Inaugural Speech prof.dr.ir. H.A. Reijers, June 26 2015

HYBRID SCIENCE

A CHESS STORY

You are listening to the words of a failed man. But before I will explain that, I would like to talk about chess. Even though I am not particularly good at it, it is a fascinating game.

As many of you may know, in 1997, the reigning world champion Garry Kasparov was beaten in a six-game match by the super computer Deep Blue. Many commentators perceive this defeat as a landmark event and draw a range of conclusions from it about the advent of the computer and the end of human intellectual supremacy. I myself am more intrigued by what happened after the event.

Kasparov picked up an interest in *advanced chess*, a chess game in which a human and a machine can join up to play against teams of other humans and machines. In 2005, the first large chess tournament was organized where teams of humans, machines, or combinations of these could compete. Strong grandmasters who worked with several computers at the same time entered the competition, as well as teams that registered their chess-specific supercomputers. During the tournament it became clear that teams that consisted of a human *plus* a machine dominated computer-only teams. The chess machine Hydra, a chess-specific supercomputer like Deep Blue which I mentioned earlier, could be easily defeated by a strong human player with an ordinary laptop. However, the biggest surprise came when the winner of the tournament was announced: It was not a grandmaster with a state-of-the-art PC, but a pair of amateur American chess players using three computers at the same time. Kasparov observed that human strategic guidance combined with the tactical acuity of a computer was overwhelming (Kasparov, 2011).

While this was the first large-scale tournament, over the past years seven other large, so-called Freestyle tournaments were organized. When considering the winners of these events, more than half of these teams consisted of amateur human players - only three of the winning teams involved an International Master or Grand Master (Nickel, 2014). Kasparov drew the following conclusion from this collaboration between man and computer:

- **Weak human + machine + better process superior to a strong machine**
- **Weak human + machine + better process superior to a strong human + machine + inferior process.**

Here, Kasparov uses the term ‘process’ to relate to the interplay between human and computer.

MYTHICAL CREATURES

This story gives you a glimpse of the power of a *hybrid* system, where humans and computers work closely together to accomplish a particular task. I find it entirely appropriate that Freestyle teams

position themselves as *centaurs*, referring to the mythological creature with the head, arms, and torso of a human and the body and legs of a horse.

The Capitoline Centaurs are two Roman, grey-black, marble sculptures of centaurs from the 1st or early 2nd century AD, as found at Hadrian's Villa in Tivoli and on display in the Capitoline museums in Rome today (Wikipedia). They are copies of 2nd century BC bronze Hellenistic originals and various other copies exist, for example in the Louvre. Interestingly, there are also other mythological, hybrid creatures that are still held in high esteem in some quarters – such as the griffin in the logo of VU University.

The fascination for hybrid creatures or systems goes back a long way, but they still seem to appeal to us in modern times. What I find a significant theme is the *rise* of hybrid systems in all aspects of our society.

A notable example is the self-driving car, as developed by Google and other technology firms. Despite its name, which suggests a fully autonomous car, this is currently – and likely to be for some time - a system where man and technology need to interact closely. Especially in situations where the computer is unable to manage a particular driving situation or environment, it is important that the human driver can resume control at any time. In this way, the computer takes care of the standard driving situations whereas the human is to deal with complex, exceptional situations.

There are examples of hybrid systems on other levels as well. The notion extends to physical entities, such as the cars I already mentioned as well as people themselves, when they use advanced prosthetics. Less tangible items can be hybrid as well, such as *methodologies* and *organizations*. Think, for example, of the digital support services that various companies, such as airlines, offer. Human operators exploit social networks, such as Twitter, to identify troubleshooting opportunities, while they use automated translation services, like GeoFluent, to interact with customers with whom they do not share a common language (Brynjolfsson & McAfee, 2011). In healthcare, pathologists are using a system called C-Path to examine human tissue to find new features of breast cancer that predict survival rates (Beck, et al., 2011). CrowdER is a hybrid approach to entity resolution in databases, where machine-based techniques to weed out obvious non-duplicates, while using precious human resources to examine just those cases where human insight is needed (Wang, Kraska, Franklin, & Feng, 2012). And there are many more examples. Here, I should emphasize that it is not so much the interaction between humans and technologies that fascinates me, but also the added fact that their complementary skills result in an overall performance that could not have been achieved by relying solely on humans or technology.

There is a recent book by MIT economists Erik Brynjolfsson and Andrew McAfee, which is entitled "Race Against the Machine" – not to be confused with the rock band with a similarly sounding name. These people have studied the advent of information technology and its effect on the economy – I mean the economists, of course, not the rock stars. One of their analyses revealed a list of jobs that until recently were believed to be the exclusive domains of humans, but which have now been fully automated. Their main message, however, is not a pessimistic one, in the sense that computers will outperform all human activities and ultimately take over all jobs. Rather, they emphasize the great potential of competing WITH machines, instead of competing AGAINST them (Brynjolfsson & McAfee, 2011):

"while computers win at routine processing, repetitive arithmetic, and error-free consistency and are quickly getting better at complex communication and pattern matching, they lack intuition and creativity and are lost when asked to work even a little outside a predefined domain. Fortunately, humans are strongest exactly where computers are weak, creating a potentially beautiful partnership."

Their call is one for organizational renovation: co-inventing new organizational structures, processes, and business models that leverage highly-advanced technology and human ingenuity. Indeed, we can see that this is happening all around us. For example, consider the advent of what business professor and Google chief economist Hal Varian has dubbed "micro-multinationals" (Varian, 2005) – businesses with less than a dozen employees that sell to customers worldwide by exploiting automated services to link up with worldwide supplier and partner frameworks . We can also see it in a trend that is called FinTech, a line of business based on using software to provide financial services with the purpose of disrupting incumbent financial corporations that rely less on software. And these companies achieve interesting results. For example, the loan approval rate of FinTech-style, small-business lenders is 62 percent, much higher than the 21 percent by traditional big banks (Smith, 2015).

BUSINESS PROCESSES AS SOCIOTECHNICAL SYSTEMS

At this point, I hope to have given you an idea of what hybrid systems are, how powerful they have become, and how pervasive. What I am interested in in my work are the hybrid systems that involve complex interactions between people and technology in the *work place*. Some of you may be familiar with them as *sociotechnical systems*, a term coined by Eric Trist and Ken Bamforth, based on their studies of workers in English coal mines. They studied the strange phenomenon that in the post-war period state-of-the-art mining machinery was deployed, but productivity declined. Their conclusion was that technological and social measures must be closely aligned (Trist & Bamforth, 1951).

When studying sociotechnical systems, there is still a choice of angles you can take, for example a focus on work teams or on tasks. The type of sociotechnical system I am studying are *business processes*, which involve all the steps that are taken to produce a particular good or deliver a particular service, and which require the actions of people and automated systems and their interactions.

Consider all the checks and calculations that are performed by the professionals within the tax office when you file your tax declaration, which are needed to reach a decision on whether it can be accepted. In a healthcare setting, a business process covers all the tests and actions of healthcare professionals to diagnose and treat your ailment. Note that a business process is more than simply a list of all the tasks and performers: It also encompasses all the logic and policies that govern the circumstances when a particular step is performed and by whom.

Organizations have started to realize the value of dealing with such business processes: These are precious assets, deserving management attention in their own right. Various studies have pointed out that a focus on these business processes delivers all types of benefits (McCormack, 2001): less conflicts between people of different involved departments, because the emphasis shifts towards

achieving a common goal. In addition, higher customer satisfaction, since in the end clients are interested in the outcomes of entire business processes rather than the performance or actions of separate departments of organizations. In this sense, the orientation on business processes that has now become dominant in many organizations makes the proper design of business processes highly relevant and in part motivates me to study them.

HUMANS AND COMPUTERS IN THE LOOP

Hybrid systems do not come without problems. One of the main reasons that experts do not expect self-driving cars to appear on our roads in great numbers for at least another decade is the transfer problem I mentioned earlier: How to make sure that a human driver can take over from the computer while the car is in motion, particularly in emergency situations. To guarantee smooth transfers, the human must stay in a state of vigilance, monitoring the performance of the car continuously. Research has shown that this state of mind is extremely difficult and demanding for humans (Warm, Parasuraman, & Matthews, 2008). What exacerbates the situation is that human drivers are likely to become engaged in secondary tasks when they are not in control, for example they may check their email, watch a DVD, or perhaps take a nap. Under these circumstances, it may not come as a surprise that drivers retaking manual control from automation need up to 40 seconds to return to normal, baseline driving behavior (Merat, Jamson, Lai, & Carsten, 2014). This is not the time frame that you would hope for when an emergency situation occurs.

The deeper problem here is that we have a very limited understanding of how to design hybrid systems such that the automated components and the humans-in-the-loop seamlessly work together. This particular problem can be observed very clearly in the context of the hybrid systems that I am studying myself, business processes. Labor psychologists have a thing or two to say on how you develop individual work tasks in a process; software developers are well-versed in developing the algorithms that are employed; organization scientists analyze the procedures and structures that need to be put in place. What we lack though are the professionals who can take care of an integrated design of an entire *business process*, working on the basis of strong theory.

THOSE PESKY EXCEPTIONS

The friction I am alluding to manifests itself clearly in the way that *exceptions* are dealt with in business processes. These are the cases that deviate from what is processed on an ordinary basis (Strong & Miller, 1995). Examples abound. Barry Schwartz is a professor of psychology at Swarthmore College and in a fantastic Ted talk (Our loss of wisdom, 2009) he describes how hospital janitors, who often have to follow very tight regulations on how to perform their cleaning duties, run into all types of exceptions, such as the task of mopping the floors in a hallway where you would sometimes meet patients who are recovering and are just taking their first steps out of their bed, regaining their strength. A slippery situation. Another notorious example is the case of Delta Air Lines, which was much debated in 2011 in the United States (Ott, 2011). 34 US soldiers flew home after they served in Afghanistan, while they had orders that specified that they could take four bags home with them without additional charge. The Delta agents in the US that checked them in for the

last leg were using the standard regulations, however, charging each of the soldiers to pay USD 200 for the fourth piece of luggage. That this was an exceptional situation was emphasized when the soldiers were also asked to pay these fees immediately. Staff Sergeant O'Hair reportedly noted: "A lot of the guys didn't bring credit cards because, heck, how much do we need credit cards in Afghanistan?" (Starnes, 2011).

The standard response in many organizations is to deal with exceptions as signals of poor process quality that can and should be eliminated to improve performance (Strong & Miller, 1995). According to that mindset, standardization is seen as a means to provide assurance of a particular quality level by its employees and to achieve economies of scale. While quality and efficiency are clearly legitimate performance objectives, a problem arises when they are considered without their potential impact on other performance dimensions, in particular service quality and customer satisfaction. Research shows, for example, the detrimental effect that *scripting*, i.e. the usage of pre-defined scripts when interacting with customers, may have on their satisfaction (Victorino, Verma, & Wardell, 2012). A mindlessly followed procedure in a business setting can cause an employee to ignore the greater variation in customer demands or other customer signals (Ashforth & Fried, 1988), which would be noticed with a more flexible approach to designing the encounter. Recall again the case of the janitor, mopping the floors of the hospital in the presence of recovering people.

With the advent of standardized ways of interacting with companies, you yourself may also have noticed the downside of being straightjacketed into forms of interaction with all kinds of service providers, such as your bank or your energy provider. While in the distant past we were able to interject our specific wishes in a direct conversation we had with an operator or service clerk, more recently we had to resort to scribbling down our comments and requests in the margins of the paper forms we used. Nowadays, even this has become virtually impossible with the digital forms forced upon us, sometimes causing frustration and sub-optimal service.

An approach to dealing with exceptions that is slightly more enlightened than striving for full standardization is to use people as troubleshooters. In this approach, people are expected to do whatever cannot be achieved by a standardized, automated approach, namely to deal with the specific properties of a case and the circumstances under which an exception occurs. What can be observed, however, is that the troubleshooting role is often poorly integrated with, and supported by, computer systems. This is referred to as the "irony of automation" (Bainbridge, 1983): Designers seek to eliminate people from processes because they are unreliable and inefficient, yet they leave people to perform all the tasks the designer could not automate. The result is "an arbitrary collection of tasks, and little thought may have been given to providing support for them" (Bainbridge, 1983). A secondary problem with this approach is that in such strictly separated systems where computers process the vast majority of cases it is difficult to develop and maintain the human expertise to take care of the exceptional cases. This is especially true if the human troubleshooters are not aware of the logic that is being used for dealing with standard cases and how this logic evolves over time.

In my field, I see promising and less promising approaches to dealing with exceptions specifically, and the design of business processes in general. What I believe to be less-than-helpful approaches rely on segmenting business processes into different classes, where each class allows for a different level of automation and involvement of people for making decisions and carrying out actions. In my view, this segmentation gives us a false sense of gaining control and making progress.

I believe that for the majority of service processes people and automated systems *both* should play a substantial role. Hence, I think we should focus on developing the knowledge to support such hybrid processes – not so much on arguing about the nomenclature for various types of different systems, such as workflow management, case management, adaptive case management, dynamic case management, and what have you. These kinds of discussions are still dominating the practical discourse.

Much more promising is the research that is done by various of my academic colleagues, and I wish to single out the group in Ulm led by professor Manfred Reichert, on developing fundamental technologies to deal with exceptional situations, in terms of supporting people to deviate from pre-defined steps, analyzing the causes for these deviations, and linking back knowledge on such exceptions to the way the process is supported for future cases. As many of you know, I have been working in industry with a variety of technology vendors. I can only emphasize my enduring state of surprise about how sophisticated some academic systems are and how crude the systems that are considered as the state-of-the-art in practice. I believe that there is considerable potential for a better cross-fertilization in this area. And it is not the academic community that is holding back here.

At the same time, I do not think that most academics that looks into the design of business processes addresses the problem in a fully satisfactory manner. My impression is that the focus of most endeavors in my community are too much oriented towards the *technological component* of the hybrid system that a business process is. In other words, we often seek the solution in a yet more advanced system with even more features. Specifically, this predisposition treats people as *users*, but not as actors *within* the overall system that is to be designed (Alter, 2013). The repertoire of design elements seems to be much wider. I like to mention three other elements.

First, we can look into *human resource* measures, such as the composition of the teams of people we choose to commit to business processes, the decision-making authority to be granted to them, or the training we wish to provide to them to deal with exceptions. Simply explaining the 5 classes of most occurring exceptions on the basis of collected data already seems a good idea in many settings.

There may also be other *artefacts* that we may wish to include into the solution than automated systems, such as guidelines, work instructions, protocols, and checklists, which may provide light-weight support in comparison to the full-fledged technologies we tend to think of. The impact of checklists in improving safety in airlines has inspired healthcare professionals (Gawande, 2010), but I see plenty of opportunities to embrace this concept in other domains.

A final, but in my eyes very powerful direction, is to look into *process* measures to start dealing with exceptions in different ways altogether. Exceptions, in fact, may indicate opportunities to open new products or services or to extend current offerings.

A good example is a car rental agency, which tended to direct customers to exact locations in crowded parking lots to pick up a specific car (DeVine, Lal, & Zea, 2012). Customers had much difficulty locating the car allotted to them due to unfamiliarity with the parking lot or inconsistencies between where the car was believed to be and where it actually resided. This confusion generated all kinds of exceptions: people taking the wrong car with them, people raising calls – in frustration – to get support from service employees not much more knowledgeable than themselves, people trying to cancel their reservation, etc. The actual solution that was adopted was the “pick any car” policy.

When people could pick a car from a much wider area of the parking lot, this was more efficient to operate than the old system and it generated less exceptions. What is more, it also created valuable revenue opportunities: The economy- and luxury-car choices were parked next to each other, so travelers with families were often tempted to indulge on a larger, more expensive vehicle. Note how this particular measure does not rely on technology at all, although it is definitely possible to come up with alternatives that do, for example using navigation software to guide customers to their car. My whole point is that we need to be able to identify such measures, such that we start to understand the whole spectrum of technological and human capabilities, and next to predict their relative strengths and weaknesses.

TOWARDS A DESIGN THEORY

Broadening the repertoire of elements to focus on when designing business processes is important, but just one step towards a design theory for business processes. We need to make other steps as well. Clearly, business process designers need to draw from theories and findings from behavioral psychology, organization science, and computer science. Yet, we require new theory, too, which extends these elements and considers them in an integrated way, in particular with respect to the technological, human, and process measures I mentioned. A highly promising basis is Work System Theory (Alter, 2013), which embraces a breadth of system aspects that should be considered. In particular, it acknowledges how restrictive it is to see systems as purely technical artifacts and people as end users only of technology, not as the active participants they are. Nonetheless, even Steve Alter, the main proponent of Work System Theory readily admits that in its current stage it is a far cry from a theory for design and action or, for the initiated, a type 5 theory (Gregor, 2006). I only said this to impress you.

To develop a design theory I believe that it is crucial that at any point we can derive a thorough understanding of how an operational business process unfolds, both to find indications for improvement opportunities and to evaluate the effectiveness of measures already applied. This is the area of *process mining*, a field that is pioneered by one of my mentors, Wil van der Aalst from Eindhoven University of Technology. The types of analyses that can be performed through the application of process mining techniques are stunning. They often provide drastically different views on how business processes unfold in comparison to the opinions people have on this topic, both the management overseeing such processes *and* the business professionals carrying them out. One of my favorite analyses was the outcome of a study that we performed within a financial process of a governmental agency. Here, we found out that one process participant had collected all the authorizations of all systems in use over the twenty years she worked there – a situation we were assured was impossible (Aalst, et al., 2007).

Process mining in its current state, which relies on the automated registrations of IT systems being used in business processes, provides us with a better understanding of business processes than traditional process analysis methods in which the views and experiences of people take center stage. Yet, we must acknowledge that process mining will not provide us with a complete understanding either. To broaden and deepen our views, we need to extend the types of data sources that we rely on for analyzing business processes. This is a theme that I am currently investigating with various PhD students and others, and I believe it has much potential. Still, we need to realize that much

knowledge about how a business process behaves and is organized is tacit. We cannot easily infer from data why people undertook the actions they did and at the same time we have a blind spot for their actions that do not leave digital traces. While this situation may change by the advent of increasingly personal and embedded registration services, for example tracking where individuals are at any given point in time and reporting on their work context, our best bet until that moment is still to interact with the business professionals carrying out the process. For the time being, the irony is: to truly understand a hybrid system we need to rely on hybrid analysis techniques.

While design necessitates analysis, it obviously does not equate it. The big challenge I see is to contribute to a design theory for business processes that gives explicit prescriptions in the form of methods, techniques, and principles of form and function, cf. (Gregor, 2006). Work that I have been involved in since the time I conducted my PhD studies involves the collection and refinement of design heuristics (Reijers & Limam Mansar, 2005): principles that have been successfully applied to improve the performance of business processes under some circumstances and that seem worthwhile to replicate in other settings. Some of these involve the use of technology, others deal with the process itself, and yet others with the humans active in the process. I am very glad that these are now considered as fundamental business process management knowledge, and will be incorporated in the Online course on business process management by Queensland University of Technology. This course will be launched as of October this year. Research that I am conducting with one of my PhD students and others involves the extension of these principles, as well as the enabling of business professionals themselves – not highly trained analysts – to apply them to their own work situation. The further extension, refinement, and validation of these heuristics is one of the paths I wish to follow.

THE HYBRID MAN

To come up with a theory for business process design is perhaps an overly ambitious goal for a failed man – a qualification I already used in my opening. It is failure in the sense that I have not found a way to live up to the ideal that I developed at a young age. In my early childhood, I would often take my bike to visit the town library – a trip that my parents allowed me to make on my own, already at a very young age. I remember these as magical visits. I marveled at the many books, and the many topics they covered. After a dinosaur infatuation, which grasps many children I suppose, I settled on history and I particularly enjoyed to read about famous individuals.

A person whom I came to admire very deeply is the Renaissance scholar Leonardo da Vinci. To many, he is the embodiment of the “homo universalis”, because of his great contributions to diverse fields as architecture, sculpting, engineering, chemistry, cartography, botany, mathematics, anatomy, geology, and, perhaps most magnificently, painting. When I read about his accomplishments, I decided to pursue excellence in all fields I entered. It did not seem unrealistic at the time.

More universal geniuses had been around, even in the Netherlands. I learned about Christiaan Huygens, who was born in The Hague. While many may know about his accomplishments in mathematics, physics, and astronomy, he can also be seen as a pioneer author of science fiction (Andriesse, 2007), which impressed me mightily.

It did not take very long until it became painfully clear to me that the ideal of the universal man was unachievable. I had no talent for the fine arts - whatsoever. No Mona Lisa would ever leave my hands. I received mediocre grades for the language classes I took. This precluded me from reading the original writings of Plato about the feats of his teacher, Aristotle, another all-round genius. There were other shortcomings I became aware of, too, but let's try and keep up the spirits during this final part of the speech.

I decided to turn to the other side of the spectrum: to become a specialist. And the object I picked to focus my specialization was the computer. I started studying computer science and while I cannot say I enjoyed the first years of my studies very much, I persisted – I had no backup plan – and ended up doing my graduation project within the provincial government of Zeeland. It was here that I realized that my training in formal methods, modeling, and system engineering was insufficient to deal with the data management challenges of the organization in question. It seemed that I had to talk -- with real people, mind you -- to reach a proper analysis of the problem or to arrive at any system design at all. This was an epiphany. I came to realize that I required techniques from very different domains – the exact and the social sciences – to accomplish my goals. It was the start of many steps to acquire a range of very different skills, both in a practical sense, as a consultant, and academically. In the end, I did not become a "homo universalis". However, I am content to settle for the predicate of a "homo hybridus".

CLOSING

I come to the conclusion of this inaugural speech. I am very glad to have made the move to VU University. It is a place where interdisciplinary work is well esteemed and warmly encouraged, which can be experienced in different ways, for example through the activities of the Network Institute. At VU University, I have set up collaborations with researchers from different areas, notably within the Faculty of Economics and Business Administration, the Academic Center of Dentistry, and my own department, the department of Computer Science. There, I also gathered a small group of people around me who share my passion for interdisciplinary research. I extend my gratitude to the management team of the Computer Science department and the Faculty of Exact Sciences, as well as the board of VU University, who have given me the opportunity to work in this hybrid environment.

This is also the moment to thank a number of people individually. The philosopher Michael Oakeshott once remarked that it takes three generations to make a career (Brooks, 2015). The skills that you need to succeed as a teacher — verbal fluency, empathy, but also endurance — arise in great-grandparents, are amplified by grandparents, and are then further passed down. In my case, at the end of these chains, are my parents. I want to thank them for everything they handed on to me. I can only hope to be the kind of parent to my children that they have been, and still are, to me.

In an academic sense, I have two fathers. The first of these is Kees van Hee, who was my first supervisor during my PhD studies, but also my manager when I worked as a management consultant for Bakkenist and Deloitte. To me, he is the closest approximation of a contemporary, universal man. He is foremost a researcher, a mathematician, and he was already a computer scientist before the term existed. But I also admire his business acumen as a manager, salesman and entrepreneur and, in particular, his social skills – if only I could tell a joke like he can, I would tell you one right now.

My second academic father is Wil van der Aalst, my second PhD supervisor and nowadays my close colleague in Eindhoven, where I am still working part-time in his group. He is simply incomparable as a computer scientist. The things I learned from him are numerous, but unfortunately the things I cannot seem to learn from him are more numerous still. He is a great source of inspiration to me and I cherish each of the sessions I spend with him, for example when we talk with our PhD students.

There are other colleagues whom I like to thank, first and foremost because working with them is such a joy. In fact, I believe that one of the greatest benefits of being a researcher is that, to a very large extent, you can select the people with whom you cooperate. In which other job does it feel so natural to become friends with the people you work with? So, thank you, Jan Mendling and Jan Recker, for your friendship and the many things you taught me about doing good research. Thanks to Marlon Dumas and Marcello La Rosa for teaming up to describe the fundamentals. I am also grateful to Remco Dijkman, Arthur ter Hofstede, Manfred Reichert, Irene Vanderfeesten, Eric Verbeek, and Barbara Weber for too many things to mention. It makes me glad that many of you could join this ceremony today.

My final words of appreciation go to my wife, Maddy, and my children, Timon and Mayu. To me, they are the Alpha and the Omega. I hope that we will keep on exploring this wonderful world together, for a long time to come.

Ik heb gezegd.

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