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***Abstract* — This paper is discussing the intuitive interaction with robotic systems and the conceptualisation connected with known organisational problems. In particular, the focus will be on the manufacturing industry with respect to its social dimension. One of the aims is to identify relevant research questions about the possibility of development of safer robot systems in closer human-machine intuitive interaction systems at the manufacturing shop-floor level. We try to contribute to minimize the cognitive and perceptual workload for robot operators in complex working systems. In particular that will be highly relevant when more different robots with different roles and produced by different companies or designers are to be used in the manufacturing industry to a larger extent. The social sciences approach to such technology assessment is of high relevance to understand the dimensions of the intuitive interaction concept.**

I. Introduction

The research on intuitive robot programming in manufacturing has already 25 years (see Heise [12], Cypher [7], Münch et al. [27] and Kaiser [16], among other authors). However, in recent years it seems that intuitive programming as well as the intuitive 'use' of technology becomes a high relevance for a variety of processes in industry. The intuitive use of technology has become a feature in more information and communication technologies (ICT) products (see Akan et al., 2011[1], and Colombo et al., 2006 [5]). Furthermore, it became also a need in the development of complex equipment and machinery [3]. That has been the case of computerised numerical control (CNC) machine tools, flexible manufacturing systems and industrial robotics [7]. Such kind a new approaches demonstrate as well new problems related to the way people must interact with equipment and machinery. Following that rationale a challenge for the management officers and analysts has been the modelling of work organisation under such conditions.

The complexity of manufacturing equipment is revealed, in particular, by the need of programming or re-programming (off- or on-line), and by their increased multi-functionality. For instance, new programming methods can enable the automation of small lot sizes or even single work pieces, hand drawings made with a digital pen can be transferred into robot programs automatically, or robot trajectories can be defined by guiding the robot using tactile feedback. Such flexibility can improve the task performance, with direct effects on quality, safety and productivity [2], [4].

In the definition of intuitivity, Mohs and colleagues understands the existence of unconscious application of prior knowledge that leads to effective interaction [23]. We can apply this definition to human-robot interaction (HRI). The HRI systems should be designed support tacit or formal knowledge in the production process. But is the dominant model of work organisation enabling and recognising the role of tacit knowledge in the work processes? In the intuitive interaction process, the decision process must include a tutor, as a robot operator or a software programmer, depending on the organisational options. But also the robot system (as an autonomous agent) is included in the decision process. It should be, however, subject to mutual confirmation (human and robot). Only then it is possible to effectively reduce the effort involved in the control design, according to Kaiser [14].

There are several limitations and conditions to the development of intuitive interaction approach. They should, however, be tackled with the aim of improving the working environment and the decision and control process. Clearly, those are needs for a safer workplace and for higher productive outcomes. The knowledge of those social dimensions has to increase to improve the human-robot interaction tools and systems.

II. New Methods in HRI: Which Organisational Implications

Intuitive use of technology has become a need in the development of products (especially ICT) whenever the more complex they become. That is the case for consumer electronics (TV, mobile devices, PC, etc.), but also for manufacturing equipment with programmable control (industrial robot, CNC machine tools, conveyors, etc.) [2].

Today it seems that is possible to use new methods through "augmented reality" approach, basically for simulation tasks. Here, the operation is done through innovative visual markings. This approach allows programming, e.g. an automatic surface fitting, at a constant contact force. The augmented reality approach provides also major opportunities for HRI within safer environment. Furthermore, it can be used in tele-robotics because it allows the operator to work as if he is present at a remote work

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environment. According to Akan, B. et al., augment reality can also be used as a mean for visual feed-back to the robot operator [1].

In the same way, Kock et al. (2011) mention that "assembly equipment is best utilized by not being dedicated to a particular product or line – instead, it should be quickly reconfigurable to produce a new batch of a completely different product or sub-module (agile assembly)". [39]

Such new approaches to HRI have been analysed using interdisciplinary analysis methods, joining social scientists and computer scientists. The studies we are developing at ITAS-KIT on technology assessment and work (see [25] and [26]) are using that method. Such methodology envisages increasing the knowledge awareness on the use of intelligent robots (as working tools or machines) at the shop-floor level in the manufacturing industry. We have collected as much information possible on case studies and interview processes, mostly in Europe and Japan. It envisages also understanding the available organisational alternatives where intuitive robot interaction can be applied in higher levels of performance and productivity outputs. Preliminary results confirm assumptions that referred the positive correlation participative approaches with intuitive robot interaction and the performance outputs. Further empirical observations are to be reported in the near future on these results.

In fact, the industrial automation is achieving more advanced capacities that envisage higher production performance levels, better quality standards and increased flexibility. New requisites are to be found in industry: "being easily combined with manual labour in a safe and natural way, without adding safeguards and interlocks that increase engineering and installation effort beyond economic viability" [39].

Most of those capacities are being developed in the field of applied artificial intelligence to manufacturing tasks. Intuitive interaction can play a role for improvement of those capacities. This can be confirmed at the robot manufacturers, while it can be a specific approach in their research and development activities. Cases from ABB, KUKA, Kawada among others can be mentioned [16], [23], [28], [39], [41].

To summarise, we can conclude that robotic systems do not determine the model of work organisation to be adopted. But robot manufacturers are aware that most organisations limit their options in terms of configurable automation systems. They know that is possible to develop the way production systems are used

III. SOME PROBLEMS OF ORGANISATIONAL DESIGN IN HRI

However, several important social aspects of automation are still not yet solved, and little research has been done. By social aspects of automation we mention those that are connected to the development of work organisation [6], [10], [11], [14] or the new job design issues related to safety requirements [17], [19], [29] or the socio-technical principles applied to complex manufacturing [8], [9], [30].

Safety is one of those aspects. Other aspects deal with ergonomic design, situation awareness, risk assessment and quality of working life. Thus, the overwhelming research topic refers clearly to the "social implications of robotics" (Tranfield [28], Eason [7], and Das and Jayaram, [6]).

In manufacturing industry, the integrative tasks in advanced automated systems can be taken by human workers. The same applies to the control tasks. Most experts agree that it should be taken by humans in working environments (in manufacturing industry, or professional services). Even when the technological autonomy has a major role within organisations [10], [14], [18]. Humans are also better at dealing with unexpected events to keep production lines running. Interaction of humans with robots increases the importance of such aspects [17]. Intuitive programming, augmented reality and programming by demonstration are interesting concepts that deal directly with safety, control and participation in the decision process [15].

While most robots operate in industrial settings where they perform different tasks (assembly, welding, painting, drilling, etc.) the direct interaction implies basically a risk assessment in terms of safety [1]. This refers not only to the ergonomic dimension, but it clearly strengthens organisational issues (social implications) where different options are available [25], [26]. Widening the perspective with respect to the social implications within the intuitive interaction between humans and robot systems is the central motivation of this approach. Hereby the different technical options of intuitive interaction have to be analysed and assessed with regard to increasing decisional options for the human operators. This means that intuitive HRI can increase the technical autonomy (autonomous robots or agents in complex systems) and displace the human labour necessary. In other cases, in order to facilitate the human operation in working environments it could be needed to have intuitive HRI to enhance the safety policy and increase productivity. Finally, high qualified work environments with robots usually need more sophisticated systems for co-working strategies [21], [24], [29], [34].

Studies on human-robot interaction from S. Thrun [27], or Bernstein, Crowley and Nourbakhsh, [3], Schraft and Meyer [26] Kiesler, and Hinds [17] or Hinds, Roberts, and Jones [14] and other authors, also stress these problems. Some even underline that in few years the human-robot interaction will become a primary concern in the majority of robotic applications.

Also for some authors it is possible to discuss the recognition of gestabulary or feedbackulary [40] as standards with specific commands. Others mention also the need for the development of intuitive teaching methods to be applied in small and medium-sized enterprises [35]. At least it seems clear that different contributions to solve the current problems in HRI are yet to be found. And most of those contributions would come from different scientific backgrounds, as social sciences to be one of them.

[1] see EN ISO 10218-1:2006, *Robots for Industrial Environments – Safety Requirements – Part 1: Robot*, 2006

IV. INTUITION AND SAFETY: LIMITS FOR ASSISTIVE ROBOTICS?

Some authors still states that intuitive programming of robots, i.e. Programming by Demonstration (PbD), is needed to transfer human skills to the robot, as is mentioned by Colombo, Dallefrate and Tosatti [5]. However, the aim should not be to leave the human operator without skills but to develop methods that allow human operators (or tutors) to "teach" simple tasks to robots, and not "transfer" them.

As Kaiser [11] mentions, robots should provide the capability to autonomously execute certain operations and relieve the operator in manufacturing environments from difficult control tasks. For this KIT researcher, robot skill is the ability of the robot to safely change something from a current state to a desired one (from the programmer point of view) in the presence of uncertainty. And that would be done with the individual control functions applied using only initialization data and direct sensorial information at runtime. This research confirms also that it is most important that the access to the necessary information is as easy and intuitive as possible.

Such approaches are even more important whenever "dependability of complex robotic systems in anthropic domains during normal operation is threatened by different kinds of potential failures or unmodeled aspects in sensors, control/actuation systems, and software architecture, which may result in undesirable behaviors", as de Santis and colleagues reveal [29].

The introduction of robotic assistance enhances the manual dexterity and accuracy of instrument manipulation. That can be the case in robotic surgery or at the manufacturing industry [15], [38]. Albu-Schäffer and colleagues from DLR, refer in their study that the sensor technology, like the integrated joint torque sensors and link side potentiometers in addition to the common motor position sensors, are used in their light-weight robot. It allows for the implementation of safety features which go far beyond the state-of-the-art in industrial robotics and facilitate the opening of new markets like medical applications or future service robotics scenarios. Potential industrial application fields are the fast automatic assembly as well as manufacturing activities performed in cooperation with humans (industrial robot assistant) [41].

A recent European project (SMErobot) developed these tools for PbD. The reconfigurability and modularity of the control system have been exploited in order to implement Programming by Demonstration based on manual guidance and in order to use a low-cost programming device, as is developed by Colombo, Dallefrate and Tosatti [5]. They propose the next research steps to extend the proposed control architecture with the objective to have a robust and interactive robot control, where the target is to have an intelligent controller, safe and robust, able to understand complex tasks and to share them in simplex commands. Such conditions are related to the intuitive interaction concept that we intend to develop in this proposal considering the experiences and robot manufactures strategies in this field. Scenarios based on those strategies and technical limitations can be envisaged in further research steps.

V. QUESTIONS FOR FUTURE RESEARCH

Generally, there is an aim to develop in the future a more advanced manufacturing industry in Europe, in which safety and intuitive programming and control will play a central role. Today, manufacturing sectors are facing still problematic productivity levels due to organisational design and to technology design problems. However, organisational models that are able to achieve flexibility under complex frameworks are those that include advanced automated systems with well-designed organisational options. And to achieve higher productivity levels means also that companies should have conditions where highly skilled workers can improve their working capacities and resources using such robotic systems with higher levels of competence and quality, as well with simple, precise and intuitive modes of interaction.

Learning processes, competence building, decentralised decision making, participative organisation model, are concepts with higher relevance in manufacturing environments with increased automation systems with advanced human-robot interaction systems. Operators and intelligent robotics will use their own stronger skills, and that would mean a clear concept in terms of work organisation model where the development of competence, decision making and task enrichment systems could deliver a better quality standard of work life and also new research questions. That can be pursued integrating new industrial robotics developments in the manufacturing industry.

Programming of industrial robots consumes still today a lot of time and requires experienced personnel. Intuitive interaction can decrease the amount of effort and increase the accuracy of programming and planning. As several authors underline, for many tasks, especially in small and medium-sized enterprises and with small lot sizes, this effort does not pay (Eason [9], Ribeiro and Barata [30], Schraft and Meyer [35], Ritter et al. [31]).

The traditional programming methods for industrial robots is also too complex for an inexperienced robot programmer or to an operator, thus external assistance is often needed. Intuition can support such competence building. Thus, the focus of industrial robot programming from coordinate-based programming paradigm should change to object-based programming scheme using intuitive approaches. That would make possible the robot operation to become much easier and controllable.

In this context, several major questions can be found to develop new conceptual approaches to the intuitive interaction of human operators with industrial robots. For example, it would be interesting to know how far are the intuitive approaches to robot design related with new concepts of HRI. Are the image schemes and their metaphorical extensions useful to user interface design? Is the human-robot interaction being driven by problems of confidence of humans about technology? Such questions must be answered considering that robot users are usually skilled workers with training to perform their manufacturing tasks, and some [2] specific robot operation training. In the case of industrial robots they are usually qualified workers of the manufacturing sector, and in the case of professional service robots can vary their qualification level, but the robot users are usually of higher qualification, like medical doctors, radiologists, astronauts, mining geologists, timber experts, etc.

In manufacturing industry it is important to know what the criteria for new programming is in place. And also one must know which new operation concepts can be developed at the computer integrated working cells that associate robots, AGV, CNC machine tools and other automation elements. In industrial sociology research on manufacturing robotisation the focus has been also on the knowledge about which social competences and skills are needed for robot operators. Most findings demonstrate the existence of several distinct organisation models that use the skill needs differently. The occupational competence develops accordingly to those different options. The options can have a strong relation with managerial strategies towards competition and performance.

Independently of the organisational options, it will become important to know how far tacit knowledge at the shop-floor can be articulated with intuitive robot operation and control. Such question needs an inter-disciplinary approach from socio-psychology and computer sciences. Both approaches can contribute to facilitate the use of workers competences and professional experience to improve automation processes.

However, such aims and research questions make sense if there is an interest from robot manufacturers to develop a new model of work organisation. In the next research steps, we will collect more information on this issue. It is especially interesting to know which kind of research and development has been done in terms of integration of robot systems in complex work organisation models. Manufacturing departments with several types of CNC machine tools, conveyors, automatic warehouses, sensors and robots of different types have specific problems to cope in terms of interaction. The communication systems between the equipment units present always operational problems, but the integration of humans in such systems is usually as difficult. Human operators must have adequate conditions to perform their tasks (training, experience, skills), and must have additional social competences to be integrated in working teams and to perform their tasks with such equipment. The lack of analysis on these topics can be a source on safety problems or to unexpected events due to deficiencies in the situational awareness. Human factors analyses have also important elements in the research of new robot equipment for manufacturing applications.

When developing the intuitive design of industrial robots (hardware, software and system integration), the robot experts in the manufacturing industry do not have very clear their implications. It is still an unknown field the knowledge of the relation between such intuitive design, and the possibility to enable other qualified workers to operate in such manufacturing equipment. In other words, could one say that intuitive design enables the possibility of less skilled operators to perform such equipment? Or is a necessary approach to improve the production safety in a wider sense?

When these options occur an assessment is needed for a wiser decision process. Those options require inter-disciplinary knowledge and also collaborative research. But in this respect, are social sciences approaches (sociology, psychology, economics, political science, anthropology) developing meaningful inputs to the relevant research? From the literature research [21] the number of papers in this approach direction is not evidently large. At least, when it is compared with other similar work using ergonomic and working conditions studies. And that means that such social sciences approaches are also needed from the academic side. And they should also have empirical evidence and contribute to the conceptual development in this field.

As P. Dario and his colleagues already said in 1996, "most of these problems are new for the robotics researchers, used to deal in the past with robots which operate in strictly controlled environments (like industrial robots) and/or conditions (like, for example, robots for space, or for submarine or nuclear applications). However, it is important to observe that many of the problems posed by the interaction between human and robots in different environments (for example when the robot must 'live' in a place, like a house, where a human being lives) are quite familiar to other research communities. Psychology, anthropology, social science and industrial design are some of the areas with which the robotics community will be "forced" to collaborate increasingly in the future. It is our opinion, however, that these collaborations will further fertilize with stimulating and intriguing new ideas in interdisciplinary fields of robotics" [42]. Some decades later, this is still a scientific challenge and a research approach still difficult to achieve.

VI. CONCLUSIONS

The quantity of studies on HRI has known recent increase and the debate on intuitive interaction demonstrates a high interest in the field. The robot manufacturing industry is also becoming more involved in such research activity while the product development also needs further attention of safety issues. However, the bigger the need for safer automation equipment, the higher is the intensification of applied research on ergonomics and working condition studies. However, that would also imply further development in the social sciences approaches to this same topic.

For example, in the intuitive interaction process, every decision taken by either the tutor or the robot system should be subject to mutual confirmation. Only then it is possible to effectively reduce the effort involved in the controller design as Kaiser concluded in his study [16]. As Heyer also mentions, "how robots fit into existing organisational

[2] Depending on the work organisation model: either the workers can participate in the decision process, proceed some programming fine tuning, apply quality control procedures and develop basic maintenance tasks, or they only apply standard procedures of surveillance and basic operations. In the first case they should have higher training on robot operation, and in the second case just basic training procedures.

structures, and how they are accountable to the organisation in terms of safe and reliable operation is yet to be determined" [13]. In this work we have tried to establish some key questions for further research developments and to try answering such problems.

It is clear that there are several limitations and conditions to the development of intuitive interaction approach, but they should be tackled with the aim of improving the working environment and the decision and control process. Those are needs for a safer workplace and for higher productive outcomes. The knowledge of those social dimensions has to be increased to improve the HRI tools and systems.

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