A classification of carrier and content of information

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Mass customization is a driver for increased assembly complexity and the variety and complexity of products and parts require new and effective information and information flows to support final assembly operators. How to best present and convey information is however a difficult task. The aim of this paper is to develop a classification of carrier and content of information that can be used as a support for task allocation and design of new information systems for an assembly environment. The developed classification is mainly based on how different carriers and contents are being used in assembly and related to literature. In the design of new decision and information systems both carrier and content needs to be optimized and the concept of content and carrier needs to be contextualized in order to be useful in a task allocation and design process.

Automation, Assembly, Carrier, Content, Design, Information

1. Introduction

Mass customization, individualization and personalization of products are drivers for an increased assembly complexity in today's production systems. In the assembly environment the high variety of products and parts require new and effective information flows to handle the massive amounts of information. Final assembly operators have a need for fast and reliable information as well as better decision and action support. But how to best present and convey information in an assembly context is however a difficult task. Previous research have stated that the amount and content of information is a contributor to production complexity [1, 2]. It is of great importance that the right information is presented at the right time in the right way. Classifications have been put forward regarding what makes information of high quality [3]. Research has even indicated that proactive behaviour can be accomplished by analysing the type and amount of information to be presented and how to structure information [4]. The presentation of information can be broken down into two parts; carrier and content of information. Carrier concerns the medium of information e.g. paper, screens, and PDAs while the content concerns the mode of information e.g. text pictures, sound or movies. In the design of new decision and information systems both carrier and content needs to be optimized. However the concept of content and carrier needs to be contextualized in order to be useful in a task allocation and design process.

The aim of this paper is to develop a classification of carrier and content that can be utilized in a task allocation process to support the design of new information systems for an assembly environment. The developed classification is based on how different carriers and contents are used and the existing need on information systems.

2. Automation in an assembly context

Automation in an assembly context does not only consider mechanical tasks it also concerns cognitive support for control and information tasks. In an assembly context the support functions for operators are increasing. A transition has been made from tools such as electric screwdriver (that only provided mechanical assistance) to information support systems e.g. Pick By Light systems, which also provide cognitive support. Thus the scope of automation have widened through the use of information technology. Automation has an impact on the operators cognitive functions, thinking as well as doing [5]. But in what situations is this support needed and how is the information needed best presented?

2.1 Quality of information in assembly

The perceived complexity in an assembly system is in relation to the amount of information in the system. Information systems in an assembly context should aim to support operators reducing the perceived complexity. However, to design such information systems is not a trivial task. A information system can be divided into the following categories [6]:

- *What* information to present – contents, meaning
- *How* it should be presented – format, context and receiver characteristics.
- *When* it should be presented – timing in relation to the decision, whether it should be presented automatically or on request.

The role of intelligent decision support system is to support decision maker with better quality of information. According to Kehoe it is the quality rather than the quantity of information that is of importance [3]. Six qualitative criteria are presented for how to create efficient information: relevance, timeliness, accuracy, accessibility, comprehensiveness and format [ibid]. Hollnagel argues that quality is not necessarily a feature of the information but rather of the interaction with information [6]. On the other hand, in order to form decisions a certain amount of information is required. The information gap theory presented by Endsley claims that more data does not necessarily result in more information [7]. The problem with today's system is not the lack of information rather to find what is needed when it is needed [ibid]. To ensure quality of information the quantity might have to be filtered. However, it can be ambiguous to decide which information to consider relevant [8]. The amount of information needed by the operator is however individual and dependent on their level of expertise [9]. There is a potential risk of cognitive overload if the operator is surrounded with a large number of information, which creates stress [10]. This highlights the importance to present quality information rather than quantity.

2.2 Cognitive automation in assembly

Cognitive automation ($LoA_{cognitive}$) could be described as the amount of technique and information provided to the operator in order to know what, how and when to do a specific task in the most efficient way (LoA_{cog} = 1-3 in the matrix, seen in figure 1). When the technique or machine is performing the task i.e. higher physical automation (LoA_{Phy} = 5-7), the cognitive automation is mainly used for control and supervision (LoA_{Cog} = 4-7).

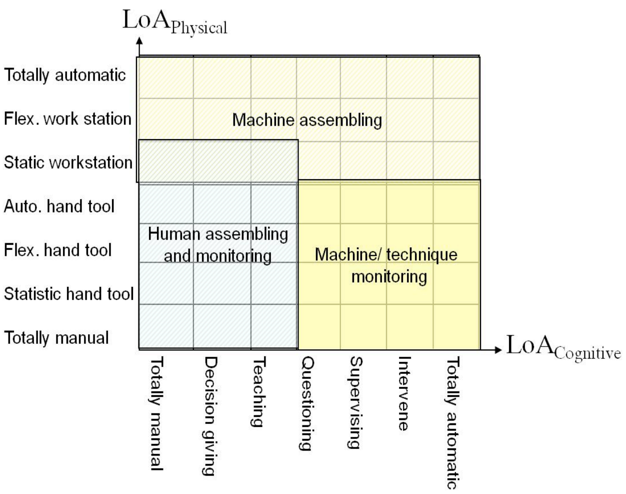

Figure 1. LoA matrix and taxonomy [11, 12]

It is equally important to acknowledge the cognitive dimension as the mechanical. Although, when companies redesign their system, they often only consider the mechanical Level of Automation (LoA), while the cognitive LoA is left to be solved afterwards. There is also a tendency at companies, when the mechanical level of automation is decreases so is the cognitive level [13].

Case studies shows that over 80 % of final assembly tasks are performed by operators based on their own experience [14] i.e. without any decision support (LoA_{cog} = 1). If more automation should be used in final assembly it is better that these systems provide information rather than decisions [8]. Meaning that it is better to support operators with good information support rather than telling what to do without explaining the rationale behind the decision. Humans actions are determined by their understanding of the situation not how the designer expects or assumes the user to view it [15]. This puts high demand on the system to be sufficiently transparent and adaptable to the user's needs [6]. One constraint applicable when designing for human centred automation is that automation must be accountable [16]. Meaning that automation systems must inform the operator of its actions and to be able to explain them if requested. Further, human operators must be in command and needs to be involved, and in order to be involved the operator needs to be informed [ibid].

A concept model has been developed [17], see figure 2, aiming for two things. Firstly the main loop which is a more quantitative way of describing the task allocation between operators and technique. The LoA matrix is part of the 'SoPI analysis' where the current states measured LoA values are analysed together with the companies triggers for changing the system i.e. internal or external demand such as increased flexibility etc.

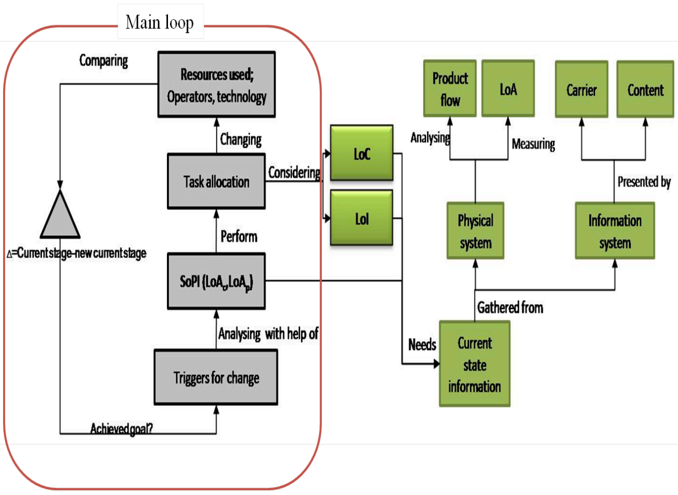

Figure 2. Concept model [17]

The second part is the areas on the right side, which are important areas to consider when performing a task allocation. Level of Competence (LoC) and Level of Information (LoI) are two important areas to consider, these could be further related to measuring the cognitive LoA in the current system [11] but also how the information is presented to the operators i.e. carrier and content of information.

2.3 Carrier and Content of information

Presentation of information can be broken down into two parts; carrier (how to present) and content (what to present) of information. Carrier concerns the medium of information e.g. paper, screens, or PDAs while the content concerns the mode of information e.g. text, pictures, sound or movies. This is a trivial definition but yet with a powerful potential when designing information systems since the carrier and content can be decoupled when analysing the system.

In order to investigate the number of information carriers and what they convey, two types of mappings can be done; one with focus on the exchange of information and one with focus on type of carrier [18]. In the design of new decision and information systems both carrier and content needs to be optimized, this could be done by measuring and analysing the companies cognitive automation [19].

3. Usage of Carrier and Content

This section will explore the concept of carrier and content and present different examples of carrier and content within different contexts.

3.1 Carrier of information

The environment or context in which the information system will be used in will have an impact on the design needs of the carrier. A short cyclic and high variety setting will pose different demands than a long cyclic and low variety environment. For instance the assembly operator working on a driven assembly line with a cycle time of 60 seconds or less does not have time to read instruction. Support is rather given by Pick By Light systems or similar to help the operator to identify which parts to assemble but not how to perform the task. The size of the work place and need of tools will also be important factors to consider. As product variety and complexity increases so does the need for more information.

Work instructions presented on a paper, as a bill of material or a drawing is a mobile although static way of presenting information. The drawback is that it is slow when frequent updates are needed or inconvenient when having many variants in the production. To better handle a variety of products and frequent updates digitalisation might be needed and presentation on monitors rather than paper.

If there is a need for mobility the carrier can be made mobile for example using hand held units. An experimental study has examined how the information source (carrier) affects the quality and productivity when presenting assembly instructions. The information source (carrier) used was an iPod touch and a static screen. The GUI that presented the information was a web-based system displaying text-based information (content). The study shows that quality is positively affected by mobility and shows indications of increased productivity [20]. In a dynamic context with a lot of movements, many variants and large action range, mobility is an important parameter. Even in quite restricted stations mobility can make a difference [21]. Another example of optimisation of carrier can be seen in research evaluating how display size have an impact on pointing performance [22].

3.2 Content of information

Content is a wide concept containing the actual data or information that is to be conveyed to the recipient. The recipient in this context is an assembly operator. The content can be presented by different modes such as text, picture, movie or sound. Each of these modes has their benefits, drawbacks and area of usage. Text has been the most common mode to use in work instructions, but pictures have become more commonly used. However guidelines to help engineers to make these decisions are few.

As the variety of products increase or the complexity of the product itself increases more elaborate instruction are needed, which put higher demands on the content of information. In an assembly context much focus in on the development of information systems but not so much focus on the actual content. To address this a multimodal approach was developed making use of many different contents [23]. Antifakos et al. used accelerometers to enable individual instructions based on the action of the user [24]. This was to supply correct information depending on the situation each individual was facing. This shows that the content can be designed to fit the individual operators situation and competence. Augmented reality is another example of optimised content. Augmented assembly instructions can be provided in forms of pictures and text by tracking objects such as pens or fingers [25]. This allows a work instruction that dynamically changes in response to the users actions.

3.3 Effects of Content and Carrier

When mapping Kehoes [3] list of parameters influencing quality of information onto the concept of carrier and content, it is apparent that carrier and content address different parameters. In the case of carrier the design choices will affect the timeliness and format thus influencing the quality. It will have an impact on the accessibility however in Kehoes definition it is expressed that this parameter should not concern the medium transferring the information. While the content design will influence all parameters proposed to affect the quality of information. Manipulating the two parameters, content and carrier have an impact on Kehoes quantitative measure, thus affecting the effectiveness of the information system. When discussing carrier (how) and content (what) the *when* is missing. However different carriers can make it easier to control the *when* e.g. a mobile ICT tool is very beneficial in providing attention triggers and the information can be adjusted to fit the individual [21]. Further, since the quality of the interaction with the information can been altered by the choices of carrier and content, the quality of information can be improved be these choices.

The same LoA can have many different solutions of carrier and content. For example, LoAcog = 3 = Teching, can be a drawing on a paper or a text based list on a computer screen. Each solution has its benefits and drawbacks for a certain context. This implies that LoA alone cannot be used as decision criteria when designing cognitive support for assembly operators. It is evident that guidelines for what carrier and content to chose for a certain context are needed as help in a task allocation process. Figure 3 illustrates an example of a fixture being used as both carrier and content to secure quality for screwing tasks.

It is important to recognise that not only contextual parameters such as cycle time and station size need to be taken into account. It is also important to acknowledge that individual factors such as experiences and competence are interlinked with the need of information and when and how it is needed. The experienced operator often works by own experience (LoAcog = 1). Optimised carrier and content can be used to design smart cognitive support to increase that figure to ensure quality while supporting different experience levels of operators providing different needs of cognitive automation.

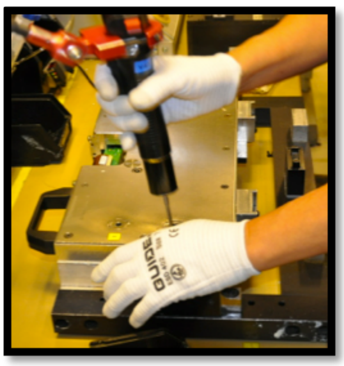

Figure 3. Fixture as carrier and content (“Smart” assembly instructions)

The development of cognitive automation might lead to an atrophy of mental skills [15]. Hence the design and use of cognitive systems must be made in awareness of its implications.

4. Conclusions

The results from the paper shown the importance to see cognitive automation as an enabler towards a more effective and competitive system by adapting the operators needs. The concept of dividing the possible solution into carrier and content makes it easier to adapt to the operators individual needs. Further it gives an opportunity to give a more nuanced view of the information flow within an assembly context.

A start has been made in the development of a classification of content and carrier of information. Further development is needed in order to give better design suggestions of information systems. Further case studies and experiments are suggested to quantify the relationships between carrier, content, and quality and time parameters. The classification could then be incorporated in the presented concept model and used as a guideline when performing task allocation.

Acknowledgements

This work has been carried out within the Sustainable Production Initiative and the Production Area of Advance at Chalmers. The support is gratefully acknowledged.

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