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RESEARCH NOTES

Researching "Grand Challenges"

A "Grand Challenge"

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Abstract Attempts have been made to identify the grand challenges (GC) in quite different disciplines including Computer Science. These major problems should be solved within one or two generations and the solution would have great societal and economic impact. GCs are to be distinguished from the improvement of methods where the basic problem has already been solved ("emerging fields"). Among other purposes, a common understanding of GCs within a community helps to focus efforts and resources and to create a climate of competition. With our study we try to gain an impression whether a certain consensus is within reach in Business and Information Systems Engineering (BISE; Wirtschaftsinformatik, WI) in the German speaking area. We used a multi-staged opinion survey among scientists and practitioners of WI and could establish an order of precedence concerning the most important GCs. At the top ranks the item "Control of systemic risks in global networks", followed by "Humanlike Information Systems in business context", "Determining the influences on the degree of automation und integration", "Influence of WI on the solution of semantic data processing problems", and "Overcoming of communication barriers in inter-company integration". We discuss drawbacks of the GC concept as well as attempts to improve the method. One main problem is to distinguish the terms "grand challenges" (GC), "emerging fields" (EF), and "new research goals" (NR).

Keywords Grand challenges · Societal and economic benefits · Control of global networks · Humanlike IS · Degree of automation

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1 Introduction

In recent years many approaches have been made to identify or to define "grand challenges" (GC) in different, narrower or broader operating areas, including computer science.

The question arises whether such an approach can also be opportune for "Wirtschaftsinformatik" (WI; engl. Business and Information Systems Engineering, BISE). GCs cannot be "dictated" by higher authorities but should if possible be based on a broad consensus within the community.

In this paper we would like to "throw a stone into the water". The title of this paper suggests that our effort is a first, incomplete attempt.

2 The Nature of GCs

2.1 Definitions – Examples

In 1901/1902, David Hilbert published 23 unsolved mathematical problems. In the history of science this is often regarded as the first list of GCs. This list had an extraordinary influence by inciting generations of researchers.

The term GC was re-introduced in the U.S. in the 1960s and especially in the 1980s: Among others it was supposed

to push high-performance computing, partly as an answer to Japan's 10-years-project "Fifth Generation Computers" (National Science Foundation 2011).

Some popular illustrations that serve to explain the nature of GCs are

1. John F. Kennedy's call (1961) "before the end of this decade, a man will put his foot on the moon" (achieved in 1969).
2. The complete decoding and mapping of the human genome (several research initiatives had been triggered in the 1980s; the challenge was considered as passed in 2003).
3. Proof of the Higgs particle (achieved in 2012 with a very high probability).

Table 1 shows a summary of some main characteristics of GCs (see also Eder 2009, pp. 33–34).

2.2 Delimitations

As a demarcation line we mainly use the following questions:

(a) between new research fields (NR) and emerging fields (EF):
Is there already a breakthrough in the basics that proves the feasibility (→ EF)?

(b) between EF and GC:
Is there already a breakthrough in the basics that proves the feasibility (→ EF)?
Is the goal new (→ GC)?

A pure utopia is no GC. A GC is not meant to push an already initiated development without a real basic innovation. A simple transfer of a technology into a new field of application is also not considered as a GC. This is often called an "emerging field" (EF), and it is not trivial to distinguish it from a GC. Therefore, it may be hard to decide whether the basic problem is solved and the challenge is "only" to refine the solution and transfer it to new fields of application (EF), or whether we need a change of paradigm or a completely new breakthrough.

Table 1 Characteristics of GCs

1. It has to be a fundamental problem
2. One should be able to solve the problem within one or two generations
3. The proof of the contrary must not already be adduced (e.g., the impossibility to determine the biggest prime number)
4. It usually requires big trans- and interdisciplinary efforts
5. Broad fields of application with considerable social and economic relevance must be in view
6. Scenarios have to be formulated which are easy to communicate (in order to persuade potential sponsors)
7. In the first instance it is sufficient to specify the challenge, not yet the solution

The BISE journal organized a special issue "Emerging Research Areas in Business and Information Systems Engineering" (No. 1/2014) where the authors were asked which new fields of research (NR) might be very important. The contents of the articles show that most authors interpreted the "call for paper" in a way that addressed scientific research, not so much R&D in non-academic institutions. However, with GCs the solution is most important, regardless of whether the method to reach it is scientific research or by continuous improvement, by progress on the learning curve or by "trial-and-error-experiments" in firms or government. It would be hard or even impossible to assign the success of the Apollo project to research in laboratories, experiments of rocket engineers, programmers, project controllers, or the physical and mental fitness of the crew, but the challenge was met. Of course, if academic research is successful, it can alleviate new solutions, thus there are relations to GC as well as to EF.

It is also important to stress the difference to initiatives that are just to enforce already existing research topics and often involve the foundation or reorganization of institutions and political processes, but in this connection sometimes also use the obviously attractive term "grand challenges". One example for this was the 7th Framework for Research and Technological Development of the EU, also known as the Lisbon 2020 strategy. Wording such as "strengthening", "frontier", "research", "excellence and well-networked knowledge institutions", "the creation and maintenance of world class infrastructures" were characteristic for this political plan (Chuberre and Liolis 2010).

Some further problems of distinguishing between GCs and similar categories are mentioned in Sect. 3.1.3.

2.3 The Purpose of GC Initiatives

With the efforts to identify GCs, various goals can be addressed:

1. Creation of an "attention focus" for leaders in politics, public administration, business, universities, research.
2. Stronger "welding" of experts within a discipline and cooperation across disciplines.
3. Motivation of highly talented and leading experts to adopt a special challenge or even "arouse … enthusiasm" (McGettrick et al. 2005).
4. Suggestions for (young) scientists in search for useful objects of research.
5. Creation of a climate of competition ("race to reach the summit first").
6. Motivation of potential sponsors.

2.4 Rough Overview of GC Approaches in Different Disciplines

Selected results of an inquiry into GC initiatives of different disciplines can be found in Mertens and Barbian (2013, pp. 7–14) and Becker et al. (in this issue).

2.5 The Special Approach of the National Academy of Engineering

An interesting version is a GC initiative of the National Academy of Engineering in Washington. This association has sent its members a questionnaire asking for the 20 greatest engineering achievements of the 20th century and for the engineering grand challenges for the next 100 years (Table 2). This survey is part of the "war for talents". The message is "Look how engineers have contributed to the benefit of mankind and what still has to be done – join us!". It especially addresses young people before their choice of a profession.

Table 2 Greatest achievements and grand challenges of engineering (National Academies 2008)

Greatest engineering achievements of the 20th century	Engineering grand challenges
1. Electrification	1. Make solar energy economical
2. Automobile	2. Provide energy from fusion
3. Airplane	3. Provide access to clean water
4. Water supply and distribution	4. Reverse-engineer the brain
5. Electronics	5. Advance personalized learning
6. Radio & television	6. Develop carbon sequestration methods
7. Agricultural mechanization	7. Engineer the tools of scientific discovery
8. Computers	8. Restore and improve urban infrastructure
9. Telephone	9. Advance health informatics
10. Air-conditioning and refrigeration	10. Prevent nuclear terror
11. Highways	11. Engineer better medicines
12. Spacecraft	12. Enhance virtual reality
13. Internet	13. Manage the nitrogen cycle
14. Imaging	14. Secure cyberspace
15. Household appliances	
16. Health technologies	
17. Petrochemical technologies	
18. Laser and fiber optics	
19. Nuclear technologies	
20. High-performance material	

The listed positions on the right side do not fulfill all definitions of GC according to Sect. 2.1 as they partly merely mean the further development of known procedures and technologies

3 GC of WI

3.1 Own Survey

3.1.1 Procedure – Interviewed Persons

With our survey we tried to give examples what GCs of WI might look like. We started with an intensive literature study including an internet search. Moreover, we engaged in a couple of informal discussions (see Fig. 1).

In addition to the mentioned collection of GCs from other disciplines we formulated first proposals for GCs of WI. Altogether 13 GCs were worked out which we sent to 16 professors of WI. Moreover, in a kind of pre-test in September 2012, we had the opportunity to discuss this preliminary set with 16 MBA students at the University of Würzburg. Furthermore we debated the questionnaire with 17 board members of committees at the GI – Gesellschaft für Informatik (German Informatics Society).

After this first interview round we developed a questionnaire. We put the 13 original GCs into a sequence by weighting. We also generated 10 GCs from the pre-test so that we came out with 23 "candidates" for GCs (see Table 3). Additionally the people in our sample had the opportunity to formulate an own suggestion ("free response").

We sent the questionnaire to 110 specialists of WI as shown in Fig. 2. Together with the subjects of the pre-test, 138 respondents were involved in this investigation. When there were doubts with the interpretation of the free

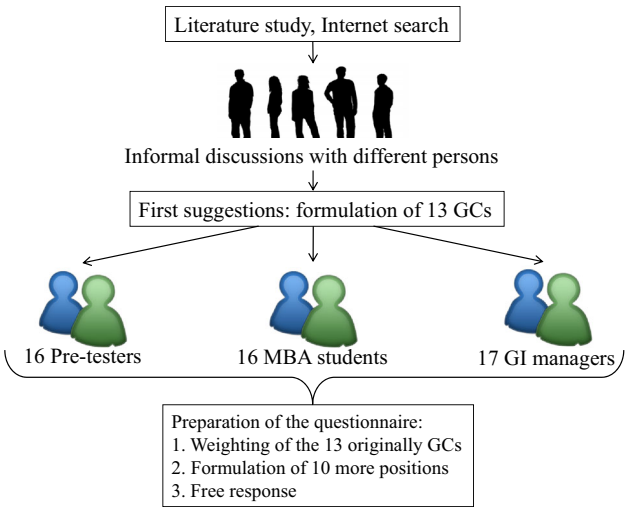

Fig. 1 Procedure for the preparation of the questionnaire

Table 3 Questionnaire "GC of WI" (explanations are shortened) and the ranking according to the number of mentionings

Order	Challenge	Explanation/remark	Weighted number of mentions	Delimitation
1	Control[a] of systemic risks in global networks	Concerns the need of competent advice for decision-makers (protection of nodes such as banks, suppliers, design of network topologies, support of lawsuits, legislative amendments), as well as avoiding the loss of control in automatic financial transactions	215	GC
2	Humanlike Information Systems in business context	Forecasts in Computer Science show that access to IT should be more intuitive, which means that it should be adapted to natural human behavior. One design goal is that growing segments of the population, e.g., the elderly, must be able to clear the hurdles	196	GC
3	Determining the influences on the degree of automation und integration	Automation policies do not only affect the shaping of business institutions and models but also the product policy and product design (e.g., degree of automatically acting on-board electronics in vehicles). Scheduling systems are heavily affected (using exact and heuristic algorithms; automatically designed, started and evaluated simulation runs; various types of artificial intelligence). Different groups select different solutions (e.g., Boeing others than Airbus). A large number of factors, influences, and interdependencies have to be taken into consideration	194	NR
4	Influence of WI on the solution of semantic data processing problems	There is a general trend to more semantic information processing, especially in computer science. The new possibilities are beneficial for business purposes. An example is "sense-making of big data", e.g., for predictive analytics	192	NR
5	Overcoming communication barriers in inter-company integration	Humans are able to communicate in almost every country, e.g., by means of "bad English". IT systems should be able do so, too. This means that a system B would not only understand a request by system A but perform the task. A solution of this GC would allow to increase the automation of global systems without a proliferating (international) bureaucracy for standardization. Prerequisites are among others industry-specific thesauri, semantic nets, and ontologies	191	GC
6	A general broadening of perspective into additional neighbor disciplines, systematic approach in interdisciplinary work	- Social sciences - Neurosciences, Psychology - Healthcare - Ecology - Energy supply	185	EF
7	Standardizing the human–computer interaction in economic sectors and industries	We have a conflict of objectives between the competition of IT firms developing the best ideas for Human–Computer Interaction (HCI) (e.g., log-in dialog, multi-factor authentication, sensor technology, knowledge identification procedures) on the one hand, and the ambition of the users (e.g., clients of banks, people who buy at vendor machines or in the internet) to keep time and effort during the HCI at a minimum level on the other	173	GC

Table 3 continued

Order	Challenge	Explanation/remark	Weighted number of mentions	Delimitation
8	Assistant systems to customize the parameters of Decision Support Systems (DSS) and to interpret the results of big and sophisticated models	Recent developments such as in-memory-computing make it possible to calculate DSS very fast and with reasonable costs, especially simulation models in the broadest sense (e.g., for forecasting and risk assessment). The bottleneck will then increasingly be the rapid configuration of the parameters ("entry system") and a reliable interpretation, personalization, and visualization of the results ("exit system"). Assistant systems are a step on the way to full automation	172	GC
9	IS for relative laymen, especially members of supervisory boards	Computer Science and WI have caused gigantic complexity with global networks of the economic and business systems. That is why there are malfunctions, sometimes leading to breakdown. Therefore WI has to propose better information systems for supervisory boards including a personalization of the reports to laymen among the members. To prevent fraud, the IT systems might send early warning messages to the board's members without intervention by top management	165	GC
10	Contribution of WI to the competitiveness of economies respectively nations in the global competition	There is a danger that a country might invest much money in science and research, but due to a questionable policy of international knowledge transfer the profit could be harvested by a competing country (Samuelson 2004). In the long run this transfer would impede the allocation of resources for research. This problem is increasing in connection with a "megatrend" towards tight integration of R&D, production, logistics and IT	164	EF
11	Management of hybrid service bundles	Examples: bundles offered by automotive industry, mobility service providers, gasoline stations that offer quite different forms of energy, providers of digital networks, or producers of pharmaceuticals	163	EF
12	Personalization of instruction and training in business contexts, real-time instruction	With growing automation, jobs for people with average qualifications, e.g., on the assembly line, disappear. On the other hand jobs requiring very special knowledge, for example to teach-in robots or software agents, will arise. Technical progress such as "cyber-physical systems" or "Industry 4.0" entails that the competencies needed for the new jobs might change in short rhythms. Therefore expensive training courses for medium-sized and large groups of workers do not make sense. Instead, it is probable that new forms of computer-assisted and web-based teaching and training will gain importance. An example are nanodegrees (see Renner 2014). Contributions of WI are: Collaborative learning by employees working for different firms, learning in social networks, using knowledge discovery and data mining during the learning process, recommender systems using pattern recognition, learner models, offering help (in real-time) when an employee runs into difficulties during a task	163	GC
13	Adaptability to turbulences	We learn more and more to thoroughly plan and develop complex IT systems. However, we face exceeding difficulties when conditions change during the productive mode	162	GC

Table 3 continued

Order	Challenge	Explanation/remark	Weighted number of mentions	Delimitation
14	Use of the enormously improved price-performance ratio for economic or information system purposes	Algorithms and application systems, especially for scheduling and control that use huge computing capacity, become affordable as soon as the time needed to run them is dramatically reduced, e.g., by still more parallel processing, new hardware architectures, and particularly by in-memory simulation	161	EF
15	Asymmetric data distribution	Big global corporations that collect and use personal data may violate national and international law so that governments cannot protect their citizens	160	NR
16	Contribution of WI to additive fabrication (3D printing)	Presumably additive fabrication will not only educe completely new technologies of production but new systems for Material Requirements Planning (MRP I and II) and for logistics. Elements of real-time scheduling and control, cloud computing and apps must be integrated	160	GC
17	Contributions of WI within the border area of computer science, medicine/care, and health care institutions	Demand pull (especially the unfavorable demography in the German speaking countries) as well as technology push, such as rapid progress of IS in medicine, imply the risk that organizational problems and inadequate business models might prevent appropriate integrated solutions	159	GC
18	Implementation of WI basics at the secondary school level	It is paramount to modify the content of teaching WI with considerable far-sightedness. The goal must be to prepare the next generation of pupils to work in an environment full of automatons. Presently young people in search of a profession have doubts about what WI really means	156	GC
19	Integrated personal documents	There is a dangerous development or even an inflation of non-harmonized personal documents being equipped with chips or biometric features. At the interface between application systems and people in their role as citizens, customers, employees, patients etc. there are completely different login procedures. One GC is a standardized multifunctional document with a robust but secure interface	156	GC
20	Future of IT firms in the German speaking area	Which new business models are appropriate regarding the hardware-software combinations with rapidly improved price-performance ratio and ubiquitous availability (commoditization)? Is it worthwhile to create a special strategy or even a culture named "Software made in Germany (or Austria or Switzerland)" characterized by high quality and reliability from the start on the market, and by long time spans between the releases?	156	GC
21	Investigations for effectiveness/efficiency of flexible data protection	During the discussions of privacy often the fears of special groups or single persons dominate. This makes it difficult to find solutions which are reasonable from an economic point of view. In the long run, irrational concepts could cause drawbacks for the society	150	GC
22	More focus on business IT from the point of view of the customers and consumers (consumerization)	Usage of IT systems by consumers including the knowledge available in electronic channels, e.g., concerning consumer goods. The gap between the skills and preferences of "nerds" and those of the "average users" and the gap between the goals of producers, service providers, and consumers must be bridged	148	EF

Table 3 continued

Order	Challenge	Explanation/remark	Weighted number of mentions	Delimitation
23	Automatic monitoring of the positive and negative impact of IT systems after implementation	Examples are: Could the capital lockup be reduced by an MRP I system? Is a parameter for the calculation of safety stocks too high? Has the average duration of customer relationship increased after the implementation of a CRM package? Are the active debts higher than before the implementation of a new bookkeeping system, and – if so – which types of customers are involved?	145	GC

[a] Originally the word „identification" instead of „control" was used in the questionnaire, see Sect. 3.1.2.2

responses or comments, we tried to clarify them via e-mail or by phone.

3.1.2 Results

3.1.2.1 Order of the Proposed "GC Candidates" The respondents were asked to express their preferences according to a mark system. We weighted the valuations as follows: "1" counting threefold, "2" counting twice, and "3" simple. The individual results of all questionnaires were summed up. The order that resulted is shown in Table 3. Here we have added a further column with the delimitations. It indicates whether the position might be assigned to the types EF ("emerging fields"), GC ("grand challenge"), or NR ("new research fields"). However, this allocation remains somewhat subjective or arbitrary.

3.1.2.2 Remarks on Selected Positions In this chapter, we select a couple of GCs from our project. Our didactic aim is to give an impression of the variety of challenges in terms of methods, algorithms, applications, and technologies. While we begin with GCs no. 1 and 2 of our ranking, the choice of the other GC is rather arbitrary.

Control of systemic risks in global networks: Principally one has to pay special attention to systemic nodes and edges. This is comparable to events and activities on the critical path of a project network receiving more advertence than the events and activities that are non-critical because they are on a path with time buffers. At the end of our study, the Gesellschaft für Informatik started a similar initiative. There our GC "Control of systemic risks in global networks" was ranked in the "top five", however, the name was modified to "control" instead of our original term "identification". In recent discussions, we were convinced that this might be more suitable.

Concerning worldwide supply chains and nets of physical goods (Supply Chain Management, SCM), the body of knowledge there seems to be more elaborated than in the finance area (especially interrelations of banks and insurance companies). An important statement is: "Examining and controlling risk propagation from the network and supply chain perspectives has become vital to overall network security." (Huang et al. 2008).

There are a lot of causes and remedies for disturbances in networks which cannot be discussed here. For more systematic lists see Singhal et al. (2011), Vitali et al. (2011), and Mertens and Barbian (2014).

Tasks where information systems may help are:

1. Control of the systemic nodes. This is extremely important since in big, especially global networks only a small portion of the nodes can be continuously and extensively protected.
2. Systematic collection of data and information from the data pools of different institutions in a central data warehouse (information sharing), and data fusion in a data warehouse. Knowledge extraction from this data warehouse.
3. Forecasting the date of a dysfunction. Here we have to consider collaborative planning, forecasting and replenishment in which different institutions participate (Mertens et al. 2012).
4. Forecasting the propagation and the effects of damaging one node, e.g., by predictive analytics.
5. If, as it is common in banking, psychological influences such as a bank run contribute to the problem, forecasts are very difficult. Ronald Bogaschewsky calls this "impact assessment of scenarios of scarceness". Here it would mean exploiting social networks to anticipate reversals of opinions, e.g., loss of confidence in the banking system which would make the danger of a bank run grow. Text mining might be one of the appropriate methods.
6. Quantifying the probable overall damage.

The indicators which are presently used, such as the size of a bank, global activities, and integration with other

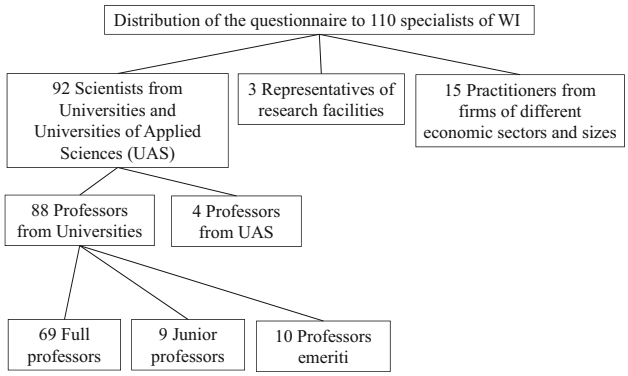

Fig. 2 Target groups of the survey (with number of addressees)

institutions, are rather general and preliminary: The ratios are static. E.g., in the report "Global systematically important insurers: Initial assessment methodology" of the International Association of Insurance Supervisors (July 2013), among others the following criteria are proposed: "Total revenues", "Revenues derived outside the home country", or "Number of countries" (in which an insurance group is operating) (IAIS 2013). However, a resilient control of systemic nodes can only succeed using dynamic analyses.

As far as we can see, a central class of methods are big simulation models with deferred feedback (System Dynamics).

Humanlike information systems in business context: This goal may be regarded as a sub-goal of full automation (Mertens 1995) or "total digitalization". Principally, high hurdles in Human–Computer Interaction (HCI) should be eliminated which inhibit people who heavily use those automated systems in their professional and private life, but are no specialists in computing. Gadatsch and Vaziri (2013) coined the interesting term "barrier-free information systems". A kind of 1–0- or yes–no-logic similar to a physical on–off-switch is not appropriate since in many situations it would lead to disapproval, loss of time, or even to cancelling an activity. As a result, people may abandon their attempts to use a ticket machine or an online banking system to pay a bill and look for a person to assist them. As long as full automation is not possible for a certain process, we have to aim at processes which are similar to the communication between a layman and a specialist, comparable to the report a patient gives his doctor.

The same is true for the communication between the computers of different firms or of machine tools, e.g., in the supply chain or in the Industry 4.0 concept. This is the GC "Overcoming of communication barriers in intercompany integration" (ranked no. 5 in our research). Elmar Sinz wrote: "Machines should communicate with each other like a man who is able to express himself in "bad English" in almost every country of the world."

Probably the challenge can be met by a new combination of well-known methods of automated decision-making systems in business. Examples are tools to handle stochastic data, dialogs in natural language where we have reached astonishing success (Berg 2013), fuzzy logic, artificial intelligence including knowledge-based systems and software agents (multi agent systems), the calculation of clusters, recommender systems, semantic information processing (see GC no. 4), and the extremely rapid simulation of alternatives.

To meet the GC, it would be necessary to modify basic results of Computer Science concerning thesauri, semantic nets and ontologies to obtain more industry-, function- or process-specific tools.

In the long run, the alternative would be a very detailed international standardization of protocols which is likely to be burdened with political conflicts ("war for standards").

Determining the influences on the degree of automation and integration: The optimal degree of automation is dependent on time and location. It is a function of the following parameters:

1. Availability of human resources (quality and quantity). This determines the costs of the resources and the working time. Supposed that the technology of automated railway control centers became sufficiently mature, then the Deutsche Bahn AG (German railway company) ought to give the Mainz main station high priority for an investment into the automated solution since Mainz is a systemic node in the European railway net (in 2013 there was a sudden scarcity of technical staff because of illness and vacations which lead to an almost 100 % breakdown of the control station) (Mertens and Barbian 2014).
2. State of automation and integration technology (costs and performance).
3. Knowledge of the general public when it comes to managing the IT systems.
4. Acceptance by society.

Generally in Germany we will see a trend towards higher degrees of automation and integration because of the unfavorable demography.

One participant in our research, a very experienced and formerly high ranking manager from a software company (he wants to remain anonymous), mentioned: "One GC is to search for low-tech approaches. Productivity and cost effectiveness must not necessarily be connected to high-tech."

The higher the degree of automation and integration, the more dangerous the propagation of errors and disturbances becomes. Models from biology, ecology, economics, epidemiology, and general systems theory should be analyzed whether they could be used for WI.

A very helpful approach is the DeptRank developed by the Institute of System Design of the ETH Zürich. It measures how much the crisis of one node would reduce the economic value of a net (Vitali et al. 2011; Battiston et al. 2012).

Standardizing the human-computer interaction in economic sectors and industries: Presently, if we are customers of several banks, insurance companies, shipping companies, bookkeeping firms, online shops, E-journals etc., we experience a competition for the best human-computer interface. At the end of the day, this may be an advantage in that the best ideas will win. However, people would proceed with higher speed, fewer mistakes, and less assistance by specialists if they had to learn only a small number of standardized procedures. Some of these trends to standardize are already visible with prevalent interfaces of, e.g., cash machines of banks.

Assistant systems to customize the parameters of DSS and to interpret the results of big and sophisticated models: The restrictions of mathematical optimization combined with the limited precision of the restrictions due to draggled data as well as "fuzzy" prescriptions for conflicts between goals (e.g., punctuality of shipping versus increased workload for the employees) impede the usage of exact systems of planning and control such as Advanced Planning Systems (APS) in many firms. Frédéric Thiesse worries that the present efforts to actively manage data quality might not help to improve the situation. This problem on the one hand and the growing relation between performance and price of the hardware on the other hand suggest the use of bigger and more realistic, but complicated heuristics and simulation models. The consequence would be a kind of unnatural decision process in business if several of those models can be computed during the session of a high ranking committee with varying suggestions and assumptions for the parameters while the configuration of the modified model and the interpretation of the computed results takes weeks.

On the input side, the challenge is to determine the parameters (semi)automatically. This means, e.g., that the weights for variables in mixed objective functions and the definition of degrees of freedom of the restrictions including tolerances follow something like fuzzy logic. On the output side, the so-called data cemeteries generated by the computer must be interpreted. We might cast a glance at the algorithms of OR, intelligent software agents, expert systems, techniques of automatic visualization, e.g., for workload profiles or the results of methods to level capacity usage functions, calculations of probability ranges concerning financial risks and also the knowledge transfer between specialists in a network.

The Wassermann AG (2009), which is specialized in decision support and planning systems in the logistics industry and in SCM, has a product called White Box APS. In this context they are developing appropriate man-machine dialogues which give an impression what this new generation of systems might look like (Dickersbach 2010).

Besides systems on the input and output side of big computational models, we also recognize the need to facilitate the information retrieval tasks in "big data" by automatic assistants.

IS for relative laymen, especially members of supervisory boards: Existing MIS, especially those in controlling and risk management, mostly follow the pattern that those to be surveyed, e.g., CEOs or CFOs, send reports to the supervisory boards in which they comment on the facts and figures, thus reflecting their personal impressions or goals. It is important to keep in mind that the members of these committees have different roles and/or heterogeneous competencies; so they are "relative laymen" in relation to business or technological details. Important examples are politicians on boards surveying gigantic projects for the infrastructure of a country (such as airports) or government-owned banks. This leads to the problem that dangerous facts are trivialized, or that bad news is postponed. If more and more facts which are the basis of such reports are collected by IT systems, e.g., a Project Management System (PMS), it becomes reasonable to let the systems write the reports and forward them automatically and in a personalized version to the supervisors (Mertens 2014). Antetypes are the red and the black box of airplanes which, after an accident, are sent to a control board. The flight captain or managers of the airline have no chance to modify the report because it is sealed. This method implies techniques of WI such as the automatic detection of interesting and important facts by data or text mining, personalization or orientation to roles and responsibilities of the recipients. After having read these reports, the surveyors may request the top management of the company or of the project to provide special reports and/or ask questions about additional facts, e.g., concerning risks or delays in the critical path.

More focus on business IT from the point of view of the customers and consumers (consumerization): Hubert Österle put it bluntly: "Business IT is focused too much on itself or the own company, respectively, and considers the user only as a customer to whom one should sell as much as possible and for that purpose use the internet data." The GC proposed by Österle (shortened: "Consumerization in IS") puts the consumer in the center of attention, and the enterprise has to offer him/her digital services for all situations in life. This challenge is related to GC no. 20 ("Future of IT firms in the German speaking area") (Österle and Senger 2011).

The products of the software industry in the German speaking countries might, in the long run, not follow the

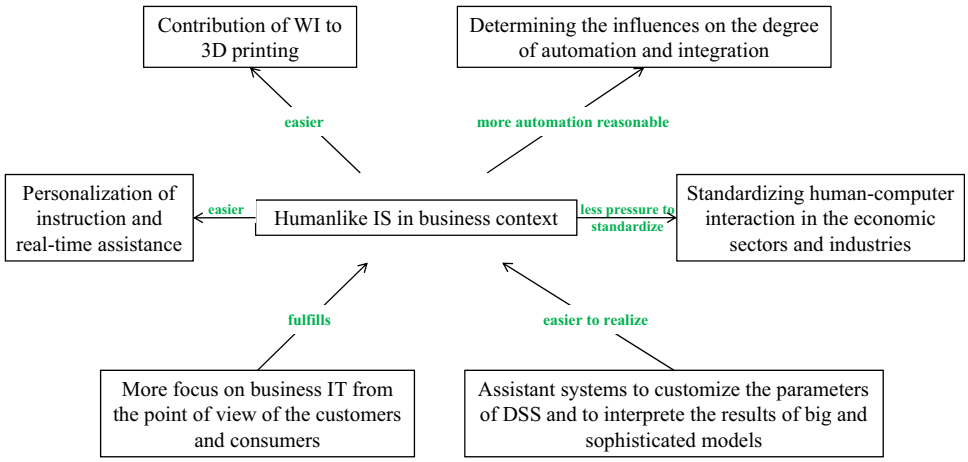

Fig. 3 Example for the network of GCs

strategy "We test something new and try to be on the market some months before our competitors. If our products have a lot of bugs at the moment when we begin to sell them, we will simply improve them by the next release". But consider the additional costs, workload, and stress for the customers who are "no-nerds" for managing all these new releases and updates.

Automatic monitoring of the positive and negative impact of IT systems after implementation: Rainer Thome relates this proposal to a research project and to some tests (Thome and Schinzer 2005). We might see it as the automation of a task within IT controlling. Often IT systems are regarded as successful if they perform well from a *technical* point of view and are accepted by the users. On the other hand, it has to be kept in mind that, e.g., after the implementation of a new MRP I system, the average capital commitment or the supply time increases. Due to many influencing factors it is no trivial task to control such effects. This is especially true if one wants to disaggregate, for example, to analyze which parts, customers, shipping ways etc., are responsible for the deviations. It is obviously an important aim to survey the automatic functions and processes by an automatic system and to communicate the results in an appropriate way (e.g., by an early warning system). An antecedent are the monitoring systems of airplanes or nuclear power plants.

3.1.2.3 Free Answers Methodology: We received 79 "free answers" that were not listed in the questionnaire. They were handled as follows (number of entries in brackets):

1. Allocation of GCs to positions in our opinion survey if there were close relations (43).
2. From the remaining 36 proposals, which were "new" GCs, we attributed 20 GCs to new groups.
3. We allocated the remaining 16 to a category "Selected opinions" as it was not possible to form a cluster. Some of these positions are described separately in our report (Mertens and Barbian 2013).

A *selected opinion: Flexibility – short-term reaction to disturbances*: Leena Suhl asserts that presently planning systems are not able to manage short-term disturbances and rescheduling.

There are three principal approaches:

1. Pre-planned alternatives are computed and stored within computer-based systems to plan the resources of an enterprise (e.g., APS, PPS- or PM-systems) for events with a probability higher than a threshold.
2. The alternative solutions are not calculated in advance and then kept in memory, but automatically elaborated as rapidly as possible, regarding the special situation. Maybe it is possible to profit from progress with recent concepts of software engineering such as Scrum.
3. Within the space of constraints the system does not search for the optimal solution but for a robust one.

3.1.2.4 Selected Relations Between GCs Several GCs are interdependent because finding a solution of one challenge alleviates the solution of other problems. One could develop networks and use them to set priorities. Preference would be given to efforts promising results which promote research on as many other problems as possible. In the example (Fig. 3), we tried to represent the relations in a kind of minor semantic network.

3.1.2.5 General Conclusions If we do not only consider the scores that the single proposals for GCs were attributed to, but try to take a look at the overall picture including the relations between the GCs and the suggestions beyond our questionnaire, we might resume as follows:

1. Considering that the "GC candidate" "Control of systemic risks in global networks" was "the winner", the participants seem to share the opinion that WI is responsible to contribute to identifying risks and help to reduce and control them. Franz Schober remarked: "Systems which precautionary assist management to handle natural and terrorist catastrophes". Walter Brenner writes: "One GC is "Cyberwar" defense. The security of critical infrastructure and the protection against attacks will be the third task of WI besides automation and innovation." Drastically Martin Wiener: "IT leads to illusions concerning control and reliability. Therefore we need IS for the management of crises and disasters." We might assume that future WI will become also a science of networks (Mertens and Barbian 2014).
2. Business information systems must become more humanlike. The buzzwords "digital society" or "digital business" may only refer to the "binary world within the computer" or to the chips and electronic circuits. Regarding the man-computer interface we have to consider that humans are not organized like a digital construct. That is why semantic IT plays an important role also in a business context.
3. There are special features in the German speaking area such as the basic concept of the welfare state or the demography and its consequences like the scarcity of skilled labor as well as the high proportion of elderly and/or handicapped people and immigrants. This particular constellation may involve that in WI the priorities have to be somewhat different from those in the discipline IS outside this area. Maybe we will need something like a cultural orientation of WI.

3.1.3 Critical Remarks on our Approach

Some people answering our questions, participants in discussions, e.g., after presentations, and reviewers made skeptical remarks:

1. Our multi-stage process to collect the estimations and opinions of members of the WI community is not free from subjective elements. In other words: A commission recruited of different specialists might lead to different results. The approach proposed in Sect. 3.1.4 could turn out to be the better alternative. There are also some remarkable findings when one compares the results of the study of Becker et al., presented in this copy of BISE, with ours
2. A further problem is that respondents are inclined to propose their own field of specialization as a candidate for the "honor" of being a GC. On the other hand, we had colleagues arguing that scientists or practitioners who did not find their own main project in the ranking of the GCs doubted the seriousness of the research method
3. The fulfillment of most GCs cannot be definitely measured. Whereas in other fields this kind of target line exists (e.g., total identification of the human genome), in WI we mostly do not have comparable events. Jan vom Brocke wrote: "Only few of our GCs accomplish the standards of natural sciences…. So we have to elaborate more precisely what the real nucleus of the GC is and by which research results it is fulfilled." Eckart Zwicker says: "Our proposals leave a wide range for interpretation, quite different from the landing on the moon." If one makes the exact definition of a target in terms of content and time as

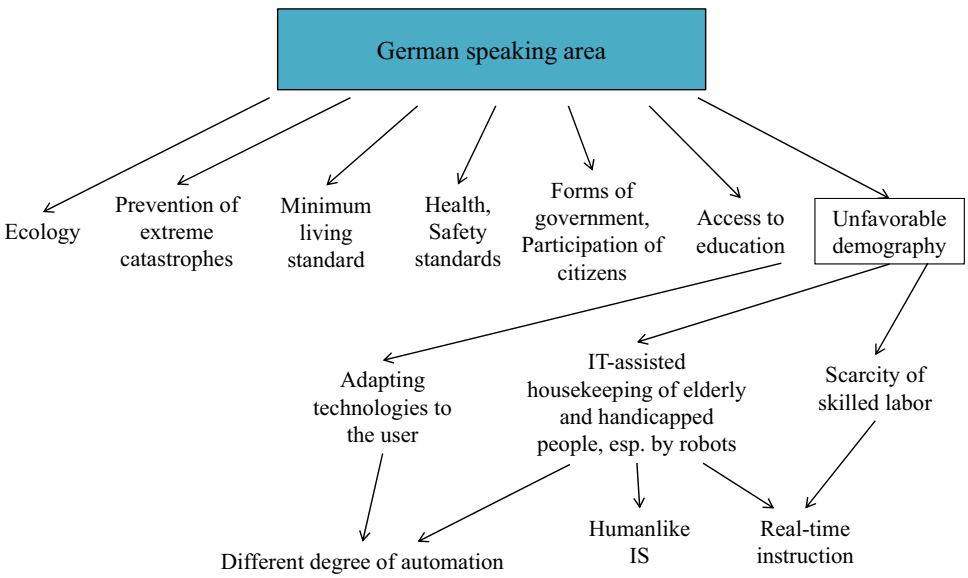

Fig. 4 Fundamental problems related to German speaking areas

a condition sine qua non, there would be no denying the fact: In WI there are almost no GCs. However, in many other disciplines it is also difficult to define an exact target line. Some examples prove that there are "fuzzy" criteria here, too (see also Sect. 2.1):

(a) First transplant of a heart by Barnard (1967): His first patient died 18 days after the operation. Whereas the surgeons were successful, the specialists of biomedical sciences did not succeed in suppressing the rejection of the foreign organ.
(b) Experimental identification of the Higgs bosom: The proof only reaches a level of significance of nearly 100 %.
(c) Realization of artificial intelligence proven by the computer's defeating a man in chess: Human opponent of which level of excellence?
(d) Foot on the moon: Why was it to be realized by the end of the sixties and not, e.g., by 1975? (Probably a later date would have meant less risk for the crew because of an advanced technical solution.)
(e) Even the question which of the 23 GCs in Hilbert's list are met is not yet answered unanimously.

4. Other critical remarks concern the different levels of aggregation (e.g., Thomas Hess and Benjamin Müller). Martin Bichler considers it as a main problem of GC research to find an "optimal level of aggregation". Werner Sinzig is worried: "Our collection is too detailed. After some aggregation the subjects develop more vehemence."

3.1.4 Proposal for the Next Course of Action

Several discussions during and after our project imply that the GCs for WI should be derived from fundamental goals or problems of humanity (Fig. 4). Vishal Sikka, Chief Technology Officer of SAP, is cited: "With HANA we can tackle the biggest problems of human society: Cancer, Alzheimer, hunger, wasting of resources." (Finsterbusch 2013) This approach is akin to the formulation of main goals and subgoals in enterprise planning, e.g., using the so-called Dupont Pyramid. In following this idea, we started by looking for a widely accepted list of these "supergoals", e.g., the Millennium Development Goals of the United Nations (2013a, b). Soon we became aware that a differentiation between economic or cultural areas or states is inevitable. For instance, the problem "unfavorable demography" has a very high significance in Germany but less so in France. Therefore we complemented "unfavorable demography" in Fig. 4 and detailed this entry in order to arrive at possible GCs of WI.

If one would prefer to deepen this approach, value driver trees might be worthwhile (Mertens and Meier 2009, p. 228).

3.1.5 Special Problems and Dangers of the GC Approach

Focusing a large percentage of the researchers of a field (see Sect. 2.3) should not go so far that creative mavericks, lateral thinkers, or geniuses feel daunted because they have no chance to access resources that are not in the budgets of a GC initiative. Just imagine what otherwise the fate of personalities such as Darwin, Feigenbaum, Kopernikus, Plattner, Turing, or Zuse might have been.

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