Assistance Systems Supporting Operators In Manufacturing

H.-H. Erbe

Technische Universitaet Berlin, Institute of Vocational Education and Continuing Formation

Franklinstrasse 28/29, D-10587 Berlin, Germany

Tel +49-30-31473298 Fax +49-30-31421611

E-mail: erbe0232@mailszrz.zrz.tu-berlin.de

Abstract

Man-machine interfaces like CNC-controls at machine tools or controls at manufacturing systems are regarded as assistance systems to support the shopfloor workers. The characteristics of these systems are discussed with respect not only to map the functional constraints of the manufacturing system but also the intentional constraints based on the underlying design. A shopfloor information system supporting workers in their overall decisions and a multimedia based maintenance assistance are also mentioned.

Keywords

Man-machine interaction, group work, productive maintenance

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: [10.1007/978-0-387-35390-6_58](https://doi.org/10.1007/978-0-387-35390-6_58)

L. M. Camarinha-Matos et al. (eds.), *Intelligent Systems for Manufacturing*
© IFIP International Federation for Information Processing 1998

1 INTRODUCTION

To operate a conventional machine tool no assistance system is necessary, i.e. all the physical functions of such machines are clearly direct observable. The intentions of the workers are more or less in a one to one mapping to the output. They are directly manipulating the material, handling the tools, using the material properties to determine the cutting velocity, feed-rate, cutting depth etc. Their intentions are directly coupled to the physical manipulation.

With the arising of numerical controlled machine tools this situation changed abruptly. The workers now had to manipulate software to cutting material in a milling or a turning machine. Often they were not even allowed to program the movements of the tools and to set the parameters. They only had to feed material, to change tools eventually and to follow a prescribed plan of the programmers.

To avoid errors caused by malinterpretation of functions a certain assistance for the workers appeared necessary. The first time the machine tools got a small display to observe the forthcoming of the programmed manufacturing process. Later when CNC machines were introduced to the shopfloor a monitor allowed a better interpretation of displayed signals for removing arising problems.

This was the first assistance „system“ to support the manufacturing process. Controls at machine tools or manufacturing systems could be regarded as assistance systems. New controls based on open system architecture are providing not only data for supervising the running manufacturing process but also information on the state of the system by interpretation the signals of the diagnosis. Furthermore context sensitive help information and planning boards for shopfloor control are integrated.

2 CHARACTERISTICS OF ASSISTANCE SYSTEMS

Devices assisting the functions of a system decomposed in parts and describing the functions of this parts and their input-output behavior are called system-oriented. Such assistance systems are designed by aggregation of input-output relations of the individual elements of a manufacturing system. This makes it possible for the resulting system to work. However to make it functioning effective the design must not result in an assistance system that constrains the behavior of human operators to only one possible manufacturing process.

Devices assisting the human operator in adaption to the systems behavior in a holistic sense are called human/worker-oriented if they support workers not only that they can run the manufacturing system properly but they will also run it based on gained experiences.

The assistance system should define a space for the operators bounded by goal- and resource constraints. Within this space they should be allowed to act freely according to subjective criteria.

Following Rasmussen (1995) a manufacturing system can be regarded in two ways: decomposition in parts and isolated analysis of the input-output limitations and output-input compatibility of the elements to be assembled into the system; abstraction and functional separation to analysing and understanding the functionality and the behavior of the working system (Figure 1).

Behavior during work in a human-machine system is oriented towards the requirements of the system perceived by the individual operator. The tasks, i.e. what has to be done, can be well bounded by an assistance system, whereas when and how should be left to the experience of the operator. There are a space of possibilities defined by the limits of functional acceptable work practice, acceptable efficiency and by the resource profile of the particular operators, i.e. workload accepted by the individuals. Within this space of acceptable work practice many degrees of freedom are left for the operators to choose among strategies. This freedom will be used by operators to shift among possible strategies to match resources to local conditions and to optimize performance criteria.

To motivate the necessity of assistance systems designed in a human/operator-oriented sense the analysis of Rasmussen are used:

The effect of the variability are moving around the normal performance or work practice. This space of fluctuating performance embedded in a space of acceptable performance is subject to gradients like pressure from management toward

Figure 1 Analysis of System Behavior (Rasmussen, 1995)

improved effectiveness and individual or group preferences for the path of least

resistance. This movements tend to migrate toward the limits of acceptable work practice resulting in errors, missing goals and conflicts.

Normally humans tend to close their degrees of freedom during normal work by developing a repertoire of heuristics to replace continued analysis and decision making. The only indication available of the limits of acceptable work practice of this adaption is the occurrence of errors at the boundaries. This implies that one effective approach to design assistance systems is to make these boundaries visible to the operators and to support them in learning to cope with the control characteristics of the manufacturing system at the boundaries.

The man-machine interface - the assistance system - should not be designed so as to support an operating procedure chosen by the designer of the manufacturing system. Instead the assistance system should present such features of the work environment which should act as behavior shaping constraints around the operators adaption in a way that matches human perception.

3 ASSISTANCE SYSTEMS SUPPORTING WORKERS

Support of operators during situations which cannot be pre-planned, is more effectively given by the creation of an information environment which makes visible the internal functional relationship which should be effective as behavior-shaping constraints, rather than by giving advice based on a designers preconceived ideas about the proper way of approaching a task. That means: a map of the deep structure of a system supports navigation more effectively than route instructions.

If a manufacturing process is based on an automated decision making tool this should provide convincing reasons for explaining the decisions it has made. The workforce should be capable of understanding how datas, rules and knowledge have been integrated to formulate production plans. Custodio& Pinto-Ferreira (1996) ask „how to implement an information system that allows the communication between the shopfloor and the upper levels of the management“?

The answer could be by using an adequate interpretation of datas, for example with the help of multimedia. A workers information system was developed and tested at shopfloors (Fleig, Schneider, 1996). The system is installed in a column (Figure 2) at the shopfloor level to provide an easy access for the workers. It is aimed to fill the gap between the intention to shift decision making to the shopfloor for decentralizing the organization of enterprises and the missing technical support for this purpose.

Besides providing tools for the necessary information exchange to run the manufacturing process, this assistance system for workers should facilitate the gathering and exchange of experiences between the workers, gained from their decisions and the achieved results with respect to throughput-time, schedule of delivering to customers, required quality and to run a stable process (process capability).

What we are missing are assistance systems supporting group work. The principles of total productive maintenance demands for groups of workers cooperating despite of different professions or qualifications to maintain the manufacturing process in all of its dimensions. Together they must have a model of the internal processes of the manufacturing system. This model should be supported by assistance systems. The behavior shaping constraints of actions for purposeful changes of the internal processes of the system have different sources: physical laws, company objectives, intentions of the cooperating workers, rules and regulations.

Regular pattern of response by a manufacturing system to the operators activities are suppositions for operators acting purposefully. Thus, operators opportunities to plan depend on their knowledge about the sources of such regularity, i.e. the internal constraints shaping the systems behavior.

Control of a manufacturing system involves operations on and through its

Figure 2 Column of the Shopfloor Information System

internal constraints and can take place via the causal constraints of the physical elements of the system or the intentional structure of the operators. Therefore, assistance systems should represent the behavior shaping constraints of the manufacturing system.

The focus in design of assistance systems supporting operators has traditionally been in providing facts about the state of the manufacturing process and about functional relations. Little effort has been spent on intentional information. Any operator making efforts to control the operating state of a manufacturing system

will have to operate on and through the internal constraints of the system. This control involves operations on the causal constraints of the physical elements or on the intentional constraints originating in other actors of the system. Whether one or the other mode is appropriate depends on the task situation and the physical structure of the manufacturing system.

Figure 3 characterises work systems. Concentrating on manufacturing systems, the right side of the figure is important. The tasks of the operating group is basically to ensure that the functioning of the system actually reflects the intentionality of the original design while their own personal goals and preferences have little significance. It follows that the information presented for the operators with aspects to functionality must be based on the physical laws as applied to the productive processes of the particular system including the limiting conditions set by the restrictions.

However providing intentional information, the reason for the design is very important to improve the reliability of the manufacturing system. In order to understand the functions and the behavior of the automated manufacturing system the operators must be familiar with the intended control strategies. The internal functions of an automated manufacturing system are only the medium for processing this intentional information.

Of course, information on internal functions are necessary for the maintenance of

Fig. 3. Work System Characteristic (Rasmussen [1])

the system as the operators now have to take over these tasks for enhancing the availability of the manufacturing system. But blue prints and operating instructions only communicate what and how to do, but no important information about why.

In order to provide effective support by assistance systems the analysis and deliberate considerations of the path of propagation of both functional and intentional information through the different organizations involved in design and operation are important.

The discussion shows that for manufacturing systems the basis of assistance systems should be derived from the causal and intentional constraint underlying system design. The goal is not to match a display format to the mental models of the operators but to design an assistance system forcing the operators of the group to adopt a faithful mental model of the manufacturing system in a way they can directly manipulate the different constraints so as to match the goal state and prevent the system from entering malfunctions (Rasmussen, 1995).

4 ASSISTANCE SYSTEM SUPPORTING MAINTENANCE IN GROUP WORK

To get and to maintain a productive and flexible manufacturing process one has not only to consider a suitable technology in an adequate workorganization like production islands but also the availability of the whole process. As the responsibility of this process is usually divided up to different staff members in a factory it generates a lot of indirect non-productive work. Production islands are one suitable workorganization overcoming at least partly these difficulties. There are several skills coming together forming an experienced group to fulfill the demands of the manufacturing process.

To enhance the availability of the machines of the island it should be considered if it is of advantage to integrate the maintenance into the productive tasks of the manufacturing group.

The objective is to achieve a reliable, flexible and productive manufacturing process based on skills and experiences of the workers and not only on a highly automated and sophisticated equipment.

One can make the effort to organize the maintenance in a centralized way algorithmically based on recorded machine datas. But many deficiencies or break downs of machines do not occur unexpected but indicate themselves in the working process. The skilled workers know their machines but on the other hand they should be able to understand and interpret the signals at the diagnosis screen. Then they can act very quickly deciding what to do: to take measures by themselves or get support of an expert to avoid a break down or to remove a deficiency. If there is a need for an expert, so the problem has been meanwhile encircled and a possible stand still time can be shortened.

It is not necessary that all workers of a production island have the same formal qualification. The main goal is to complete each other within the tasks to be done, thereby getting experiences in maintaining the whole manufacturing process (planning, executing, controlling). An assistance system therefore has to be suitable to the tasks, i.e. supporting group work. With respect to figure 3 it should be a system with characteristics in the middle part: actors and system share control.

Genuine expert systems or learning systems are not adequate. But parts of it could be put together to create an assistance system integrated within the work tasks and oriented to the demands and qualification of the group which runs the manufacturing process.

There are two parts of the assistance system. The first is a model based fault diagnostic supported by multi- or hypermedia (Figure 4).

Only already existing signals at the machine tools will be evaluated. Thereof, typical parameters can be gained very accurately:

- increase of friction caused by missing lubrication.
- slacking belts indicated by incorrect voltage of the spindle.
- defective drives and different inertia of axes can be recognized.
- state of tools.
- defective encoders.
- defective hardware switches/software switches.
- inaccurate positioning, etc.

Figure 4 Scheme of Diagnostic.

This information is set up and interpreted by digitalized pictures of components, drawings, checklists of machine functions, etc.

The second is a knowledge oriented system to support the maintenance tasks and the training/learning on the job (Figure 5):

- storage and manipulation of gained experiences within the group.
- planning boards to support preventive maintenance.
- information of the machine builder.
- tele-supporting via internet.
- training modules on advanced material processing connected to load spectra of the machines.

- maintenance strategies and cost calculations with respect to availability of

Figure 5. Surface of the Knowledge Oriented System

Hohwieler/Krüger, TU
Berlin 1996

machines and equipment.

The functionality of this assistance system depends on the activities of the group using the different equipment and devices available to maintain and enhance the availability of the manufacturing system.

The institutional intentionality of the control strategy are:

- cooperative work of different professions forming the group of workers within the production island (electronic, mechanic of machine tools, material processing).
- the present and increasingly gained experiences within the cooperative work are guidelines for preventive maintenance and facilitates the interpretation of the reason of break downs.

Both together can provide knowledge and advises just in time at the workplace. Assistance systems do not have solutions for possible cases on stock but are giving hints for procedures to find a solution and by the way learning how to proceed in subsequent cases.

5 REFERENCES

- Custodio, L. and Pinto-Ferreira, C. (1996) Issues and difficulties in the design and control of manufacturing systems, in *Theoretical Problems on Manufacturing Systems Design and Control* (ed. G. Putnik), Pre-Proceedings Workshop associated to BASYS '96-2nd IEEE/ECLA/IFIP International Conference on BALANCED AUTOMATION SYSTEMS, Lisbon.
- Fleig, J. and Schneider, R. (1996) Facharbeiter in der Werkstatt informieren. *Technische Rundschau*, 25.
- Rasmussen, J. (1995) The concept of human error and the design of reliable human-machine systems, in *1. Berliner Werkstatt Mensch-Maschine Systeme* (ed. H.P. Willumeit, H. Kolrep), ZMMS-Spektrum , Vol. 1, Technische Universitaet Berlin.

6 BIOGRAPHY

Heinz-H. Erbe, born 15.03.1937, Graduated Engineer in Aircraft Construction, Dipl.-Ing. of Mechanical Engineering, Dr.-Ing. of Engineering Mechanics, Professor of Vocational Education and Continuing Formation (Mechanical Engineering).

1968 - 1975	Research Assistant at the Institute of Mechanics, TU Berlin
1975 - 1980	Head of Research Group on Fracture Mechanics,
Federal Institute on Material Research, Berlin
1980 - 1986	Professor of Mechanical Engineering together with
Vocational Education in this field, University of Bremen
1986 - Present	Professor at Technical University Berlin, (Vocational Education and
Continuing Formation in University and Industry)