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Assembly Modelling and Time estimating during the early phase of Assembly Systems Design

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Abstract: An approach for assembly time estimating following sequence and process modelling since the conceptual phase of new assembly systems design is proposed in this work. The purpose is to support the decision about their levels of automation (LoA) following a dedicated modelling language labeled ASML offering a better visibility about processes design and analyses. ASML provides an easy way of defining several systems alternatives based on an initial ASML model representing assembly motions using a standard vocabulary and structured executing architectures. The correlation of early phase modelling with time estimating proposed in this paper to support LoA decision is up to us new to the literature. The approach of modelling and time estimating was tested on assembly examples and a computerized tool was also developed and tested. Several related applications such as processes time performances evaluating, time savings, productivity assessment, lines balancing, and cost estimating are proposed as well as other possible future applications presented as perspectives and future works that can be supported by the defined environment dedicated to early phase assembly systems design and automation decision.

Keywords: Assembly sequence, ASML, time estimation, system design.

1. INTRODUCTION

This research belongs to our studies in the context of deciding the Level of Automation (LoA) for new assembly systems design and optimization. The topic aims at determining the optimal assembly system design alternative for a given manufacturer conceiving a new assembly process. A suitable approach has to be consequently applicable in the early phase of systems design where the product is generally completely designed or at the end of its finalizing steps, while the system allowing its assembly has to be conceived based on the few available information about the product as well as the planned future production. Designing an optimal system, especially in the difficult manufacturing context of global competition, becomes crucial. The finality of our developments is to help and orient designers in the design of assembly lines with most suitable automation levels.

The paper will be organized as follows: in section 2, a literature review will be presented. Our modelling approach will be presented in section 3. In section 4 new proposals will be presented. The paper will be concluded in section 5 with perspectives and future works proposals.

2. LITERATURE AND PRACTICE REVIEW

In this section the literature about Level of Automation (LoA) deciding will be presented. In a first subsection, a quick background will be highlighted followed by a second one where existing LoA methodologies will be briefly presented.

2.1 A QUICK BACKGROUND IN THE TOPIC OF ASSEMBLY AUTOMATION

According to the literature, as well as our industrial feedbacks in France and in the United-States, we realized that the topic of deciding the LoA for assembly systems design is still debating even in the current industrial context and existing advanced manufacturing technologies. In such countries, even if labor rate is important, several tasks in assembly continue to be achieved manually. Boothroyd noted in (Boothroyd, 2005) that many workers assembling mechanical products are still using the same basic tools as those employed at the time of the industrial revolution. The reason of using manual or automating such tasks remains questionable. From another side, manufacturers realized that an increased usage of automation does not necessary result in increased benefits (Frohm, Lindström, Winroth, & Stahre, 2006). A survey in German companies about automation (Lay & Schirrmeister, 2001) shown that more than a third of the 355 surveyed companies planned to reduce the level of automation within their plants because of a non-suitability. The discussion on the question to automate or not is also not well documented and the path that leads to the final decision is not traceable (Ross, 2002). This makes the decision more complicated and the research worth doing where, in addition, the literature is not abundant and the support for making automation decisions is poor (Lindström & Winroth, 2010).

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2.2. LOA LITERATURE METHODOLOGIES REVIEW

The literature in LoA deciding can be classified to a first class concerning LoA assessment and guidelines for improvement of existing processes, and to a second one where methods aim at new systems design and LoA deciding approaches defining. From time criterion point of view: timekeeping for the first class, or time estimating for the second, we realized that this criterion is much important for approximately all the encountered methodologies of both classes. In fact, most of LoA methodologies are considering time aspect. Boothroyd used time estimation based on developed time standards in order to estimate assembly handling and insertion time for the finality of assembly process cycle time estimation (Boothroyd, 2005) (Boothroyd, Dewhurst, & Knight, 2011). In this orientation, assembly time estimation standardization has already been a research debating topic since 1948 with Methods Time Measurement (MTM) assembly motions time estimating (Maynard & Stegemerten, 1948). Ross (Ross, 2002) also considers in his LoA deciding approach different time drivers and parameters such as cycle time, the period of time available to starting mass production. Windmark et Al. (Windmark, Gabrielson, Andersson, & Stoehl, 2012) consider input time parameters in their LoA calculation such as cycle time, downtime, setup time, and batch production time. Gorlach et Al (Gorlach & Wessel, 2008) consider for cost estimating for their LoA methodology several time parameters such as cycle time, shift duration, manufacturing times for different operations: direct workers, quality control workers, re-workers, auxiliary workers. It can be consequently deduced from the references previously cited that time estimating is almost supporting LoA deciding, but allows also estimating the process cost for some of them where estimating different alternatives costs appears to be obviously one of the most important criteria in the topic of LoA deciding in assembly.

3. OUR APPROACH IN SYSTEMS MODELLING AND THE SUPPORT TO LOA DECIDING

In our studies, we would like to highlight, first, that searching optimal system design or LoA means finding the most suitable process the most closed to what is needed for a considered manufacturer from the given product to assemble design as well as planned productivity points of views with a lowest cost as possible. In addition, the system to design has also evidently to fulfill the different involved manufacturer criteria, constraints and capabilities such as initial investment potential. Process productivity criterion will require an estimation of the system production cycle time and other time criteria reflecting productivity performances and the related resulting system balancing study. This paper aims at defining time estimating framework and methodology for assembly systems alternatives to assess. This methodology uses ASML modelling language (Salmi, David, Summers, & Blanco, 2014) already defined in the context of LoA. In this approach, multiple ASML scenarios have to be generated and assessed. A scenario consists in one of the several options or alternatives in the assembly system design. A modelled ASML sequence with resources allocations considering the execution technology for each resource (human, machine, or robot) with consideration of the characteristics and performances of each of them will represent one system alternative through all the scenarios to consider and assess.

Estimating time for the different scenarios will make possible assessing systems ability to respond to productivity requirements, comparing scenarios and evaluating time savings from a scenario to another. Time estimating per task or per resource though the whole assembly lines will provide a way to evaluate and enhance the designed system's resources synchronization and to analyze and perform the global system balancing since the early design phase.

Because of the importance of time estimating in assembly and LoA optimizing, our focus in this paper will be dedicated to processes time estimating based on ASML models with rules for time estimation and others for performances assessing and improving that will be defined in the different sections though the paper.

3.1. ASML ASSEMBLY MODELLING: ESSENTIAL ELEMENTS & PRINCIPLES REMINDING

ASML language allows assembly operations representing using a standardized vocabulary of assembly elementary motions. The representation using defined rules to follow provides a good visibility and an easy understandability of the whole assembly process to design. It includes the selected assembly sequence considering based on product design, the required assembly motions and their precedence constraints, resources allocation as well as their management.

ASML uses specific symbols and rules for modelling. Basically, an ASML model can be considered as a block scheme representation of actions associated to conditions (Table 1). Actions contain elementary assembly motions using a list of standardized motions. Conditions consist in the different circumstances and conditions required for immediate next and previous actions through the represented sequence (Salmi, David, Summers, & Blanco, 2014).

An ASML sequence starts by a starting point and ends by an ending point. The ending point can be the end of the whole assembly or just the end of a sub-assembly (Table 1).

Table 1: ASML basic elements (reproduced from **(Salmi, David, Summers, & Blanco, 2014)**)

Action	***Condition***	
Action	Action *i* — C_x / C_y — Action *i+1*	
Starting point of Sub-Assembly/ Assembly	***Sub-Product Assembled / Sub-Assembly End***	***Final Product Assembled/ Assembly End***

3.2. ASML MODELS STRUCTURE

ASML as a graphic tool for scheduling allows representing serial sequences, parallel sequences (AND divergence and convergence), or decision sequences (OR divergence and convergence) using specific symbols (Table 2).