Development of a methodical approach based on value stream design to identify automation potential and subsequent implementation of a functional prototype

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Abstract—**Many companies are faced with the challenge of identifying automation potential in their company. This necessity can be motivated by factors such as a shortage of skilled workers, an increase in personnel costs or error avoidance. The desire to be recognized as an innovative company can also be a motivation for achieving a high level of automation.**

This paper intends to provide assistance in identifying and categorizing automation potential based on value stream design, as well as implementing a subsequent automation. Promising processes can be recognized by clustering. By combining, restructuring, or rescheduling the process steps, work – like assembling or handling parts – that is easy to automate can be carried out in one station using a robot.

A functional prototype is developed that meets the requirements specified by Stihl Tirol. A high degree of flexibility is required here, which in turn stands in the way of adhering to a specified cycle time. By using digital image processing, deviations are to be detected and, if possible, compensated for. By using a tool changing system, the prototype is intended to form a platform for evaluating other screwdriving processes in the company. In this way, a wide variety of screwing cases can be tested without great effort and automation of these can be included in the planning of new assembly lines. On the one hand, this prototype is intended to show how a company can proceed from identification to actual implementation and, on the other hand, to demonstrate further application possibilities by illustrating the flexibility.

Index Terms—**Value stream design, Automation potential, Robotics, Digital Image Processing, Automation**

I. Introduction

MOVING by itself is the meaning of the old-greek word αὐτὸματοζ , *automatos* [1] from which the term automation is derived. Plenk says, at least since the beginning of industrialization, people have tried to make life easier for themself by developing machines and devices that take over tasks and carry out processes independently. The Power Loom introduced in 1784, for example, relieved the weaver of the task of moving the shuttle, thereby increasing productivity. [2]

Companies, regardless of industry, are facing enormous challenges through digitalization that is changing the daily lives in practically all areas, whether private or professional. [3]

While the digitalization of production is very advanced these days, the production tasks often have to be done manually. This may result from different factors as technical possibilities, cost-effectiveness, time reasons or something else. To overcome these obstacles and implement automation to the production, innovative ideas have to be developed.

A concerning factor is the shortage of labour across all sectors in Austria. The Institute for Business Education Research 'Institut für Bildungsforschung der Wirtschaft (ibw)' [4] found that 37.0 % of the metalworking industry had a need for plant/machine operators and assembly workers in 2024. Particularly in 20.3 % of large companies with more than 250 employees, there is a frequent need for workers without specific qualifications and without professional experience. People without a specific qualification but with professional experience are frequently sought in 39.2 % of such companies. At 43.3 %, a large proportion of the metal industry states that a loss of quality or a higher susceptibility to errors in products or services is more likely or more likely to occur due to the lack of employees. The development of labour and skills shortages is also seen as increasing by 62.3 %. [4]

Lastly, taking away hard or monotonous work from employees is another good reason to implement automation in production. The term robot can be traced back to the polish and czech word *robota* [1], that means 'work hard'. Not only can it bring improvements for health, for example if heavy packages do not have to be lifted anymore, but also for motivation. Imagine a worker who only screwed parts together can move on to more complex and interesting tasks.

II. Methods

A. BPMN 2.0

The Business Process Model and Notation 2.0 (BPMN2.0) is the de-facto standard for representing processes in an expressive graphical way [5].

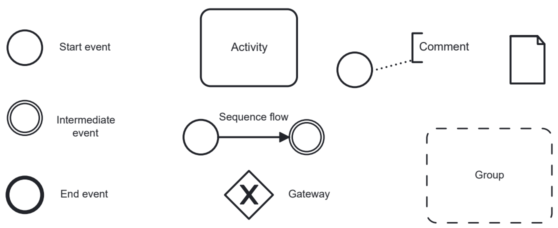

Fig. 1. BPMN2.0 symbols.

Figure 1 shows a collection of standard symbols of BPMN2.0 created with the open-source software *Camunda Modeler* that is distributed under the Massachusetts Institute of Technology license (MIT license).

B. Value Stream Design

Value Stream Design (VSD) is a well-known and widely used method of lean production. The aim of VSD is to present an existing value stream transparently, identify waste and eliminate it. After the analysis of the current state, the VSD is then used to develop a target state for the value stream with the aim of achieving a continuous flow of materials and short throughput times.[6]

McManus and Millard [7] describe Value Stream Analysis (VSA), which is often used synonymously with VSD in the literature, as a method by which lean principles are applied in the examination of business processes. VSA can be defined as a method that can be used to increase the understanding of a company's development efforts for the sake of improving these. [7]

Figure 2 shows a Value Stream Analysis of a metalworking company. The processes are always drawn from left to right on the lower part of the sheet. The customer is at the top right, production planning is at the top center and the supplier is at the top left. The basic value stream thus runs as a connection of these units in counterclockwise direction.[8]

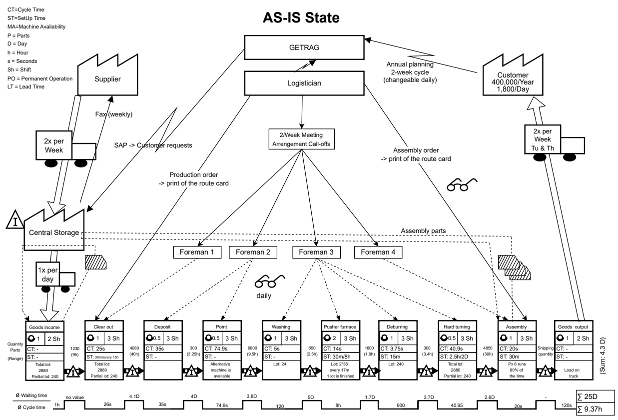

Fig. 2. VSA showing the as-is state of the example company GETRAG based on [8].

In order to develop a concept for automation, the system must firstly be observed to be analyzed in the further procedure. Secondly, promising process steps can be identified by clustering and rating them in terms of technical feasibility. The automation potential can then be further increased by restructuring or redesigning the production line. The planned procedure is shown in Figure 3.

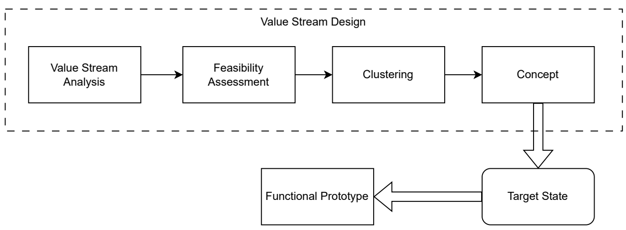

Fig. 3. Planned procedure using the value stream design.

1) Value Stream Analysis: Ten assembly lines defined by Stihl Tirol were observed and documented. This was done in collaboration with Jannik Löhle [9]. The focus was on the work steps of the respective production processes. An overview diagram (Figure 4) can help to understand the process as a whole. This corresponds to the process flow shown in Figure 2 in the lower section, where the stations are depicted as one element. The VSA is visualized using the BPMN2.0. The individual process steps provide a detailed representation of the sequence in the manufacturing process, as can be seen in Figure 5. The lack of processing times is intentional, as the Value Stream Analysis only serves as an overview and times will only be discussed after further evaluation of the automation potential. This will become clear in the following steps. Supply chains are also not discussed in this paper, as this would go beyond the scope of the work. The flow of information in the process between the assembly line and the Enterprise-Resource-Planning (ERP) system has already been optimized and is therefore not relevant in the Value Stream Analysis carried out.

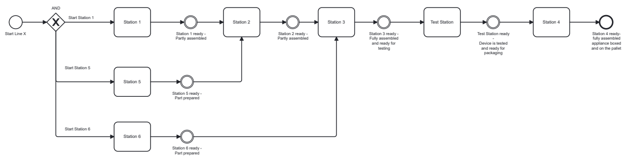

Fig. 4. Overview diagram of a fictive assembly line. (Data privacy)

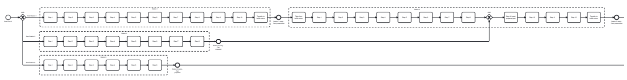

Fig. 5. Cutout from the process step diagram of the assembly line.

2) Feasibility assessment: Once the process has been outlined, the individual steps are assessed according to their feasibility. A traffic light color scale is very suitable for this. Here, green stands for simple feasibility, for example an accessible screw connection for which existing solutions can be used. For process steps with a yellow color, more effort is required, for example a tool change or the production of a special tool, in order to achieve technical feasibility. Red steps are very difficult to automate.
Whether an individual step can really be automated is only examined in detail after an automation concept has been created. The amount of work required for a comprehensive analysis of the technical feasibility of all process steps is far too great with so many lines included. This is mainly because, compared to the total number of steps, only a few are suitable for a useful automation solution.
With the evaluated process, shown as an example in Figure 6, a clustering can now be carried out to find similar processes. The visualization of the evaluation can also provide a good overall picture of the automation potential. Here the readability is not crucial, only the colour is needed to understand the automation potential.

3) Clustering: The individual work steps are divided into three defined categories:

- screwing,

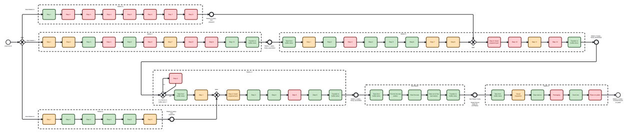

Fig. 6. Evaluated process of the assembly line.

- gluing and
- part-placing,

where gluing is described as the application of stickers and part-placing as the gripping and positioning of components or component groups. The reason for choosing these categories is that these operations occur most frequently in the assembly process and that they can be performed with existing solutions such as grippers or screwdrivers.

4) Concept: A concept that only requires a small amount of conversion work on the existing line is now developed. The three categories of gluing, inserting and screwing are each considered individually and an automation concept is developed for each. The automation is done with a robot arm manipulator with 6 degrees of freedom. With the visualization of Value Stream Analysis, steps that are close to each other can be identified. The stations with the highest number of potentially automizable steps are shown in Figure 7. As the positioning in the real system is important in this step of the Value Stream Design, all planning steps are carried out in the layout plan of the assembly line. After assessing every process step

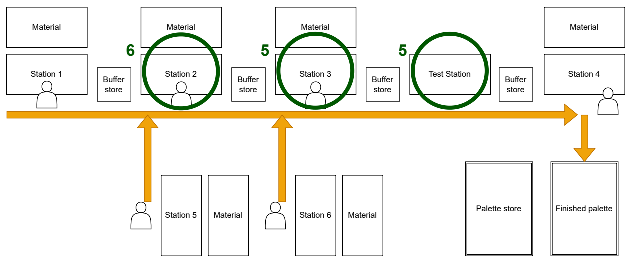

Fig. 7. Layout of the assembly line with annotated automation potential. The yellow arrow represents the work flow, beginning in the left corner. The green circles mark the stations with their according number of automizable steps.

that should be automated in detail, the concepts for each category are implemented in the layout of the production line. This can be seen in Figure 8 where the robot cells are incorporated in the existing line.
A downfall of the part-placing cell is the supply of devices. This would require the buffer stores to be redesigned to allow an automatic handling of

appliances.
The stickers should also processed in the combined part-placing and gluing cell. One challenge of an implementation would be the different geometries and the exact positioning of the stickers, as well as the combination of the vacuum gripper for the stickers and the gripper for the device.
For the screwing cell, the challenge lies in the ability to change the tool automatically during runtime and the adherence to the conveyor cycle time.

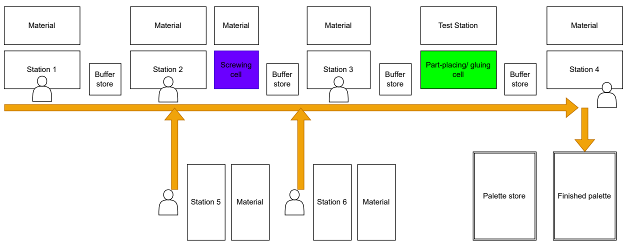

Fig. 8. Alternated layout of the assembly line with the developed robot cells.

In accordance with Stihl Tirol, the task of screwing is chosen as application. Whether and how such a concept of a screwing cell works, in particular the processing of different fasteners, is proven by designing and building a functional prototype.

C. *Machine Vision*

Machine vision is, according to Nof [10], often used in automation. These systems are used for measurement, guidance and inspection tasks. This technology plays a crucial role in increasing manufacturing efficiency and assembly quality through automated handling. [10]

To enable the robot to react to small movements of the workpiece carrier or irregularities of the position of the upper housing, the VS-C160MX with infrared flash from Keyence was selected as the camera system. With the configuration software *VS Creator* various distinctive points can be recognized and measured. This can be seen in Figure 9.

III. Prototype

The requirements for the functional prototype were defined together with Stihl Tirol as follows:

- Mobile screwdriving cell
- Simple integration into existing lines
- Automatic tool change
- Pick-and-place application
- Automatic screwing of an iMOW© housing

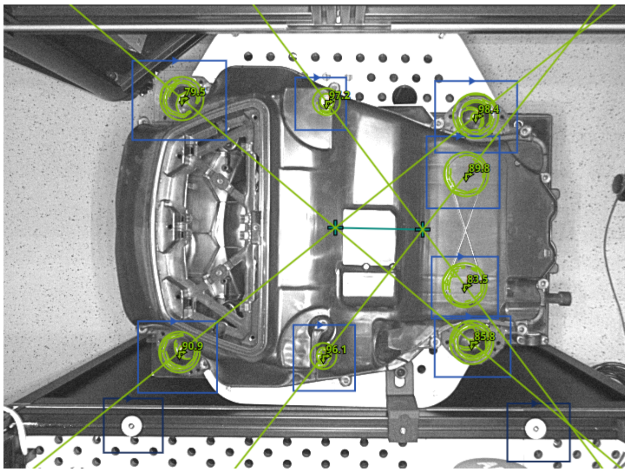

Fig. 9. Illustration of the extracted features for measurements.

The mobile approach of the cell can be seen in figure 10 on the basis of the transport rollers and the possibility of moving the cell over the assembly line without any interference.

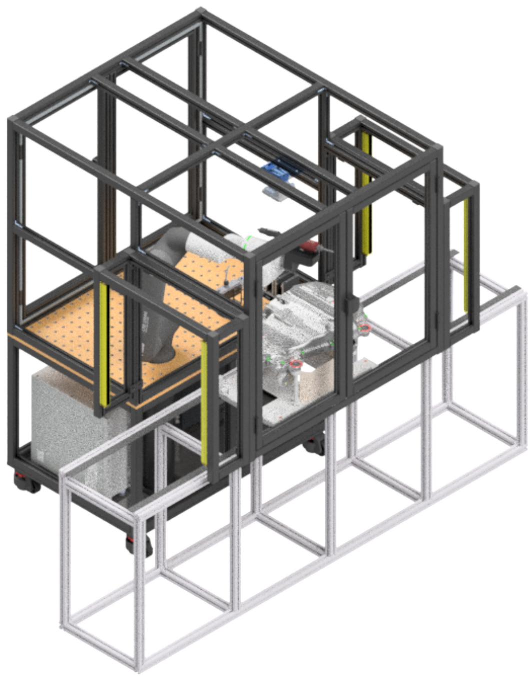

Fig. 10. Planned screwing cell [11].

By using light curtains for the openings of the cell, the safety can be ensured and the part can be transported through with the conveyor belt. However due to safety standards the geometry of the cell had to be adopted in terms of space between the light curtains and the robot. The prototype was developed in collaboration with Anton Brotsmann [11]. Figure 10 shows the planned cell.

The system consists of

- a CRB 15000 5-950 from ABB as robot manipulator with the according controller OmniCore C30,
- a screw feeder STF8010 with external supply unit from Stöger Automation,
- the screw driver system SPATZ04 from Stöger Automation that uses the ETD ES21-04-I06-PS motor, as well as the matching controller Power Focus 6000 from Atlas Copco and
- the VS-C160MX camera from Keyence.

The connection of these components with the ABB OmniCore C30 robot controller is shown in Figure 11.

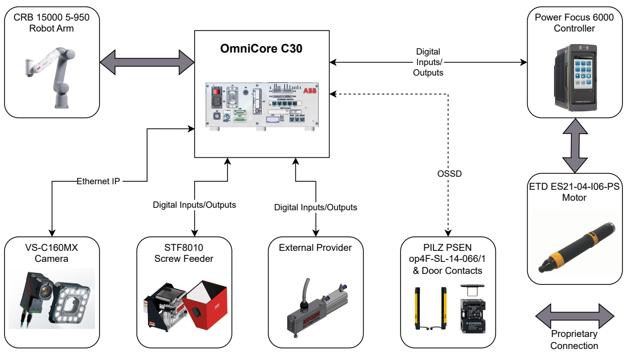

Fig. 11. Communication protocols of the components with the robot controller.

To confirm the accessibility of the screws and simulate the automated process, the geometry of the housing and the SPATZ04 are implemented into RobotStudio©. There a collision set can give instant feedback if the tool or the robot is colliding with the housing geometry. As a result of the simulation, an adapter was developed, which can be seen in Figure 12, where the attached **S**TÖGER **P**ick&Place Schraubroboter mit **A**utomatischem **T**oolchange und **Z**uführsystem für Verbindungselemente 04 (SPATZ04) with the connected motor is shown.

IV. Results

To test the capacity, a production process is simulated with eight iMOW© housings that are fed in by hand. A video recording is done with several cameras to help evaluating the process times and track down any occurring errors.

Fig. 12. Mounted SPATZ04 system screwing the housing of an iMOW©.

The Figure 13 shows the mean values of the duration of the outward movement to the screwing location, the screwing duration and the duration of the return movement to the separator. On average, a complete screw assembly takes 141.34 s – this duration is almost 17 s longer than the current cycle time of 125 s.

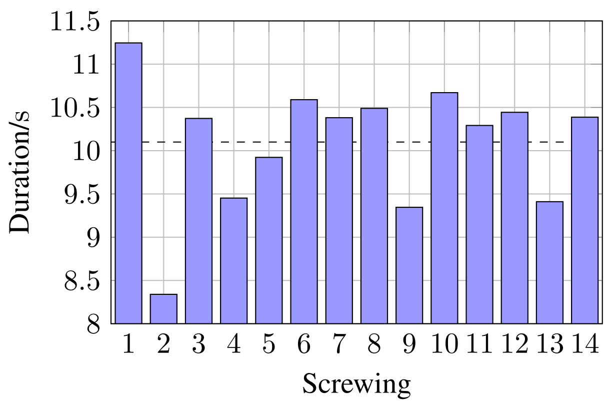

Fig. 13. Mean values of the screwing processes from eight housings with the average duration illustrated by a dashed line.

Figure 14 shows the composition of the duration of the movement times and the screwing time on average of the 14 screw connections on eight housings.

V. Conclusion

This paper represents a way of planning and realizing automation from the ground up. From the survey of the current status to the testing of the prototype, an attempt was made to provide a consistent scheme that

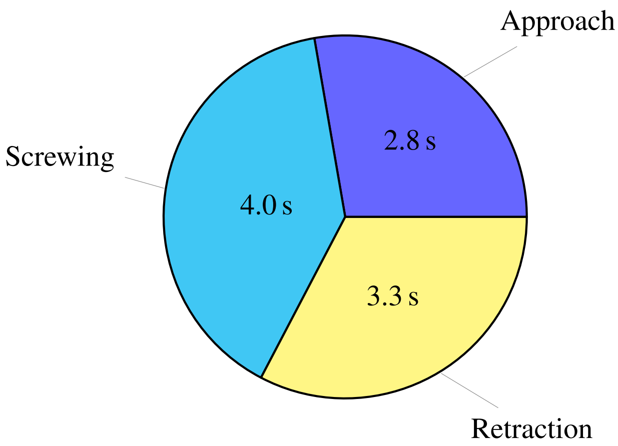

Fig. 14. Distribution of the screwing process with the average duration of 10.1 s.

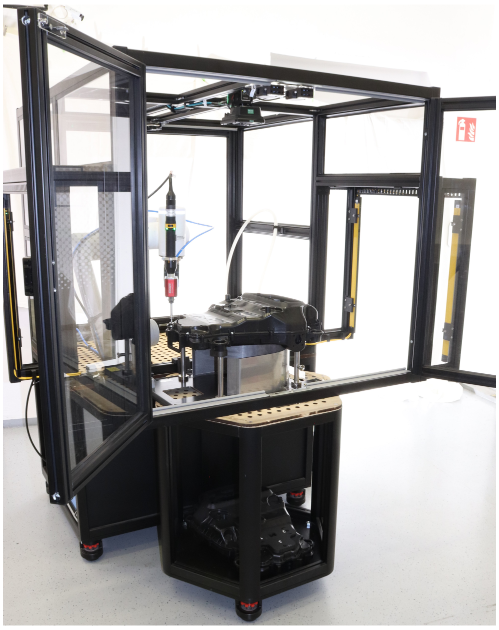

Fig. 15. Image of the developed cell.

should help to find and implement further automation solutions. The developed screwdriving cell can be seen in Figure 15.

The task of screwing iMOW© housings specified by Stihl Tirol could be realized, but not within the current cycle time. However, this functional prototype provides an important gain in knowledge, as it is not necessary to rely on simulated or estimated values. By using a tool change system, other screw connections can also be tested, which allows the prototype to be used as a test platform. It can also be used as a demonstration or training object to familiarize production planners or specialist personnel with screwdriving automation

Acknowledgment

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