On the Impact of Embedded Knowledge-Based Systems

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Abstract— **Autonomous mobile robots are well visible both in science and in popular media. Significant progress has been made lately in that branch of robotics in all involved aspects of science, technology and engineering. Interesting studies and forecasts have been made how robots, based on the science and technology of mobile robotics, have started to become parts of our lives and will increasingly do so in the future. However, we think that the fascination with the idea of robots – preferably humanoid ones – both in science and in the public has been outshining the topic that is actually making the impact on society here: The science and technology behind these advanced robots, in particular embedded knowledge-based systems (EKBSs). So the question about the societal impact of robotics is actually the question of the impact of EKBSs.**

An EKBS is a technical system with sensors and actuators that is embedded in its environment and uses knowledge representation and reasoning for controlling its goal-directed action in the environment and for interacting with humans on a high, human-oriented level of abstraction. Typically, an EKBS shares the work space with a human or humans. Examples for EKBSs in academic research are smart autonomous mobile robots. Examples in real life are smart cars, smart homes, automated high rack storage areas, combine harvesters, facility security systems, and many other tools and systems – currently existing, or in versions envisable for the future. They all have in common that they provide for human users a specialized set of services based on real-time closed-loop integration of sensor data interpretation, reasoning, and physical action. EKBS technology may increase the level of automation in systems and appliances that exist in today's versions for humans to control, like cars, homes, and combine harvesters; in that case, the increase of automation may improve the quality of service, make usage easier, or increase the effectiveness of the system. The advent of EKBS technology may also lead to reshaping services, such as moving from today's driver-assisting individual cars to a newly-tailored smart transportation service; it may (and will, we would assume) also lead to new services not known today.

So the question of today's or future societal impact of robotics is in fact the question of the impact of EKBS technology. This makes it both easier and harder. The question is easier, because we are not necessarily talking about completely different machines providing completely different services than today, but we may still talk about vacuum cleaners, lawn mowers and combine harvesters – just using higher degrees of automation in unrestricted environments, up to full autonomy in the future, maybe. It is harder, because there is no sharp functional or technological boundary between robots and "classical stuff", and no such boundary can be used as a guideline for delimiting the question.

It appears that the impact of advanced robotics, or of EKBSs for that matter, on *todays* society is essentially little. If you consider market penetration worth mentioning as an indicator for societal impact and use the yearly UN ECE World Robotics reports as a data source, then there are precisely two types of robots that have arrived in society today: autonomous lawn mowers and autonomous vacuum cleaners. But note that both are using robotics, or EKBS, technology only to a minimal extent. And, more interesting for determining the impact on society: They mimic exactly the functionality of their non-autonomous ancestors. So the situation is a bit like that of the societal impact of computing technology, say, around 1960: There were a few computers; their number was rising; a bright future for them was predicted (correctly, as we know now); they were mostly used for making more efficient calculations or procedures that had been done previously by hand; and they were completely unavailable and unaccessible (both physically and intellectually) for the largest part of society. So the impact of computing on society at that time worked essentially by sketching its assumed future impact like in science or in SciFi, and that was little impact. Outgrowths of computing that markedly influence society today, like the Internet including WWW and social networks, mobile mass communication, or satellite navigation, were beyond imagination in these days, as they provide completely new functionalities, rather than somehow improving on previously existing ones.

Saying that the impact of robotics technology on today's society is little does not mean, by the way, that this technology is of no use today and is not being used. Driver assistance systems in luxury cars, and increasingly in standard ones, are examples here. Road sign detection and autonomous parking procedures, e.g., are clearly based on advanced robotics technology (though not much on EKBS technology). But they are wrapped in "classical stuff" terminology, and normally, no robotics aspect is emphasized – maybe because the manufacturers do not wish to jeopardize the subjective "Fahrvergnuegen" of their customers by explaining that their driving skill is no longer needed in some or many situations. (Actually, in some critical situations, like in braking really hard, it is positively discarded by giving control to ABS and ESP systems.) So we have the situation here that some part of robotics technology actually has arrived in society technically, but most people are not aware of it. The influence of those devices on society is litte, since they just increase the degree of automation of existing and well excepted technology. So we would like to differentiate between social and economic impact of EKBS technology.

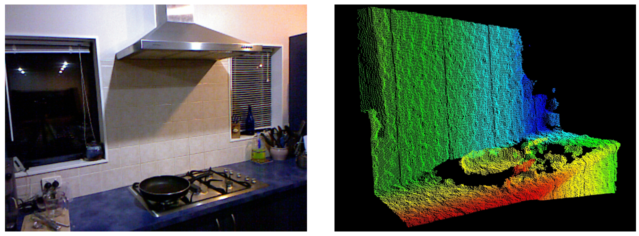
It has been argued that ”disappearing technology”, i.e., technology of which users are unaware when using some device, is a sign of good functional design of that device and of intelligent usage of the technology. If this is correct (and we tend to agree) then it follows that we roboticists should not aim at ”selling” our results to society by building robots that make their users aware of ”Hey, I am a robot!” all the time. The UN ECE World Robotics Report charts about how many service robots are installed in domestic environments, answer no useful question – or at least not the question of influence of advanced robotics technology on society. The interesting question is, to what extent has advanced robotics technology, including EKBS technology, found its way into products, appliances and services used in society, and which of these are products etc. that had not existed before that technology got available. The user need not be aware of it in any serious technical sense. We have given some current examples of such products above: Autonomous vacuum cleaners and lawn mowers, driver assistance systems. We have claimed above that the current influence of EKBSs on today’s society is little. Now the argument is: It is little in the sense that such technology gets used regularly, but it has not yet shaped society in the sense of generating some new product or service that had not been there before the advent of EKBS technology. Maybe StreetView may turn into a candidate for such a service – it contains a good deal of advanced robotics (not so much EKBS) technology, but we are currently not convinced that it is about to shape society.

We suspect that the chiefly influential ingredient of EKBSs is online sensor data interpretation, or semantic perception. In the remainder of this talk we present two examples from ongoing projects that represent the two kinds of impact discussed before: An ambient assisted living (AAL) as an example for real social impact of EKBS technology and and an application of increasing the degree of automation of a grain harvesting process which is mainly driven by economic interests.

Ambient Assisted Living

In the last decade ambient assisted living, also often coined Smart Homes, has become an active area of research, due to the gentrification in industrialized nations. From our point of view AAL is not supposed to create a complete automatic environment and replacing caregivers for elderly persons, but to support caregivers by monitoring the behavior of their occupants, analyzing the data and detecting anomalies in behavior.

One important part is the choice of appropriate sensors in AAL, which should be widely available, cheap, not interfere with daily routines of the inhabitants nor invade their privacy. Due to these requirements the standard palette of sensors includes reed switches, temperature sensors, meters for power consumption etc. For the same reasons cameras are usually not used in the AAL settings. However we feel, that under certain restrictions cameras or camera-like sensors might be employed in a meaningful way, if they are set up in restricted settings. One example for such a setting is the observation of the stove in a Smart Home. Privacy can be respected by simply restricting the field of view to the stove area, cropping everything that lies outside. Observing the stove might yield valuable information, since people showing signs of dementia sometimes forget which items belong on a stove and which objects do not. In order to address this problem we propose the usage of an off-the-shelf Microsoft Kinect sensor (or a similar product) since in addition to the normal image information (see Fig. 1a) it allows for gathering 3D information (see Fig. 1b). Whenever the stove is switched on



(a) (b)

Fig. 1: Exemplary stove setting: (a) shows a regular image of the scene, while (b) displays the corresponding cropped point cloud. Points in (b) are colored according to their depth with respect to the Kinect.

the Kinect can be employed to capture a 3D point cloud of the current stove environment. This scene can be compared (mainly in terms of geometric information) with an ”empty” stove setting, serving as a reference scene. Using octrees both point clouds can be compared quickly in terms of newly measured points and points that disappeared from the reference scene due to occlusion. Clustering newly measured points yields plausible candidates for objects placed on the stove. In order to identify if these objects belong on the stove we need to classify them. A first step towards classification is comparing the clusters with geometric primitives. Frying pans and pots usually roughly resemble cylinders of certain diameters and heights. So if we are able to convincingly fit a cylinder to a clusters, the dimensions of the cylinder lie in the boundaries appropriate for a pot or pan and the cylinder axis is more or less perpendicular to the stove plane, we have a strong indication that indeed a pot or pan is present on the stove. A further refinement of the classification can be done by additional CAD model matching, once a potential candidate is discovered for an appropriate CAD model. However if any of the initial classification conditions is not satisfied or if the data can be much better be represented by a different model, say one or more planes, then we can conclude that some object is put on the stove which might not belong there. The latter case then might ultimately result in notifying the caregiver in charge.

MARION

The marion project is an example of the economical impact of Embedded Knowledge-Based Systems. It aims to automate the working processes in the intra-logistics and agriculture areas through the collaboration of autonomous vehicles. It focuses on enabling motion and process planning for mobile machines and groups of machines.

Many industries have to continuously increase their productivity due to competitive environments. The dependencies within the supply chains thus become stronger and the participants are more interconnected with each other. Increasing the efficiency through machines provides only limited improvement to overall productivity. Of greater importance is the implementation of intelligent management of the supply chain which takes into account the specific capabilities of the machines and their mobility, especially in dynamic environments. Business process automation and robotization are often considered as to be one and the same because robots are not only technological solutions but are deeply engaged in the process organization.

In the marion project, the automation will be realized through intelligent assistant systems that perform the processes autonomously and support the people involved in those processes. The implementations will be carried out within two application areas; intralogistics transport systems in the subproject "Intralogistic automated load and unload from trailer train" (STILL) and agriculture in the subproject "Infield-transport logistic autonomous agricultural machines" (CLAAS).

Marion focuses on the motion and process planning for mobile machines and groups of machines. A partial result is a planning system that dynamically takes into account the present situation in its generated plan. This includes recognizing the necessity for re-planning and automatically generating such a plan. Appropriate processes should be carried out automatically by the system, while other processes are presented to the operator in the context-specific information to assist operator decisions.

CONCLUSION

In this talk we have argued about the social impact of Embedded Knowledge Based systems. We are convinced that the future impact of EKBS technology on society will be strong but will not purely be social. It will touch different aspects of daily life like economical interests as well.