Knowledge Systems for Food

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Executive Summary. This text outlines the author's position underlying the presentation on the *Workshop on Converging Technologies for Food* on 20 December 2005 in Brussels. According to this position central tasks in the sector of food are: more reliable knowledge and its timely and truly useful communication to those who and when they need it. Building up knowledge and advice systems by harnessing mostly existing and to a lesser extent newly researched knowledge should therefore become a high priority. An aspect in these systems which should not be confused with simple databases is that they could (by Bayes' nets technology) complement the human weakness in dealing with uncertain knowledge abounding in the food domain. Concerning the generation of new knowledge important areas are (i) development of and experimentation with simulation systems in the domain of food and metabolism, (ii) CogSci research on what causes food preferences in humans, (iii) how people can be positively influenced and (iv) how knowledge can best be transferred to them. A similarly important issue is food control for consumer protection with technology. Altogether we plead for an environment and customer centered strategy in the research policies in this domain. The goal should be a substantial and scientifically underpinned overhaul of the national and European agro-systems in their local and global functioning.

1. General aspects of food

"The European agro-food industry is the largest manufacturing sector in Europe" (CIAA 2005). So food is an economic factor of greatest importance. At the same time food is of utmost importance for the health and well-being of the European population. Therefore there is a growing awareness that, in guiding the industry's evolution, a greater emphasis has to be laid on the consumer needs and preferences for safety, quality, convenience, diversity and food for health, an approach captured by the slogan "fork to farm". Especially the health promoting aspects of nutrition are standing out, not least from an economic point of view given the enormous societal and individual costs of lifestyle-related deseases. With this focus in mind we begin with a few general and well-known observations.

The selection of food, ie. our diet, has evolved from an evolutionary trial-and-error process which has lasted tens of thousands of years. This search process resulted in regional dietary traditions and cultures and may have resulted in a statistically rather optimal diet before industrialisation started a few hundred years ago.[1] We consider this assumption, termed the *evolution thesis*, of utmost importance in all considerations concerning the feed and food topic. The strategy for selecting the diet is carried out through instinctive and acquired preferences, ie. they are acquired in the childhood and may even be predisposed by genetic heritage. Today these preferences are superposed, transformed and alienated through a variety of influences including lifestyle habits, food processing and advertisement.

Biotechnology and Biochemistry have uncovered the details of many of the processes involved in the metabolism of the human body including the substances required to keep them

[1] By this statement we mean that the average diet of some regional inhabitant would on average be close to optimal for the individuals of this region.

going. Also we know quite well the substances contained in all kinds of food especially the carbohydrates, fats, proteins but also vitamines and numerous others. So one might be tempted to conclude that from this information the ideal diet for humans in general and individuals in particular could logically be deduced. This is indeed possible – to a certain limited degree. It is for this reason that an informed consumer today is able to feed him- or herself in a rather healthy way which is one of the reasons for a substantially increased life expectancy. There are two main provisions underlying the perspective of this statement.

First, while many details of the underlying processes and the substances and their properties are known as just stated, many further details still remain in the dark. This is simply because the extreme complexity of these processes is far beyond our scientific and technological capabilities. For instance, we know perhaps just a fifth of the bacteria active in the intestinal flora to mention just one out of innumerable open questions. In other words, the notion of an ideal diet for some individual is still an illusion and out of reach for decades to come; this is even true if one were to just restrict oneself to one single parameter such as the caloric value of the food.

A consequence of this insight is that the effects of any technological manipulation on food are similarly predictable to some degree but definitely unpredictable in all details. Let us refer to this problem as the *limited rationality problem*. Many public disputes about dietary strategies (eg. concerning the quantitative needs of vitamins or the "French paradox") are witnesses to this problem. For this reason I am personally skeptical concerning the feasibility of food which would be personalized in the way that sensors on the nanolevel measure certain parameters like cholesterol or sugar levels and transform this information functionally into a certain dietary prescription. Such sensors might be useful, of course, and might guide the contribution of certain substances to the diet; but, as pointed out, human metabolism is simply too complex to be fully controlled functionally by a few such parameters.

The second provision concerns the related *problem of consumer information*, ie. of correctly informing consumers especially under the aspects of the limited rationality problem. This problem has two main aspects. One is the *pedagogic* one which concerns how to get any such information across to the consumer against his or her prejudices and acquired habits and attitudes (in contrast to the deeply rooted instincts mentioned above), under the assumption that we continue to leave the choice of food fully to the consumer rather than to some technological functional device. The other one relates to the *imprecision* (or uncertainty) of any knowledge concerning the effects of nutrition due to the limited rationality problem and to how we could harness objectively existing knowledge. It also relates to the impossibility to collect all the relevant information about the food chain of a certain product and make it readily and intelligibly available to the consumer.

When we talk of an ideal diet we instinctively have "natural" food in mind. But what does "natural" mean in this context? Humankind has affected nature to such an extent that there is no truly natural food in the strict sense available any more. All kinds of natural or artificial substances have been introduced into the food chain, let alone such technologies as the use of fire to roast a beefsteak, the baking of bread, or the brewing of beer. Nevertheless a distinction can still be made between changes in the diet which occurred over a period of centuries and the dramatic changes that are under way in the last few decades or years through the accelerating technological evolution. These changes are affecting the environment (air, soil, water), which is the basis of the food chain, are leading to additives in food of animals and humans (eg. functional food, nutriceuticals etc.), concern the substances in the food themselves which are modified for conservational and other purposes (eg. GMOs) but also contaminants which happen to enter the food chain. Given the technological progress one might even consider the possibility that the diet is not only logically deduced but even artificially designed and produced and functionally selected in response to sensory data as already mentioned. The term "individualized food", as for instance envisioned by food specialist Hannelore Daniel, is pointing into such a direction. We are concerned with these kinds of changes here and refer to *natural* food if it is *not* really affected by such deep changes.

Also note the distinction between such biotechnological manipulations of food and the development of pharmacological substances developed for medical purposes. While the latter typically are needed for people already suffering from some desease causing pain or other negative effects on the quality of life, there is, at least in the industrial world, no similar need in the case of food for healthy people. Here the changes often are rather rooted in motivations such as convenience, higher profits (eg. of the chemical industry), optimisation of quantitative production results and hence profits again, compensation for inadequate logistic organisation, lack of necessary care, and so forth. (Improving crops in areas of the developing world is quite a different matter which would need a separate discussion though, left out here for lack of space and time.)

The distinction between food for health and medication can nomore be made sharply since the functional selection of food with health promoting attributes is an active research area and a billion Euro market. Nutrigenomics (nutritional genomics) has the goal in mind to influence the delicate balance between health and desease by adapting the diet to an individual's genetic makeup and this way achieve a personized nutrition (http://nutrigenomics.ucdavis.edu/). The European Nutrigenomics Organisation (NuGO) funded by the European Commission links genomics, nutrition and health research (http://www.nugo.org/everyone). The combination of food with medication has led to the development of nutriceuticals (which is in the centre of interest of the pharma-industry). (Similarly the marriage between cosmetics and pharmaceuticals has led to so-called cosmeceuticals.)

Under all these aspects we consider, as a first strategy for normal circumstances, food to be best for our health if it is grown and feeded as natural as possible (recall the evolution thesis); or to put it in another way, we should better feed ourselves with fresh products from the regional farmer rather than with fast food from McDonalds or with processed products in packages from some Lidl supermarket ("convenience food"). Further, due to the limited rationality problem, the overall diet selection must involve the wisdom accumulated over thousands of years in the various (local and national) cultures of humankind. Regions like the Japanese Island Okinawa (boasting the highest percentage of centenarians wordwide) and their food habits have plenty more wisdom in store than could be researched in a few decades in EU-funded projects. Regarding the dietary regime this kind of wisdom should only cautiously and responsibly be complemented by scientific insight (eg. from nutrigenomics) in order to eventually achieve a substantial reduction of the enormous costs of lifestyle-related deseases. For a sustainable food industry factors such as transportation costs (not least in terms of the involved environmental costs) are also of importance. For achieving these two fundamental goals – preference for regional natural food (this way also reducing the amount of transportation) and activation of accumulated wisdom – technology could be of great help. How this might be achieved will be explained in the following.

Thereby we have to keep in mind that "policies and policy developments will continue to be the main drivers of EU agri-food industries and rural regional economies" (Downey, private communication; see also Downey 2005). Goals of such policies must be profitability at farm level, competitiveness in the global bio-economy, environmental and social sustainability of Europe's regions, food security both in terms of supply and safety, and agri-food systems that are capable of coping with climate change (Downey 2005).

2. Knowledge systems and their potential for the food domain

Since a lot of the problems concerning the food chain have to do with usability and availability of knowledge from various (distributed) sources we first point to the technology of *knowledge systems* – also known as knowledge-based systems – and their specialization to *advice* systems. This technology was en vogue already a quarter of a century ago under the term of "expert systems", ie. systems which contain the knowledge of experts in a certain domain and are able to reason about and use this knowledge like an expert would do. Note that an expert has not only a memory for facts about his or her domain of expertise, but is able to combine different facts to apply the result of this combination to a given situation. This additional capability of combining knowledge (ie. reasoning) is what distinguishes knowledge systems (or knowledge bases) from databases which just store data for targeted retrieval.

Because of several technical limitations experienced at that time and of strategical mistakes the term of knowledge systems has partially fallen into oblivion. Through the worldwide web "knowledge management" (ie. the technology which for instance enables Google to do its job in such an impressively efficient way) has become a new trendy term which however refers to a simpler technology than that of knowledge systems as it mainly concerns the (probabilistically enhanced) management of syntactic pieces of text while knowledge systems involve semantics and inference (ie. reasoning, including learning etc.). Knowledge systems experience a revival now under the term "semantic web" which characterizes the functionality of the future worldwide web and a future "Google" system (Hendler 2005). Big and successful projects in the US like CYC or Halo focussing on knowledge systems add to the renewed glamour. Also the technique of knowledge acquisition has been refined considerably since the early days of expert systems. Powerful systems supporting the knowledge acquisition process are now available on the market. Particularly promising are acquisition systems which extract knowledge from natural language text. But how to deal in such knowledge systems with the imprecision in the causal relationships underlying the kind of knowledge involved in food?

The book (Pearl 2000) discusses the example of the causal relationship between smoking and lung cancer. This relationship is imprecise in the sense that the amount of cigarettes smoked per day does not determine the development of lung cancer in a precise way but only the *likelihood* of developing the desease. But it is this likelihood which can be demonstrated beyond the slightest doubts by means of the Artificial Intelligence (AI) technique of Bayes' nets on the basis of the available evidence even in rather complex reasoning chains. Note that, despite the availability of a lot of evidence in our example, the causal relationship between smoking and lung cancer was long denied by the tobacco industry simply because the chain of reasoning based on this evidence was too complex to be "evident". Bayes' nets provide a formal mechanism to establish precise reasoning chains in the presence of imprecise information whereby the imprecision is expressed in terms of probability measures.[1] They have successfully been applied in a great variety of areas such as in operating systems for PCs and in psychology to mention just two rather different ones.

Smoking "feeds" the body with substances and therefore can well be seen as a sort of "food". Therefore this example shows that the health effects of certain types of food can be established in a precise way by collecting evidence and applying the Bayes' nets technique to compute the likelihood of the effects of such food even though imprecise knowledge is involved. The same applies to knowledge about the right treatment of soil, crops, cattle, and so forth. So knowledge systems including the Bayes' nets technique from AI/CogSci (or Intellectics) have the potential to contribute to the food technology by clarifying potential hazards and by providing advice in a comprehensive, objective and unbiased way.

Let us start with growing crops as an example. Under ideal conditions crops grow naturally without fertilizers and have the ability to partially defend themselves against bugs and deseases. But how to find out which crops fit best to a given condition and how to improve such a condition even further without interferring technologically with the natural life processes of the plants in the first place? The answer is: mainly by activating the massive knowledge accumulated over the centuries (including through recent research) by collecting it in knowledge systems and by extending this knowledge by means of learning techniques applied to data collections. The idea is that a farmer (usually supported by intermediaries) could inquire such a system with the available evidence about the condition of the soil, about the macro and micro climate, and about the wild plants growing in the environment nearby for getting advice from the system concerning the crop selection and its treatment. Similarly, and even more complicated, with lifestock production.

Yes, the idea is new in the sense that it is not yet realized anywhere in the food domain. Of course there are already information channels through which knowledge of this kind is distributed. For instance there are rich web pages containing an abundance of information (eg. http://web.aces.uiuc.edu/aim/morrill/aces/). But a farmer typically has not the time and the training to filter out from all this knowledge the one needed for his or her particular situation even if s/he finds the (rare) opportunity and capability to access the sources of knowledge of this kind. The standard way of dealing with the situation is to look around and copy what others do in similar situations in the vicinity. In the best of all realistic cases the farmer is involved in a regional expert or discussion group under some extension scheme coordinated by some knowledgeable expert who keeps an intensive communication link with scientific experts. More often than not a knowledgeable and unbiased expert, let alone a top-level expert with an expertise comparable to one stored in a suitably compiled knowledge system, is however not available who could suggest a wise decision. But even if s/he were around, could one trust him/her?

The report (Downey 2005, p.18) therefore states "that the effective transfer and uptake of the existing reservoir of knowledge has become a more crucial determinant of the future competitiveness and sustainability of Europe's agri-food industries and rural economies than the generation of new research knowledge." Similarly, the report (EC 2004) speaks of a "regionally based demand-driven approach to research and innovation" (cited in Downey 2005, p.22). Knowledge systems could be a terrific help in meeting these challenges. Such a system could combine all the knowledge available, ie. also that of the best experts worldwide, in an unbiased way; it could be inquired by the farmer or some intermediary in a specific way so as to offer advice just for the situation and problem at hand on the basis of the accumulated top-level expertise. The system could accommodate a variety of users by adapting its responses tailor-made to the level of expertise of the particular user, a technique well-familiar from a variety of user interfaces.

There have been extensive CogSci studies of human reasoning with imprecise knowledge. The result of these studies is the insight that humans are especially weak in coping with imprecision in their reasoning. This is probably due to the fact that human reasoning tends to be case-oriented (and model building). Just recall how stupidly (occasionally disguised in the form of a joke) humans often argue, eg. in the context of bad habits like smoking: "If I smoke I will die, but if I don't smoke I will die either" or "his father smoked like a chimney but became 95". Probabilistic knowledge, like the one describing the causal relationship between smoking and lung cancer, in contrast requires heavy and sophisticated computation. This is where Bayes' nets excel which provide the computational techniques to compute the probabilistic measures (degrees of belief) for the resulting conclusions in reasoning chains.

Now people could doubt whether it might be so preferable after all to apply probabilistic rules in the reasoning to arrive at realistic decisions. In response to such doubts there is a mathematical result suggesting that such arguments would definitely be wrong. Namely, in 1931 Bruno de Finetti proved roughly the following fact where decisions are coded in terms of winning or loosing money (see Russell 2003, p.474): If Agent 1 expresses a set of degrees of belief that violate the axioms of probability theory then there is a combination of bets of Agent 2 that guarantees that Agent 1 will lose money every time. In more general terms, acting against the rules of probability may become very costly. However humans are badly prepared by nature to comply with these rules as is demonstrated with the studies and the examples mentioned above. In Psychology the typical human attitude to stay with familiar, even if destructive habits rather than with probabilistic rules is known under the term of *manic defense* (Schmidbauer 2005, p.126). It constitutes an important basic mechanism for improving chances of survival and is applicable whenever no concrete and quantifiable danger can be associated with the habit. Every smoker or drinker does know that there is some danger involved, but the danger is vague so that s/he can always argue to him/herself that s/he could escape the danger. Only hard facts could defeat this defensive strategy.

Hence Intellectics technology, in this case especially Bayes' nets and knowledge systems technology, could play a rather beneficial role in the food domain (as in many others for that matter). Rather than getting confused with contradictory opinions and advices from friends or experts the advice from such a system would be absolutely clear and reliable and could provide all the explanatory reasons for its conclusions. The convincing power through such hard facts would be way more effective than under present circumstances. It could be used at all stages in the food chain, not least by the producers and the consumers. The ambient intelligence technology under development would provide the technological environment in which advice systems would appropriately be embedded. In more general terms we can say that the European society will not become a knowledge society unless knowledge will be developed into a quantifiable resource and an underlying technology, ie. the knowledge systems, will be made widely available – similarly as it would not have become an industrial society in the 19th century unless the physical knowledge then would not have been quantified into strict laws and equations.

To point to a similarly important technology, in the pharma-industry extensive computer simulations of processes in the body are carried out but the results are rarely disclosed. Such simulations of the entire human metabolism, but also of other processes in the food domain, should become one of the main focusses of public research on a European level with the results being accessible to the public (as already requested in Bibel 2003, p.249). Thereby we think of traditional simulating computer systems. But note that also comprehensive knowledge systems for all aspects of food, if appropriately designed, can be regarded and used as simulation systems so that experiments could be carried out in silico with them (in addition to their use as knowledge providers and problem solvers). So, depending on the specific application, one may choose between traditional and knowledge-based simulation systems.

Apart from knowledge systems, advice systems and simulation there is much more IT with the potential of converging with technology in the food domain. We just mention one further which is e-commerce technology which allows farmers to participate in a fair, technology driven market on an international scale as it is already functioning in Indian villages.

3. Knowledge characteristics of the food domain

In contrast to industrial production agri-food industries are distributed by their very nature rather than centralized. We may regard this industry as a scattered multinational company without any CEO and governing board (or as a cluster of mostly SMEs). Also, the transformation process of the Common Agricultural Policy (CAP), not least also under the competitional pressures resulting from the ongoing WTO negotiations, has set the goal of a *Multifunctional Agriculture*. This concept "recognises that, in addition to producing commodities, agriculture encompasses other functions such as maintenance of rural landscapes, protection of the natural and cultural heritage, support of rural economic viability and enhancement of food security" (Downey 2004). It requires knowledge-based farming and processing all the more. The question therefore is how to bring knowledge, intelligence, learning to the individual farmer (and to the SMEs active in the food chain) who cannot afford a costly research institute or competent advice by some expert knowledgeable in the international state of the art.

Again the answer could consist in the technique of knowledge systems accessible through intermediaries or even directly by the farmer through the internet. So also from this aspect this technology deserves the necessary attention. Inversely, some knowledge is inherited and accumulated at each individual farm, ie. farming across the entire continent may be regarded as a huge experiment, altogether accumulating a huge body of knowledge. This kind of knowledge deserves to be considered in a common knowledge base along with scientifically established knowledge. (The Wikipedia encyclopedic project or project named "Open mind common sense database" aiming at the coordinated collection of hundreds of millions of units of human common sense knowledge, Singh 2002, might serve as a model for the accumulation process of knowledge.) The National Agriculture and Food Research Authority (Teagasc) of Ireland does play this twofold role already now without the involvement of knowledge systems. It thereby provides a high level of advice quality not least by asking the farmer to pay for each advice. Knowledge systems could enhance this level of quality even further and extend the range of advices (to include also financial as well as other advice).

Exactly the same considerations apply to the consumer side (see also the respective points in the subsequent section). There are, for instance in Germany, a number of nutrition advice centers for the public. But they are more or less not used at all, an experience which can only be interpreted in the sense that the information must be brought directly to the consumer *by need*, ie. where and when it is needed. This means that the advice will only be effective if it is given at the moment of choice and if it is regarded as absolutely reliable and unbiased by the consumer. Again inversely, individual consumer experiences could and should, similar to the farmer experiences, be accumulated in generally accessible knowledge systems. And similarly for all other agents in the food domain.

In addition there is the need to carry out more cognitive research (by nutrition psychologists – see Pudel 2003 – and others) about how consumers and farmers can be instructed best in order to be able to evaluate and select the appropriate knowledge from occasionally conflicting knowledge chunks (recall the smoking example above). While the typical attitude of farmers/consumers to refrain from unfamiliar methods should well be appreciated, they should and could still become more open-minded to innovations which *provably* offer advantages with absolute precision (while involving likelihoods, established by Bayes' nets technology). If the arguments are regarded as reliable and specific to the question at hand humans do follow rational advice, else they rather trust their own emotional attitudes. Such advice and the hard facts behind could come from knowledge systems designed in accordance with insights from CogSci (Andler 2005) and adapted individually to the type of user of the system, possibly mediated by intermediaries.

4. ICT and Intellectics potential for the food domain

In applying these and other ideas we need to consider the entire food chain: preparation and fertilization of soil, crops, feed, and livestock production, food processing, but also organization, management and monitoring of these activities, distribution chains and logistics. Downstream the chain could be improved technologically by minimizing (transportation and other) costs and improving the speed of delivery of natural, guaranteed fresh and safe products to the end-user. Upstream consumer preferences should be taken into consideration and, for safety reasons, the consumer should be able to trace back the origins of the food and become better informed. The goal must be to meet and secure the users' "demand for safer and healthier food as well as for sustainable use and production of renewable bio-resources." It is for this demand that the European Food Safety Authority (http://www.efsa.eu.int) has been established. In the following we list some issues for both directions for which ICT and Intellectics contributions could, in cooperation with other means, be helpful to pave the way for a knowledge bioeconomy.

Downstream: Networking the software used in the agri-food sector for data sharing; establishing kind of a coherent software with a service oriented architecture (SOA) for European agriculture (recall the comparison with a company where SOAs today are on the verge of becoming a common standard); learning techniques for abstracting knowledge from experimental data concerning soil composition and means of fertilization including production and use of compost (not only in horticultures, but also in fields and forests); the role of micro-organisms in this process (eg. in view of the environmental oxygen/carbon dioxide balance, Saxl 2005, p.14, or of the pseudomonas strains with their importance for the catabolism of xenobiotica, Glick 1995, p.254); consideration of data concerning the entire ecology thereby; crop cultivation through robots (possibly even swarm micro-robots, http://i60p4.ira.uka.de/~seyfried/tikiwiki-1.7.3/tiki-index.php?page=I-Swarm); collection of knowledge about healthy conditions and feed for animals; these actions complementary to the exploration of comparable improvements through bio-, nanotechnology (eg. fertilizers by nanotechnology) and nutrigenomics including the study of their side-effects; optimizing the use of farming machinery, the logistics and the management of a farm; study of biopolymeres in food processes; intelligent packaging with (nano-) sensors for monitoring the condition of the fruits, vegetables, etc. and for the detection of deteriorated food; translating sensory and labeling code into easily intelligible information; understanding the consumers' perception of quality, risk and safety and their individual nutritional needs; knowledge extraction from user experiences; publicly accessible knowledge on quality production records; researching the taste preferences of people and their origins; separating the deeply rooted preferences which reflect a coded memory of century-long experiences from those based on acquired prejudice; discovering the reasons for obesity, cancer, diabetes, osteoporosis, and many other food-based or food and environment-related deseases; scent and taste through nanotechnology.

Upstream: Development of advice systems based on knowledge systems for farmers, food and drink industry, and consumers; use of constraint technology from Artificial Intelligence in such systems: ie. the selection is done on the basis of personal preferences from the radically restricted set of possible solutions satisfying all constraints accumulated in the knowledge system; intelligent packaging with RFID technology which allows the trace of the entire production chain including all processes involved (to help avoid scandals like the recent one with deteriorated meat in Germany); possibly even nano-tagging of substances in order to allow the identification of the origins of products and their substances (Nordmann, private communication), especially of pathogenes; (nano-) sensors in the environment (sea, water, soil, air) for monitoring toxic and hazardous substances and their origins (to enforce regulations).

5. Ethical consideration

Food as well as air is special from the human point of view in that our body gets into contact with it in the most intimate way. People rightly are therefore particularly concerned with the ingrediences in food we eat as well as in the air we breath. Following the ethical responsibility principle (Jonas 1984 – rather than just the precautionary principle, COM 2000) any action involving GMOs (eg. if GMOs are able to reduce the amount of equally hazardous contaminants such as herbicides, fungicides, pesticides etc. substantially) must therefore be accompanied with careful measures of “Begleitforschung” (see Bibel 2004) by using life-cycle assessment tools in order to make sure that any possibly emerging hazard is immediately recognized to enable appropriate countermeasures (see also COM 2004, p.20).

Concerning this point, the related aspect of the embeddedness of converging technologies and the problems involved with it are addressed in (Nordmann 2004) in detail. This feature of embeddedness underlies the ethical problems involved in gene technology (or recombinant DNA technology). Concrete threats are: the reproduction of the host organism used for the gene manipulation (eg. E.coli K-12) beyond the laboratory; release of pathogene organisms; release of GMOs (eg. maize, rape, rice) into nature by use in seeds, feed, food and drugs. For these reasons, if there is a choice between natural processes and nano- and biotechnological interactions then a clear preference for the more natural line should be taken (recall the evolution thesis and the limited rationality problem).

As pointed out in the book (Levin 1999) by the Kyoto Prize winner of 2005 biodiversity has a fragile foundation so that he justifiedly pleads for the greatest care and for couragious action. The population shares this position as the recent poll on the issue in Swizzerland has demonstrated (resulting in a total ban of GMOs in Swizzerland for 5 years). Also, 89% of the European population think that nature should be protected even if progress might be hindered, and 54% think that GMOs in food are dangerous while only 14% think they are not (EC 2005, pp.24f). The Commission should definitively take note of these opinion polls in their research policies. Since there is a huge fallow potential behind the alternate technology discussed here (including knowledge systems) there is also not really an urgent need for aiming for a more hazardous line. The Commission could play a vital role in activating this potential.

Current EU research policy does not oblige to these recommendations at all. An example in case is the EU-FP6-funded research project HEALTHGRAIN; its goal “is to identify new sources of nutritionally enhanced grain, as well as to develop methods for producing new, competitive, grain foods that are good for health and more appealing to consumers. The project is building on results from recent studies that have revealed how wholegrain foods can have a protective effect against heart disease, strokes and diabetes. But unfortunately, bread is currently mostly baked from refined flour, devoid of the nutrients and protective factors present in the outer layers of grains. HEALTHGRAIN is part of a strategy by the European

Union to increase food safety and quality, with the aim of improving well-being and reducing the risk of metabolic syndrome related diseases in Europe. This is to be done by increasing the average European citizen's intake of protective wholegrains. ... the project will give European grain producers new technologies to develop globally competitive, healthier grain traits."
But if wholegrain food does have so benevolent effects as the project correctly points out (and as is well-known already for decades) why not focus on convincing consumers to prefer it instead of the refined flour! The project's goals are useful as well but only if they are complemented with the more direct goal just mentioned. Once again we see that there is a tremendous lack in getting the knowledge in a demand-driven manner to whom, where and when it is needed, possibly through knowledge system technology.

In contrast a truly useful project funded under FP6 is BioCop. "The BioCop project is bringing together research expertise on new techniques to screen a variety of foodstuffs for multiple chemical contaminants, including pesticides, toxins and drugs. The results should help ensure that any hidden dangers in foods are detected long before they reach consumers. Chemical contaminant monitoring in foodstuffs is a highly important and complex issue, resulting in ..." (http://www.biocop.org). Since contaminants are a (sorrow) fact of life in Europe and elsewhere in the world such techniques are urgently required indeed. A similarly useful project is Co-ExTra (GM and non-GM supply chains: their Co-Existence and Traceability) which tries to explore the possibilities of allowing a pieceful and harmless coexistence of both worlds (http://www.coextra.org/default.html). Similarly, the project Sigmea examines how the contamination by GMOs can be prevented in the fields (http://sigmea.dyndns.org).

So not technology as such is the problem, on the contrary. Rather we need to find a mechanism which drives the technological evolution in an environment and consumer oriented manner to the benefit of the European population.

6. Research policy recommendations

In (CIAA 2005, p.20) the major challenge in the food domain is characterized as the task to "*understand more fully how the healthy choice could be translated into the easy choice*". We interpret this task here as one posed wrt. all those involved in the entire food chain including the consumer. There are in principle two alternatives to achieve this task of translation, one by "innovating" the products involved, the other by changing the mental disposition of the people involved by "enlightenment". While the Commission seems to favor the first option, this author holds a strong preference for the second one.

My recommendations to the Commission resulting from these deliberations are the following ones. The central tasks in the sector of food are the provision of reliable and precise problem-oriented knowledge and its timely and truly useful communication to those who and when they need it. Building up knowledge systems (which is much more than just databases or knowledge management systems) comprising established as well as newly researched knowledge should become a high priority. A huge amount of knowledge is already available; its exploitation is the weak point. These systems have the potential of complementing the scientifically established human weakness in dealing with uncertain knowledge abounding in the food domain.

Generation of new knowledge would be particularly effective in the following areas. The first important area is the development of simulation systems for the entire domain of food (production, processing, transportation etc.) and for metabolism which would produce useful and reliable data from experiments in silico.

The second important area for knowledge generation is CogSci research on what causes food preferences in humans, how people can be influenced at the moment of choice and how knowledge can best be transferred to them (producers, consumers or those in processing, logistics and management).

The third area concerns food control for consumer protection with technology (and a minimum of regulatory burden).

In summary we are arguing for a more balanced research policy in the agri-food area emphasizing an environmental and customer centered approach and the knowledge aspect also from a technological perspective far more than considered so far. In this context it is of utmost importance for the Commission to take note of the results of opinion polls among the Europeans as well as of the ethical provisions both the way discussed in Section 5. The goal should be a substantial and scientifically underpinned overhaul of the national and European agro-systems in their local and global functioning.

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References

Daniel Andler, *Cognitive Science*. Key Technologies Report, 2005.
Wolfgang Bibel, *Lehren vom Leben – Essays über Mensch und Gesellschaft.* Sozialwissenschaft. Deutscher Universitäts-Verlag, Wiesbaden, 2003.
Wolfgang Bibel, *Information Technology*. Report, European Commission, 2005. ftp://ftp.cordis.lu/pub/foresight/docs/kte_informationtech.pdf
Wolfgang Bibel et al. *Converging Technologies and the Natural, Social and Cultural World.* Report EU Commission, 2004. http://europa.eu.int/comm/research/conferences/2004/ntw/pdf/sig4_en.pdf.
CIAA, *European Technology Platform on Food for Life – The vision for 2020 and beyond.* June 2005.
Liam Downey, *Agri-Food & Rural Economies – Competitiveness & Sustainability – the Key Role Knowledge*. Key Technologies, Agri-Food Report, August 2005.
Liam Downey, *Rural Ireland 2025 – Foresight Perspectives*. Launched by the Minister for Agriculture and Food, Dublin, 2005b.
Liam Downey, Gordon Purvis, *Building a Knowledge Based Multifunctional Agriculture & Rural Environment*. Dublin, 2004.
European Commission, *Communication from the Commission on the Precautionary Principle*. COM (2000) 1.
European Commission, *Towards a European Strategy for Nanotechnology*. Communication from the Commission COM (2004) 338.
European Communities (EC), *Foresight and Transitions to Regional Knowledge-Based Economies*, EUR 21262, 2004.

European Communities (EC), *Eurobarometer-Doppelerhebung Bürger, Wissenschaft und Technologie*, FTE info, November 2005.
Bernard R. Glick, Jack J. Pasternak, *Molekulare Biotechnologie*, Spektrum Akademischer Verlag, Heidelberg, 1995.
James Hendler, *Knowledge Is Power: A View from the Semantic Web*, AI magazine, vol. 26(4), 76–84, 2005.
Hans Jonas, *Das Prinzip Verantwortung*, Suhrkamp, Frankfurt, 1984.
Simon Asher Levin, *Fragile Dominion*, 1999.
Alfred Nordmann. *Converging Technologies – Shaping the Future of European Societies.* Report EUR 21357, European Communities, 2004.
Judea Pearl. *Causality – Models, Reasoning, and Inference*. Cambridge University Press, Cambridge, 2000.
Volker Pudel, Joachim Westenhöfer, *Ernährungspsychologie – Eine Einführung*. 3. Aufl., Hofrege, 2003.
Stuart Russell and Peter Norvig, *Artificial Intelligence – A Modern Approach*. Prentice Hall, Upper Saddle River NJ, 2003.
Ottilia Saxl, *Nanotechnology – A Key Technology for the Future of Europe*. Report, 2005.
Wolfgang Schmidbauer, *Dranbleiben – die gelassene Art, Ziele zu erreichen*. Herder, Freiburg, 2002.
Push Singh. *The Open Mind Common Sense Project.* KurzweilAI.net, http://www.kurzweilai.net/articles/art0371.html?printable=1, 2002.

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[1] Knowledge Representation and Reasoning (KR) is large discipline. It is characterized by precise formalisms which are accessible in detail only to the KR-expert while the systems interface make it easy to use the technology in practice. Because of its extension and formality it is hardly possible to give a short introduction to this field in a few sentences intelligible for the public. Nevertheless the following sentences are meant to give a rough feeling for its nature.

Think of knowledge in a very first approximation as of facts (like “I am smoking” or “I suffer from lung cancer”) and rules (like “smoking causes lung cancer”). A collection of such facts and rules is then called a knowledge base. Today there are knowledge bases comprising millions of such facts and rules. The interesting feature of such knowledge systems is their capability of reasoning; eg. they might conclude from the fact “I am smoking” and the rule “smoking causes lung cancer” the fact “I [will] suffer from lung cancer”. This reasoning capability becomes particularly attractive for applications if not just a few facts and rules are involved in a reasoning chain but hundreds of them. Also note that knowledge bases are modular by their very nature, ie. combining two separately developed bases makes immediately again a knowledge base. So its development can be done incrementally, decentralized and subdomain specific. Typically, knowledge bases are developed by means of knowledge acquisition support systems whereby the knowledge comes from all available sources including world-leading experts, practitioners and the literature in the domain. The semantic web envisions a huge knowledge base distributed over millions of sites and linked through the worldwide web.

As the example given shows the reasoning in this simple form might be mistaken since I may never develop cancer although at some period in my life I did smoke. This is because the rule is not true in this absolute form. We only know that there is a certain probability that smoking causes lung cancer. So facts and rules are useful only along with some probability measures, sometimes called degrees of belief (like “smoking causes lung cancer with a probability .7 or of 70%”). So again one can draw the same conclusion but now in the form “I will suffer from lung cancer with a probability of 70%”.

Reasoning in large knowledge bases with probabilities of this kind is computationally very costly if done in a first adhoc approach. The Bayes’ nets method has made the computation feasible by a substantially refined approach. It considers all causes of a given fact (like “developing lung cancer”) which besides smoking may involve secondary smoking, air pollution and many others along with the respective probabilities. These items are combined in the form of a causal network which allows the computation of the probability of the conclusion to be drawn in focussed way even if the chain of reasoning involves hundreds of steps. This technique has been generalized to complex forms of knowledge representation such first-order logic and is readily available for applications in any field which deals with knowledge such as the food domain considered here.

Introducing the author

Wolfgang Bibel is a professor emeritus from Darmstadt University of Technology. Recently he has been involved in two foresight studies of the Commission, one for Converging Technologies, the other for Information Technology as a Key Technology:

Converging Technologies and the Natural, Social and Cultural World. Report, European Commission (2004), with Daniel Andler, Olivier da Costa, Günter Küppers, Ian D. Pearson, http://europa.eu.int/comm/research/conferences/2004/ntw/pdf/sig4_en.pdf
See also (Nordmann 2004).

Information Technology. Report, European Commission (2005).
ftp://ftp.cordis.lu/pub/foresight/docs/kte_informationtech.pdf

Bibel has also written a book entitled "Lehren vom Leben" (lessons from/about life) (Bibel 2003) which gives a rational analysis of the situation of invividuals and of society. The book contains numerous recommendations drawn from this analysis. Naturally the book also covers the basic topic "food", its function (Section 1.3, pp. 19ff), its production (eg. pp. 251, 255ff), the responsibility for its selection (p. 162), and related issues. The positions taken in this book based are reflected in our statements here.

Bibel calls his discipline *Intellectics* which denotes the union of the area of Artificial Intelligence (AI) and of Cognitive Science (CogSci) (and has been working in computer science departments throughout his career). Both subareas are concerned with the study of cognitive functions including intelligence. While AI focuses in this study on the approach of artificially realizing cognitive functions, CogSci rather studies these functions as they appear naturally. Obviously both approaches are complementary – without some knowledge of the natural functions we could not develop artificial ones while artificial functions contribute to the understanding of natural ones not least by the possibility of experimentation – and support each other for which reason they should not be separated in two different disciplines; hence Intellectics as the name for both of them.