal mechanisms should make sure that there is no possible circumvention by even very long secret authentication strings that are prune to be replayed.
- **Static data encrypted**: Data that are not necessarily processed shall at the choice of users be attributed to be encrypted and decrypted only at the client (e.g. in the browser or at a user chosen trusted third party) where the user can also choose the key management. An appropriate interface accepts such data for the repository or for sending. Evading or violating the policy should require explicit user intervention (e.g. in case of sending an email or calendar entry to a partner not being part of the crypto management). Any operation that need server-side processing (e.g. search) might become unavailable or substantially increase consumption of computing power (e.g. due to homomorphic encryption). This should be left solely at the choice of the user.
- **Validation of active elements**: it shall be possible to restrict the origin of active elements (e.g. HTML5 javascript) to origin from a server trusted by the user to disallow circumvention of the criteria above. One possible way to accomplish this would be to cache active elements after a certification process in the user-environment or at a party explicitly trusted by the user.
- **Encrypted collaboration**: when documents origin from a collaboration process it shall be possible to encrypt every piece of the document that leaves the user's device/browser using user chosen key management for encryption and decryption.
- **Availability**: The security features shall be equally available for all platforms (PCs, laptops, tablets and mobiles) for the main operating systems. Unless this is reached, laziness of users will jeopardize security and data protection.

7.7 Conclusions

Due to economies of scale IT has developed a process that increasingly focuses on very limited set of providers. Hardware and manufacturing as a business with labour and environmental demands has concentrated in far east where these aspects can be handled in a less expensive manner.

Fig. 7.5 The European cluster security, identity and data protection

Operating and systems and integrated packages of software are increasingly coming from US where the development towards cloud and provision as service is both adding momentum and possibly reducing user's choice.

In this context European IT industries needs to rethink its focus. While many innovations are coming out of Europe and is structured around SMEs such innovations i.e. such innovative companies are often acquired by large software companies in the US. This happens for the sheer reason that Europe is not offering enough potential to buy innovations and innovative companies at competitive prices. The cluster security, identity and data protection at least has the potential to become an exception, if it is handled appropriately (Fig. 7.5).

At the end it should probably not only be a decision that is driven by commercial and financial aspect, but also should respect societal and sovereignty aspects. IT and the technology coming with it is ubiquitous—from housing to traffic, office to healthcare IT is a major and sometimes the driving factor. This is getting an even further dimension with the internet of things.

Leaving the key decisions about technology to big market player only might be step back at least in societies that strongly believe in democratic values.

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Chapter 8
Women in Computing and the Contingency of Informatics Cultures

Britta Schinzel

Abstract The paper first shows how early programming was highly shaped by women, and who these were. It further shows when and why computing moved into the hands of men. Then it will deal with the culturally most differentiated participation of women in informatics studies. It turns out that low female participation is mainly a problem of the western, and north-western countries in the world. A lot of reasons are given, also only suspected ones, but there are so many diversities and influences, both in space and in time, that it is difficult to put them together into a consistent and stable picture. This also makes strategies to invite more women into (western) computing a contingent task and it requires steady accompanying measures.

8.1 Introduction

Not only Ada, countess of Lovelace marked the history of computing, but also many female mathematicians from the beginning of the twentieth century until its third quarter. Female participation in informatics broke down mid of the 1980s with the introduction of home-computers and PCs, i.e. with the quick growth of economic importance of software. Its gradual decline in Western countries contrasts with the high, equal or even higher participation of women in southern and eastern countries. With more foreign students in the western countries also the number of women in computing here has risen is still rising.

B. Schinzel (✉)
University of Freiburg, Freiburg, Germany
e-mail: schinzel@modell.iig.uni-freiburg.de

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8.2 Women in the History of Computing

The first people, who set the pace for computing programmable machines were women. It began already in the nineteenth century with Ada, Countess of Lovelace, who described the functioning of Charles Babbage's Analytical Engine, which although mechanical, already had the structure and concepts of the von Neumann computer. She also worked out several programs for computing analytical functions, as well as his program for computing the Bernoulli numbers, where she developed many structuring principles, reinvented also later.

Less well known are the early twentieth century women starting already before world war II with numeric computing and taylorizing computing work, and continuing into electric and electronic computing, like Gertrude Blanch, Mina Rees, the genial mathematician Ida Rhodes or Thelma Estrin.[1] They were mostly mathematicians coming from Eastern Europe to the US, having fled antisemitism and prosecution against Jews in Ukraine and Poland. They all worked for the national bureau of standards (NBS) and directed the transfer from hand driven computing machines to the modern Computer era. They established groups of "computers", by this already delivering a structural model for electronic machines. The term "computers" stood for female mathematicians taylorizing computing tasks and setting up, i.e. wiring programs on hardware. With Mark I, the first computer used for world war II flight curves of rockets were computed and the effects of the first plutonium bomb were simulated. And it was Grace Murray Hopper, also the first female admiral in the US forces, who led the programming of Mark I. She designed COBOL, wanted it to be an understandable programming language, and she developed the first Compiler for it. The term "bugs" stems from her. Also in England women worked for the decryption of the German code in Bletchley park.

Another pioneer women connected with warfare was Hedy Lamar She was a Viennese actress, in the film "ecstasy" she had the first naked take. In 1937 she fled her husband Fritz Mandl, who was a weapon producer, because she could not stand his jealousy, and went to the US. She was considered as the most beautiful woman in the world. The following citation is known: "Any girl can be glamorous. All you have to do is stand still and look stupid". She also worked with film music together with Georges Antheil, and with him she developed the frequency hopping for synchronizing 16 mechanical pianos driven by punched cards. During world war II she wanted to fight the Germans—she was Jewish, and from her knowledge about telegraphy, which she knew from her husband, she used this technique for steering torpedos, which could not be tracked. This method today is used for every communication between mobiles, radio communication, bluetooth, mobile internet, etc., in order to make it secure. They had a patent for it, but the US military at that time did not use it.

In the 1950s programming languages were mainly developed by women: Grace Hopper with COBOL, Jean Sammet with FORTRAN—she also wrote the first book

[1] http://www.frauen-informatik-geschichte.de

on programming languages. Later Adele Goldberg together with Alan Kay developed Smalltalk, which still is considered an excellent programming language, anticipating object orientation. Women were again deeply engaged in the norming processes. Whereas hardware development was a male task, programming, less respected, was a female one, as Alan Turing said, "something for girls" (Hellige 2014). Even in the 1960s programming was done by a high percentage of women, and when Computer Science (CS) started as a scientific subject and course of studies in the end of the 1960s still a quarter of the students beginning to study CS were female. As software and IT became important economic and social factors with the introduction of PCs in households mid of the 1980s programming and software development went from female into male hands—and at that time female participation dropped considerably.

Also female theoreticians prevailed and still do so, finding a way from mathematics to informatics, with the motivation of a real world application: for example Rosza Péter from Prague worked in classifying primitive recursive functions. But also a different track of interest more frequently attracting women leads from applications and human-computer interaction to informatics: e.g. Brenda Laurel is well known having lifted interface design to scientific investigation.

8.3 The Contingent Female Enrollment in Informatics Studies

As already mentioned, until the end of 1960s programming was a female task. With the beginning of Computer Science as a scientific discipline in the end of the 1960s or the beginning of the 1970s, where engineers and mathematicians found together, this changed. But still there were many women in CS courses, in Germany around 25%. With introduction of home computers mid of the 1980s, with the movement from mainframes to personal computers, and the increase of applications, software became more important. With this came the breakdown of the female fraction in computing: not only in Germany the figures gradually dropped to 13% and later even lower (Camp 1997, 2001). Observing this change, in the 1980s I started to collect figures of informatics student's and also scientists and professors numbers, wherever I could find them. It was not an easy task and also sometimes a very costly one. Often I had to rely on particular figures of single universities given by colleagues I got to know, especially in countries whose writings I could not read, like Iran, Iraque, Syria or Egypt.

The numbers of scientists in technology and informatics differ according to different countries and cultures, but in particular also the numbers of students. The low versus high enrollment differences in all the levels of scientific employment or education appear between north and south, west and east, rich and poor, industrially developed and developing countries. Differences occur between South Asian and South American countries on the one hand, and Australia, New Zealand, Japan, Northern Europe and the USA on the other one. Low female participation is in fact a western problem, not an eastern or southern one, nor an Arabic or Iranian (A countries) or Islamic problem, even not a Saudi Arabian. Both the decline of the Soviet Union and the breakdown of structures in the Arabic countries were catastrophic for female participation. But the differences also appear within Europe (Schinzel 2004a). Within the European Latin countries and in Greece and Turkey (called L in the following) as well as in the Slavic countries and Romania (called S in the following) the situation was (and mostly is) completely different to the one in the Anglo-Saxon, Scandinavian and German speaking countries (called ASG in the following): in L countries there was a comparatively high and constant female participation in computer science, which amounted up to 50%—it gradually sinks in the present (Schinzel 2004a). In S countries as well as East Germany (GDR) the f. p. before the fall of the iron curtain partially has reached far above 50%, but has declined thereafter. In GDR in the 1960s and 1970s sometimes there even were over 70% women both as beginners and as graduates (Schinzel 2004b). In this time the streams of students were directed according to the needs of the work market, i.e. it was possible to articulate ones wishes, but there was no guarantee to follow them, a free choice of the course of studies was not possible. But later in the 1980s there already existed free choice of ones preferred course of studies, and still the participation of women was high (Schinzel 2005a) (Figs. 8.1 and 8.2).

With the reunion of Germany the situation changed drastically at all places in GDR, the most striking one shown in the figure of the TU Rostock (Fig. 8.3).

Also at the University of Chemnitz a considerable decline of f.p. occurred, even if more retarded. The following figure, which shows the numbers of successful diploma students in Chemnitz (having begun their course of studies still in GDR

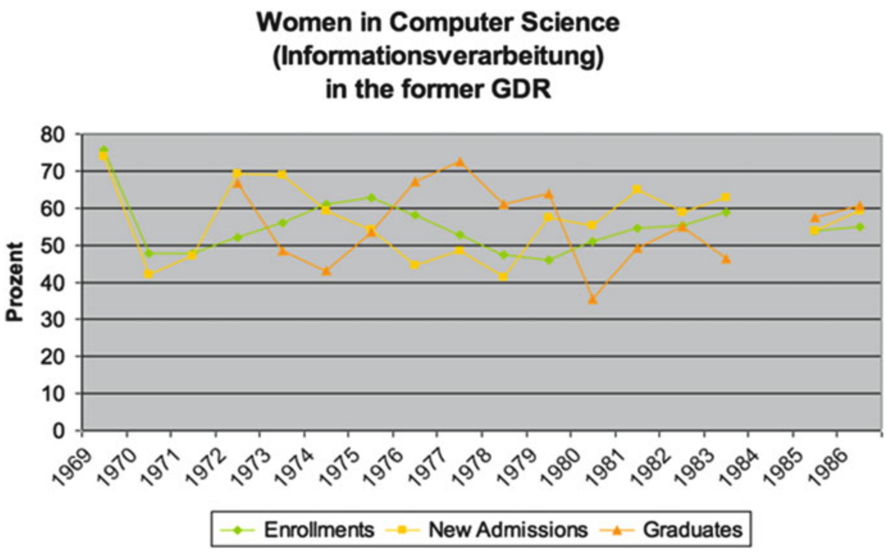

Fig. 8.1 Women in computer science GDR (Source: Dolores L. Augustine, private communication; diagram B. Schinzel)

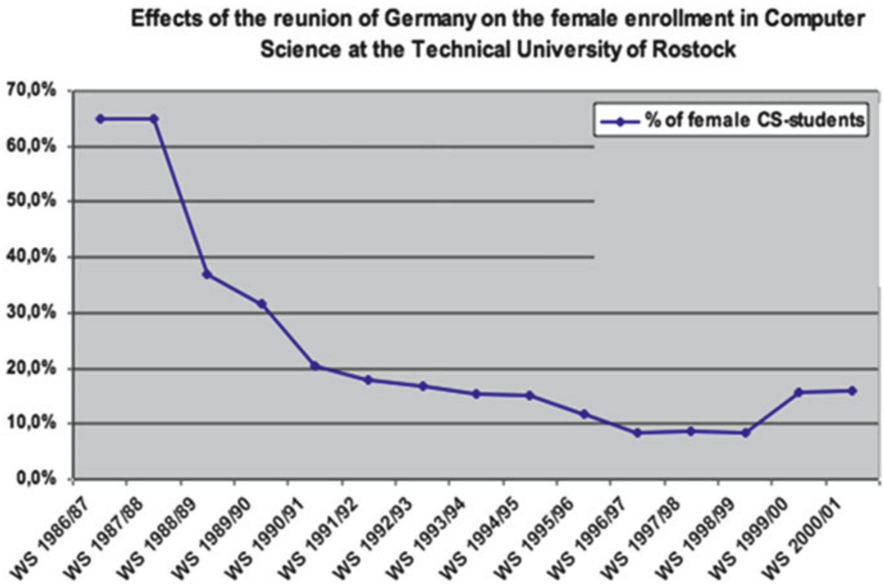

Fig. 8.2 Effects of the German Reunion (Source: Private communication with the Studien- und Prüfungsamt of the Technical University of Rostock, 2002)

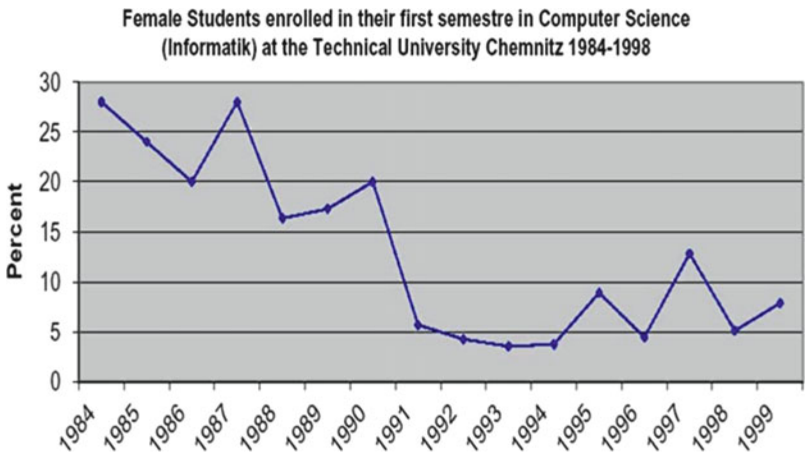

Fig. 8.3 University Chemnitz, female students. Source: Private communication with the Studenten- und Prüfungsamt of the Fachbereich Informatik of the Technical University of Chemnitz, 12.02.2002

times) also shows that the lower participation does not only rest on the female decline, but is also due to the rise of the number of male students (Fig. 8.4).

Through personal communication I heard from Hungarian and Czech colleagues considerable declines in f.p. after the democratic and economic changes. The reunion of Germany has brought a heavy break of f.p. within the former East German countries.

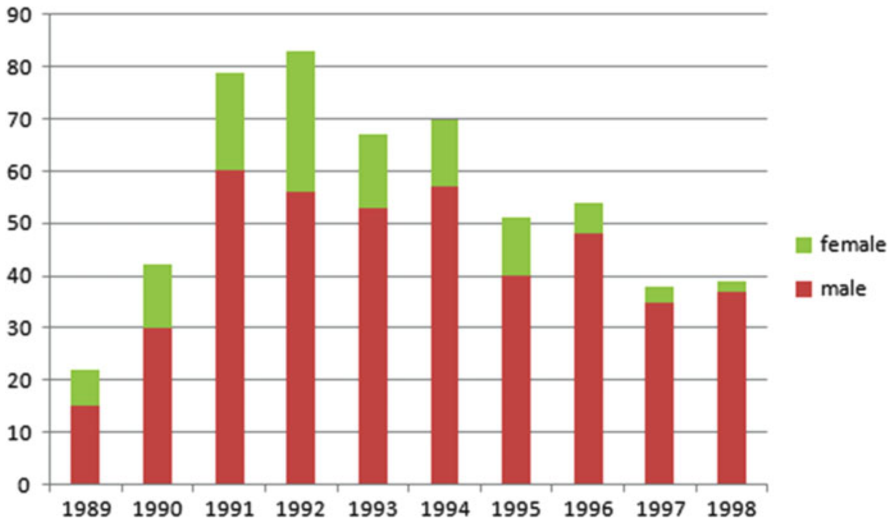

Fig. 8.4 University Chemnitz, Diploma students female students

Also within reunited Germany we can see the higher numbers of foreign female students (Figs. 8.5 and 8.6).

Also in Switzerland there are considerable differences between the German and the French speaking universities, this especially in business computing (Betriebsinformatik). But the language there is also the difference of religious traditions, that catholic French and Italian speaking Swiss and the protestant German speaking Swiss population (Table 8.1).

The actual figures 2014 in Germany show a much higher percentage of women in informatics with 29.9%. At the same time the female graduates in informatics range by 16.8%, and together with mathematics by 27.1%. (Statistisches Bundesamt 2002 and 2005, drafted 2015) The fact that the fraction (and absolute number: 9033) of female students is double as high as the fraction (and absolute number: 3809) of female graduates supports the suspect that this difference is due to the strongly rising number of foreign students with their higher female participation.[2]

8.4 Understanding the Findings

There are a lot of different and context dependent explanations for such differences, among which structural and historic reasons, as well as socio-cultural and symbolic constructions of the gender technology relation are prevalent (Schinzel 2005a, b).

[2]Unfortunately I have no access to the actual numbers of foreign informatics students.

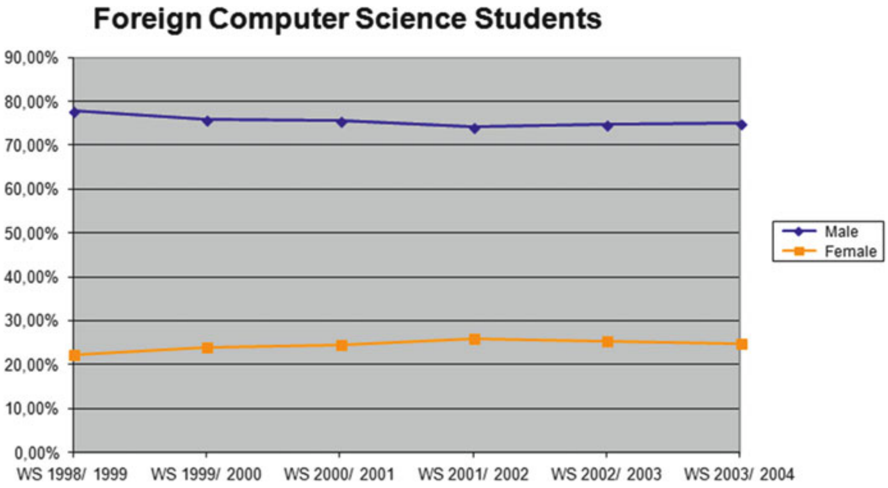

Fig. 8.5 Foreign computer science students (Source: Statistisches Bundesamt 2002)

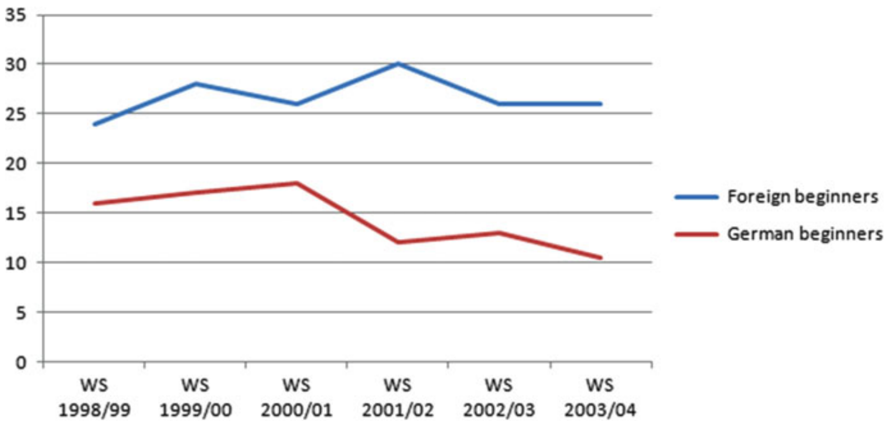

Fig. 8.6 Computer science beginners as % of total number of CS students (**w.r.t. to German and foreign students**) (Source: Statistisches Bundesamt 2005)

The near equal or higher participation of women in CS studies within the developmental and the third world countries usually is explained by the fact that only the upper class there can study at all. Especially in South America the women stemming from rich families can afford to let their household and child care be run by house personnel. It might be easier in India, Malaysia, Korea and other Asian countries as well to have cheap help for housework. Still this does not suffice as explanation, it must also be the case that in these countries gender hierarchy is not performed on the level of attribution of skills in technology and mathematics. High validation, power and income always corresponds with maleness of a profession, a fact called the vertical gender hierarchical job market. The vertical gender specific

Table 8.1 Language differences also in Switzerland

	1991		2001	
Studies	Students	Female %	Students	Female %
Computer Science				
German Switzerland	1074	4.8	1413	11.5
Western Switzerland	664	11.9	1099	13.3
Total	1738	7.5	2512	12.3
Business Informatics				
German Switzerland	332	6.6	1025	13.9
Western Switzerland	272	22.8	390	24.1
Total	604	13.9	1415	16.7

Source: BfS, Sektion Hochschulen und Wissenschaft; computation Dupuis et al. (2003)

job market contingently influences the horizontal gender specific job market, which tells, which kind of professions are gendered, e.g. social work, teaching, nursing is female and e.g. engineering and science are male. Whereas the vertical gendering is invariant in all patriarchal societies, the horizontal one is contingent according to the specific economic and social structures.

In the former Soviet Union, when mathematics was a breadless art, in Riga 1983 I found 95% of the students female, and also medicine was and still is female, but Physics and Chemistry were male subjects due to the higher respect, income and career possibilities. But for the former socialist countries again another explanation for the former high representation of women in engineering (it has declined considerably everywhere there after the economic changes) is ready to hand. Not only the communist claim of their equal treatment of women and men, and the social and ideological enforcement of women's working on the job market, had and still has large influence. For the participation in science and technology the specific education with polytechnic courses probably played and plays far greater a role. Every pupil has to attend several years of these courses implying working in industrial firms, thereby getting familiar with working in industrial, i.e. technological contexts. This makes the entrance to technological work and study for women more a matter of course. In reunioned Germany it is still very visible, how much more self confident former East German women in informatics and engineering are than former west German ones.

Also the educational structures give reasons for differentiation of gender participation. In countries where access to university subjects is directed by exams, as e.g. in A or S countries, as known e.g. from former Egypt or Bulgaria,[3] the better performance of women in respective exams leads them into techno-scientific studies. Why then are women performing better there, also in MINT subjects?

[3]In Bulgaria after the fall of the Iron curtain a quota of 50% for men was introduced, such that the access grades for men became lower than the ones for women. The same procedure is considered today in Iran because the number of women studying exceeds the one of men.

Can it be explained by the assumption that girls and young women rest more in the house than boys and therefore have more time to learn?

Another reason for difference may be the role of universities between education and research, which differs throughout the various countries. As education is considered more female this might have an effect on gendering the participation in university studies in general. Usually the fact that for instance in Turkish universities 40% of the staff is female, and that Turkey within Europe, the former socialist countries excluded, shows the highest participation of women in natural sciences and technology, is explained by the more educational role of universities there. As in the Arabic the educational aspect dominates, and with it points into a female domain in the North West the emphasis of universities is laid on research and competition.

Another aspect is the symbolic meaning of computing. In Asia and within the Arabic countries it is connected with bureau and organizational work, whereas in the US and ASG with "high tech" it is marked as technological front end, attributed as a men's domain. An Iranian female student told me, that computing is an excellent profession for women, because it can be performed in cool, quiet and safe rooms, and this attribution was confirmed by a female Iraqui colleague.

Whereas structural causes can explain the differences between the former Soviet countries and ASG countries, as well as between the third world and ASG countries, the USA etc., the difference between L countries and ASG countries seems to be caused by historic and cultural reasons. It cannot have its grounds in differences of political systems nor in the developmental state (if considering for example France and Italy). In the north-west of Europe industrialization started end of the eighteenth century with the weaving machines, steam engines and electrification, causing the labour division between home and public sphere and with it the gendering of workplace and competence. The later beginning of industrialization in southern and south-eastern Europe already met different, less distant symbolic gender—technology relations. But even earlier it is possible to refer to the symbolic gender division from enlightenment of male rationality versus female empathy and morality. It is clear that in a country which founded the Royal Society, the first scientific institution in the world, science and all the connotations which Frances Bacon put on its male values plays a greater role than in others. It may be argued that the older the institutionalization of science the more conservative paradigms remain in these institutions. But what about France and the academie francaise, the second scientific institution in the world? Renee Descartes, the founder had less definitive imaginations about the maleness of science than Bacon did. And in fact in France we find famous female scientists like Madame Curie and her daughter since a long time, and they are much more adored than comparably outstanding female scientists like Emmy Noether or Lise Meitner in Germany. German science still suffers from the consequences of the "Third Reich": during Hitler's time only 10% of all students were allowed to be female. The role of woman was that of a breeding machine of the German race. Female intellectuals had been Jewish to a high percentage, and they do not exist anymore in Germany up to today. After the breakdown of Germany with the establishment of a new democracy the education of children was willingly put into the hand of family in order to avoid comparable indoctrination of children as it was done in Hitler's time. Therefore no whole day schools and few kindergartens were established, and most of the Kitas of former GDR were closed for the same reason after 1989. Today this appears as a problem for women's participation on the job market, but a (re)establishment of public child care is difficult. The German tax and income system still heavily supports women staying at home and not working.

Also a sociological interpretation can help to find explanations. It claims that with the dissolving of gender differences in law and other institutionalized forms a particularization of gender roles has appeared, i.e. societies seem to keep up differences informally. This implies that the uphold of gender hierarchy seems to be of urgent social desire. As up to short time ago the gender difference was institutionally guaranteed, today it has to be created by action and this also has to be marked symbolically. This makes gender differences context dependent, and its creation to a process with many prerequisites bound to specific constellations. As a consequence in certain contexts gender differences can be dissolved whereas in other ones they can be kept up or even strengthened. Heintz, B. and Nadai E show how this influences gendering in different professions, in informatics, nursing and in office work (Heintz and Nadai 1998). This obviously can explain the gendering of new technologies and the horizontal gendered workforce in general, and especially the male gendering of informatics in ASF countries.

Why then is informatics less or not gendered in France, Italy, Russia, etc.? I would like to extend the argument also to the dissolving of cultural gender differences. Both in the European Latin and in the Slavic countries there exist more specified gender cultures, which allow the individuals of both sexes self conscious gender identities. These cultures are performed mostly in the interaction between men and women and among the two sexes off workplace. These groups confirm their members in their self esteem as women or men. In Italy e.g. I think of very distinctive and self confident gender cultures, not only concerning the role of mothers, but also in youth with dressing and playing the games between the sexes. In Russia I think of the common conviction of women and men, that men are incapable of organizing everyday life, giving women a fairly self conscious gender identity. Therefore in these countries a self respect stemming from being a woman as well as from being a man as such is kept up. So there is no necessity for boys or men to hold their ground nor to compete with women intellectually. Therefore women easier can consider themselves as of equal mental power, also in subjects like informatics. And boys and men need not take up the computer in order to stabilize their male identity. In fact speaking to Italian teachers they report that considering informatics as male subject or the computer as male tool would be considered as absurd in Italian schools. The borders between maleness and femaleness are well defined by a gender culture. Such gender cultures in general do not exist in our countries any more. Women are not proud of their gender here and girls gradually are losing convictions of their value in school.

I suppose that it may also explain the contingencies of participation of women in technology and sciences throughout the different European countries. In the Roman languages speaking countries the defined culture of genders also implies a self-confident identification with ones own sex both of females and of males, making it less necessary to create gender differences by definition of gendered competence.

Within the ASG countries the interaction between men and women is gendered more by hierarchy. But the making of hierarchies has to be grounded in competence and performance. Boys in mixed schools find it difficult to uphold their superiority, when observing the performance of girls, because of the obvious appearance of contrary experiences, a fact, which makes them aggressive and violent against girls. A way out is to usurp subjects as male ones, like computer science, science and technology. In fact this is what happens in Germany: Boys displace girls from the computer or put them into an assistants position. Boys claim computers and programming for themselves, since their breakthrough and high economic and social value has appeared. So what happens is the gendering of highly respected subjects, like computing, because the definition of gender identity is left much more to contingency and to the individual. As a consequence of the gendering of competence, i.e. leaving the low estimated competence to women, self-confidence of women as such is heavily reduced. The role of woman as housewife and as bewarer of ethics and culture has lost its value, the role of women on the job market is defined by gender-hierarchy, and both end up in a permanent struggle with both heavy working load and low self-esteem.

Although gender as a factor of ordering society looses its importance in general, it shows considerable persistence in many areas, and even gains importance on the symbolic level for ordering of subjects. So again a contextualisation of gender difference takes place, this time one of consideration of competence, which creates symbolic gendering of subjects, aimed to creation of borders between the genders and a social closure for women. If so, unfortunately this statement does not give rise to a politics of dissolving cultured gender differences in general, making deconstructive work questionable as well. At least such a program should imply also flanking provisions concerning the change of patriarchal identities. Else the free space opened up after deconstruction might not be used in the sense of creating an identity which includes equal value and equal rights to both sexes, but might shift an even heavier load of symbolic deconstruction on women's shoulders.

As software like every technology is value loaded, it is relevant, who is shaping it, because later on the values baked into software is shaping us, the whole society. As software and the Internet is heavily dominated by the US and an English speaking culture, there is a heavy danger of implementing this gendered culture of computing onto the whole world.

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Chapter 9
Ada: Poet of Computing

A One Person Opera Libretto

Britta Schinzel

Abstract This text will describe the libretto for a one person opera about Ada, countess of Lovelace, its development, and with it Ada's life and work. There was a big challenge to make audible and visible her abstract mathematical abilities and her insights into the capabilities of computers at the early time of the nineteenth century, as well as her (first) programming, of e.g. the Bernoulli-numbers. In particular logistic problems of the staging arising from a one-person opera are described. The solution is found with the intertwining of an oratorium-like form with stage imaging and projections, electronic devices and tuning.

9.1 Introduction and Intentions of the Libretto

My friend, the composer Viola Kramer gave me the task to write a libretto for a one person opera about Ada, countess of Lovelace, who is said to have written the first computer-program, a program for Babbage's analytical engine, which, although still mechanical, had the structure of today's von Neumann-computers. Being a mathematician and computer scientist, and with no experience in writing libretti I hesitated to undertake this, but having worked in gender studies in computing, I already knew about Ada's history (see e.g. Oechtering et al. 2001). But how can I compose mathematics, music, computers and poetics into a text to be set into music?

We wanted to use as much technology and as many IT-gadgets as possible for the staging and the stage design. And to make transparent the findings of Gender Studies w.r.t. computing within the stage design. Technology opens up world and at the same time locks off other possibilities of development, which might have been preferable in one or the other respect. In particular the socially effective information technology and its code implicitly contains social conditions and desires, which are baked into it by design, performing inclusions and exclusions.

B. Schinzel (✉)
University of Freiburg, Freiburg, Germany
e-mail: schinzel@modell.iig.uni-freiburg.de

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9.2 Short Biographical Notions and Historic Setting

Ada Augusta, countess of Lovelace, was born as the daughter of the noble Annabella Milbanke, who was skilled in mathematics and all the actual sciences, and the poet Lord Byron, who was described as an emotional, romantic, excessive and immoral person. The marriage was extremely unhappy and Annabella divorced soon after Ada's birth. In the following she tried to suppress any sign of Byron's character showing up in Ada's development. Mathematics she considered as a good disinfect against too much sentiment and poetry. And Ada was enthusiastic for mathematics and science, but also of arts and music, and more and more she also combined these with her poetical, philosophical and emotional interests. Already as a young woman of seventeen she took interest in Charles Babbage's computing engines and understood their function to the largest extent. For some time she was able to persist in her mathematical activities also during her marriage and as a mother of three children, and as such she did her great mathematical programming work. But finally this was not possible any more, both for family reasons and because the scientists, Babbage especially, would not allow her to cooperate any longer, and she started to gamble. As a young woman of thirty-six she died from cancer.

At the time where Ada lived, gender order was clear and unquestioned, although it was quite differentiated according to social layers. Scientific work was mainly left to the rich, and to be able to make one's living on it was extremely rare. The possibility to work at all was much more restricted for noble women than for women in general. So it was kind of a scandal that a countess would deal with mathematics and machines. Scientists sometimes were more open to women performing it, like Ada's teacher and mentor Mary Summerville. But for them on the other hand it might have been scandalous that Ada—as she did—would ascribe machines and electromagnetism poetical, psychical and social potential. On the other hand at her time there also existed a relation between romanticism and machine phantasms, as poetry of the time would thematize: E.T.A. Hoffmann's singing automaton Olympia, or Hans Christian Andersens "The Emperor and the Nightingale", and Mary Shelley's Frankenstein. But Babbage himself had designed his machines for mathematical and statistical tasks, as well as for economic calculations, which—as Ada had foreseen first—clearly would have social impact.

The special fascination of Ada's character was the confrontation between rationality and passion, virtue and excess, technology and fate, progress and everlasting humanness, planned determinism and chance, sovereignty and subordination, a pattern that repeated throughout all her life, as a prolongation of the conflict between her mother Annabella Milbanke and her father Lord Byron. Within these antagonistic pairs both her personal life and the course of the world history are glued together. The mother appears as the key figure: her virtue contains all hopes and all cruelties of the dialectics of the Enlightenment and its beliefs in progress—and the ideals of the French revolution: Robespierres famous "virtue necessarily and inevitably has to reign by terror!", might hold as a motto for her. It is a remarkable point, that here a woman represents rationality and the man emotions. And that the virtuos mother at least once realizes that she lacks something for her perfection—and without mercy she fights this insight in her daughter. Ada is thrown onto this arena and tries to stand her ground. Her attempts in gambling seem to be like a metaphor, collecting all this together in a nutshell.

9.3 Logistics, Production and Staging

The opera is conceptioned as an oratorium, like Bach's passions or Handel's Messiah. The only person acting on stage is Ada, but there are several choirs and one recitative to tell the story, and this in past tense. Everybody else speaks in present tense. The sentences have to be short and simple, and monologues have to be designed as dialogues. The text has to fit to the rhythms of the composer, and only the music should transport feelings, not the text.

The first difficulty was the order of sequence: if I follow her life chronologically I have to start with her lonely and cruelly controlled childhood. But the main theme of the opera is how she became the first programmer, the first person who had set a complicated algorithm into a sequence of declarations for punched cards to be performed on a computer. To present this abstract thinking achievement as the starting point of the drama, would hardly be understandable and would make listeners fall asleep. The second problem derived from the one-person concept, and this together with the demand to bind her story into the present. The third difficulty was to pack the story into four consistent scenes. It should point out her relationships to her mother Annabella Milbanke, to her father, the poet Lord Byron, the different scientists with whom she had contact, to Charles Babbage, the inventor of the Differential Engine and later the Analytical Engine, but also to her husband and the three children. Moreover her affection to technology, mathematics, to the computer and its programming had to be dealt with.

For these reasons and because of the one-person-concept the libretto turned out to be primarily a logistical problem. We decided to present four scenes, defined by the themes

1. Mother, relationship between father and mother, education
2. Males, father, poetry and relationship between science and poetry
3. Mathematics, technology, computer
4. Sickness, gaming, edictedness and death

Of course all these themes should relate to the epoch, the life feeling and episteme of Ada's life time, the technological uprise, with steam engine and first iron track based transportation, the new scientific discoveries, like electricity and magnetism, as well as the philosophical views, the beginning of Victorianism in England. All this is also culminating in Ada and her social environment, her mother and her friends, who mostly were scientists. Of course it is also demanded to point out all the later developments which Ada had foreseen incredibly wide looking.

Moreover the difficulties for a woman (see Oechtering et al. 2001), even for a noble one, to participate in scientific work, e.g. to receive scientific literature, because she could not enter a library, and her husband had to copy it for her; or to publish under a female name, she had to do it with her initials only.

A chronological sequence was not possible with the four scenes, because the themes would have to be taken up many times through Ada's life. Therefore each scene should be chronological for itself, but for dramatic reasons, not too strictly.

9.4 The Acts

9.4.1 Biografic Background

According to her biographers' storytelling (e.g. Woolley 2005) her studied, rational and mathematically trained, self controlled, religious, but also haughty mother Annabella Milbanke with her extremely shocking experiences with Lord Byron had determined Ada's education and life to a large extent, ambivalently. They had met in London, where Byron made a proposal of marriage to the "princess of parallelograms", which she first refused, but then she was attracted by the famous, dangerous and scandalous man, and fell in love with his glooming verses in the poem "Giaur". She found an excuse to marry him: she wanted to lead him onto the path of virtue. The marriage was a sensation in London, and it remained a journal's theme. The marriage immediately turned into a hell. When Annabella also found Marquis de Sade's "Justine" in his bookshelf, and she guessed that he continued a relationship with his half-sister Augusta in her own house—his daughter Medora with her was born shortly before Ada, she decided that he was lost to hell and gave up bettering him. She ordered a psychological expertise about him—it is said that it was the first one to be made in history—which assured that Byron was not sick, neither mentally nor psychically. Then she proceeded to the divorce, which was not easy for a woman at that time, and she had to make his severest sins public in order to be able to keep her daughter. From this time she followed Byron with her hate until his, and even until Ada's early death. Byron had fled her and his debts to Greece, where he died, never having seen his daughter Ada. Ada, as a last revenge to her mother's coercion and surveillance, had determined to be buried in her fathers grave. Although Annabella supervised Ada until the last minute in her life and let nobody else approach her dying bed, did not attend the funeral of her 36 years old daughter.

This marital discord was termed a symbolic item in Victorianism: It was the representative arguing between the romantic spirit, stemming against progress, and modern rational mathematical humanity in the industrialized world. And it was a media event—the press jumped on the contrahents in just the same brutal and defamatory manner as it does today (as Woolley mentions, the reference to Lady Diana is close). Annabella called it the newspaper-war, which accompanied also

Ada until her death, because the British society wanted to know what would be the outcome of this connection between genius, poetry and mathematics, infidelity and jealousy, freedom and riotousness, love and hate, virtue und depravity.

I will describe the contents of the acts and I will intertwine it with the stage design. Each scene acts chronologically from the beginning to her early death.

9.4.2 Act 1 Ada as a Child, Education and Relation to Her Mother

Annabella anxiously observed the development of her daughter, in cool distance, also in space, she met her seldom, subdued her under a strict regime of an exactly planned education, performed by childcarers and house teachers and you later by Annabellas friends, whom Ada called the furies. With a very strict controlling education, giving science, religion and ethics which should hinder a free development of her mind, a counterpart to any sign of her father's biological inheritance, his poetic, scandalous and bacchanal character. Annabella wanted to "suck his blood away from her heart", as Byron wrote in one of his poems.

In an opera you have to plug immediately into the course of the story. Therefore the opera starts with Ada in a cage, where letters and books are reached through the holes by hands or by letter doves. Surveillance cameras are installed in the stage. Ada sings that the only way to stand the situation was to deal with her mathematics books. But then she starts to dance, the cage flattens on the floor, and she walks on the lines.

The choir of lifted forefingers gives instructions to Ada and threaten her.

The recitative now reports that: Ada was a very lively child, full of phantasy, also in technical respect. Very early she was interested and gifted in geometry, architecture, biology, she read a lot and had interest in philosophy, poetry and fine arts, which she often also performed: singing, dancing, playing music instruments, woodcarving, and writing stories. Unfortunately in her mother's eyes, but and in fact fortunately the stimulations in mathematics science and technology did not have the anesthetic impacts, deterrent effects on Ada, in the contrary she was enthusiastic.

Ada developes a flying machine. She calles herself a letter bird, probably a metaphor for her wishes to be freed from the mother-prison.

The recitative reports: with fourteen she became limb and blind;

She is shown in a wheel chair, has to be fed.

Recitative: It took more than three years until she could start to move again, but then she also started to oppose. Whereas Annabella was steadily kept with her own health, drove from one spa to the other, the many manifest sicknesses of her daughter did not tangle her, neither her nervous breakdowns, nor a later cholera, which she hardly survived. Until the end control, moral leading and suppressing the father's properties were Annabella's main concern. And in the end she used Ada's cancer to isolate her completely and to convince her that her suffering was the justified punishment for her sins. But it was not Ada, had she not been able to show even in her death a last contumacy in choosing her last sleep at the side of her father. *The family grave is shown on a screen.*

9.4.3 Act 2 Men in Adas Life, Her Father, the Scientists

For Ada men were often possibilities to flee her mothers prison, as e.g. her marriage. She had an extraordinary attraction to men, with her stormy and unpretentious way, her courage and her decisiveness.

Recitative: When the thirty-four year old William King, Baron of Ockam, proposed to marry her, she took it immediately with her nineteen years hoping to escape her mother. In vain, because he was deeply subsidized to her mother.

It is shown on stage, that as a wedding gift Annabella gave her a large portrait of Lord Byron, whom she had never seen before. In Kings library she also found her fathers's works Childe Harolds and Don Juan, as important texts showing the relation between her parents—and herself mentioned. Ada realizes what she had missed up to then: poetry which reflected feelings as something acceptable, even necessary to gain complete humanity!

Moreover she realized that Babbage's machines which had found her burning interest since she heard of them in queen Victorias palace, would allow her to connect rationality with feelings, mathematics with poetry. The happyness it gave her exceeded all other joys which marriage and children, journeys or horse riding. She had found the symbiosis of mathematics and poetry, of mother and father in herself.

Soon she had three children, whom she educated according to the newest principles of Pestalozzi. Soon the children because a burden which prevented her form continuing her mathematics' and computing interests.

At the same time she gradually approached her father's spaces and ways of life and dismissed her mother's influence.

She had many male scientist friends, like Mary Sumervilles son Woronzow Graig, the mathematician and Augustus de Morgan, the "electrician" John Crosse, and Charles Babbage, with all of whom she exchanged lots of letters, with the latter often more that one a day. But her tries to be e.g. Faraday's or Babbage's assistant obviously was too much for the time. Anyway Ada continued her studies. Crosse also was the cause for losing her husband's and children's fondness until, sick and weak, she again was completely extradited to her mother.

9.4.4 Act 3 Ada's Relation to Mathematics and Technology

Ada met Mary Somerville (Pohlke 2015), who already had made magnetic experiments, solved diophantine equations, and computed planet ways. With her she went to Babbage's soireès and immediately was enthusiastic in his "difference engine". She studied the powers of steam engines, able to drag trains on iron tracks, electricity in the new telegraphs and experimented with magnetic powers. She was one of the first to drive with the railway from London to Southampton, and realized that this kind of transport and time machines, together with the telegraphs' potentials of synchronizing trains arrivals and departures would change the world completely.

one hears the whiring, buzzing, chirping of the telegraphs, jarring of the iron trains, whistling of the steam engines

> Ada: look what we have detected by now: electricity, magnetism.
> CEM (choir of electricity and magnetism): sss sss bang!
> Ada: did it exist before?
> CEM: of course! lightenings whitened the heaven, thunder-detonation
> Ada: but now not only God can lighten, we humans are also capable to do it!
> CEM: the compass shows the way to the north *(map with* compass*)*
> Ada: but magnetism also intrudes into the human body.
> She also attended mesmerist magnetic sessions (Franz Anton Mesmers hypnotismus occulta), which were taught to be able to set psychical energies free and to heal.
> Ada: Mesmerists are healing with Magnets! *(Spins of the H-atoms align within the magnetic field and swing back)*
> CEM: caution, caution, this is not scientifically verified!
> Ada: "In a mesmeristic session I had a curious feeling, it was an unnatural mental and bodily sensation". I would like to understand this mechanism.
> a single high pointed CEM-voice: Hypnosis, Hypnosis!
> Ada: My doctor treats me with magnetism, *(a MRT-tunnel with a human head to bone measured in it is seen) Music: knocking, rattling, buzz of the radiowaves in the MRT with measuring.*

Moreover she underwent a phrenological investigation, which should estimate her character, because her mother had undermined her self-esteem—which approved her doubts in her normality and psychical sanity. At that time it was not yet possible to differentiate physical phenomena from occult ones. Similarly 50 years later this again was blurred with the detection of X-rays. This gives the opportunity to point out the connection between George Combe's (see Combe 1819) phrenology and the Nazi race-ideology, but also the relations to today's cognitive- and neuroscience.

Babbage was beset by measuring, numbers, tables and statistics (see Babbage 1961). He measured everything, also life items in numbers, and he also co-founded a life insurance. He also was interested in business in order to finance his machines. When he had developed further his universal freely programmable "analytical engine" (see Babbage 1999), Ada was excited. She understood that unlike the former difference engine, which could only perform a fixed sequence of computations on a computational board, the analytical engine was able to perform variable processes in dependence of the former computation. This mechanical machine was similar to today's computer architectures, it divided memory and computational board, the latter consisted of a small set of basic operations. Control was performed in analogy to weaving machines by "chains of punched cards".

Ada approached Babbage to allow her to cooperate and give her duties. The opportunity arrived with a lecture given by Babbage in Torino, which Menabrea, an Italian officer had protocoled in French. Ada should translate it into English. Her work on analysis, design and programming the analytical engine on several examples, especially the numeric computation of Bernoulli numbers struck Babbage. He saw that Ada had completely understood his machine and its potential of programming, even better than himself, and proposed that she should add her own comments to the translation. Ada worked several months on these "remarks", until the text was three times as long as the original one (see Lovelace 1842). There she describes in detail, which problems could be solved on the machine, and in which manner the operations should be organized. According to the architecture she introduced variable cards and operation cards, and developed sets of punched cards for solving different algebraic and trigonometric problems. The interplay between the cards was organized in such a way that the flow of computation allowed all the possibilities of flowcharts: forking, iteration and recursion. Her work culminated in a program for computing the Bernoulli numbers, which Babbage had set up in his lecture, where she already used tables and diagrams as representations (see Hellige 2003).

Ada, though understanding the mechanisms of the machine, she also ascribed it metaphysical properties, saw not only social, but also poetical, musical, graphical, geometrical and philosophical potential in it (see Schröter 2015). She even realized that it would be able to treat relations, e.g. to learn musical harmonies, which would result in the possibility to compose music pieces of any kind. In fact in this machine she saw her salvation, because so she could connect poetics, music and feelings with rational science, mathematics and technology, a symbiosis which she had missed so much—she was happy!

9.4.5 Act 4 Sickness, Ediction and Gambling

After the third child Ada became quite frustrated by her duties in household and child care. But she succeeded to convince her husband to receive more mathematics teaching by Augustus de Morgan and to play the harp.

But when she could not cooperate with scientists any more, she became interested in fortune games with horse races. As she was convinced she would be able to compute a secure winning strategy she continued to play, even when her debts exceeded the family wealth. But the horses did not obey her probability computations, and she continued losing money until she had to ask William to borrow money from her mother. Since long time she had cut the connection to her, but now she could enter her house again. At this time Ada certainly was already addicted to opium, because her doctor hat treated her with Laudanum against everything: her pains, her heart- and rheuma attacks, her nervous irritations and break downs. She was already severely sick, but just for this reason she wanted to enjoy the rest of her life, and she continued playing fortune games and computing winning strategies. Together with friends who trusted either in her mathematical abilities or in the family wealth, or both, she founded a syndicate, for bookmaking for sports betting. They lost huge amounts of money and the friends began to press her. It became clear that Ada had cancer and her mother entered the sickroom. Ada could not oppose any more, and Annabella removed everybody else from the house. Only her last triumph to be buried in her fathers family grave was left to her and Lord King did not refuse it.

9.5 The Staging

The difficulties arising from the requirement of a one-person opera, where still the important figures, like Annabella, Lord Byron, Lord King, Charles Babbage and other scientists should receive a (whatsoever virtual) voice, have to be met. This is done on one hand by the installing of the choirs and the recitative, possibly recorded in advance, which play the roles with whom the whole story can be told. Ada's monologues are designed as dialogues with her contact persons. On the other hand the staging will support the understanding of contents, especially the abstract ones, working together with the figures. The choirs not only represent groups of people, like the Furies, who, empowered by Ada's mother have to control and survey her, but also virtual realities and physical measures. So for example the choir of raised forefingers will sum up the representation of moral claims set up by Annabella, the Furies, religion and society. The choir of electricity and magnetism may report the respective discoveries, or can warn Ada from drawing too far reaching conclusions about the connection between magnetism and psyche in the context of her mesmerist sessions. The choir of mathematics will report Bert Brecht's insurance-mathematical text: "ich weiß nicht was ein Mensch ist, ich weiß nicht wer das weiß, ich weiß nicht was ein Mensch ist, ich kenne nur seinen Preis". The choir of the twentieth and twenty-first century may tell about the development of phrenology, its assets in eugenics and race theories. It also talks about the development of computers and IT, which Ada predicted.

Stage images and images projected onto the floor are also important actors in this opera. E.g. visualizing the prison, in which Ada feels caged. Also parts of mathematics, physics and technology playing a role here are put into picture, either projected in formulas onto the wall, on screen, or more directly as geometric lines and figures. I also propose, single sentences or formulas to be hung on ads, like Brecht's bible verses in the beggars-opera, on which actors can point. Ada interacts with many of these figures: she dances on lines, on figures projected to the floor, or is led, restricted and pushed back by them. Also virtual realities and actors, avatars, robots and drones shall appear in projections and connect with the texts of the choir of the twentieth/twenty-first century. Movable surveillance cameras will be fixed everywhere in the cage, and when Ada flees, a video-drone will turn above her head, while the choir of furies sings: “surveillance, control, for this we are prepared. With the greatest pleasure!” Above the telegraph wires at times PRISM and TEMPORA are dragged as text, the images of Bad Aibling, and with this links, e.g. to the EU data-protection etc. appear.

Projections with formulas for computing the Bernoulli numbers, the Riemann conjecture connected with them, the Fibonacci numbers and the golden cut appear when Ada sings the respective texts.

At the same time as many new media and gadgets as possible should be used, reproducing the previously taken tunes, scenes, images, graphic novels and buttons or tweets from social networks. But also diverse media, the internet of things shall be used online at the opera performance, e.g. RFIDs can be used to allow the audience’s entrance. Also the cell phones of the audience might become active, e.g. an application with crowd sourcing for Ada’s debts, or an application of citizen science to solve the Riemann conjecture.

With the composed music also physical tunes appear, the snuffling of the steam engines, the quieking of the iron wheels on iron tracks, the zirping of the telegraphs, morse-rhythms, thunder, electronic tunes, cell phone ringing, etc. Not only texts are sung but also numbers: a cantus firmus with the Bernoulli-formula is heard, another one with Riemann’s Zetafunction, and at the same time the golden cut is projected; the choir of electricity will sing morse signs at a constant tune height and then the Enigma and Alan Turing are shown; the choir of mathematics will sing Babbage’s insurance mathematical relations between humans and numbers.

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