PROCESS-ORIENTED ANALYSIS

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Abstract

The consistency in logic between a stationary, process-oriented description of the system and its state-oriented counterpart is an important requirement imposed by automated manufacturing systems. In the late 1980s, computer-aided software engineering tools were developed to work with complex software systems. With these, the focus was on immaterial flows such as data and information. In searching for a method that could graphically describe complex systems, we developed our new methodology, Process-Oriented Analysis (POA). We have enriched the basic static diagram types of Structured Analysis with value and resource flows, and introduce consistent rules for the handling of resources, costs and data. The dynamic diagram types serve to describe the behaviour of the system, and lead to the programming of simulations and machine controls. The static diagram types reveal the structure of the system as flows and processes. The diagrams are hierarchically structured on several levels of detail, allowing an in-depth analysis of complex systems with numerous sub-systems. A system optimisation is possible based on costs or on energy. The dynamic diagrams support plant simulation, real-time monitoring and control systems, and sustainability models. The dynamic diagrams are consistent with the static diagrams, and simplify program design and coding.

Keywords:

System analysis, system engineering, structured analysis, value flow diagram, resource flow diagram, state chart, simulation, control, optimisation

OBJECTIVES OF POA

Process-Oriented Analysis is a method for the set-up and execution of projects in complex manufacturing plants. These projects can either be the planning and new conception of production plants, the reengineering of existing process lines and production systems, or the reverse engineering of processes and systems. POA is both useful in education to guide students through a project or system analysis, and for practitioners or consultants to analyse weak points in a production or a company. The advantages and objectives of the Process-Oriented Toolkit are the following:

- to provide a comprehensive Process Analysis Toolkit that highlights the importance of production interfaces, economic and energy analysis as well as code generation;
- to present the system in a visually appealing, full-colour format and an easy-to-read style that invites students to learn;
- to apply systems analysis and design in the context of optimising and planning real-world production plants.

Delimitation UML

POA uses just two types of diagrams, dynamic and static, allowing two fundamental viewpoints of a system. UML offers a higher variety of diagrams and perspectives, but the positioning of ??[[these / thesis]] diagrams is not clearly defined. The view of requirements, represented by its own diagram type in UML, is incorporated into the static diagram of POA. Using POA, the process specifications define the requirements for the system in general and for specific cases.

The single diagrams partially correspond to each other. The UML State Diagram corresponds mainly to the state-based view of the POA State Chart. There is no equivalent diagram type to the POA Flow

Diagram within UML. Therefore, the POA method is called process-oriented instead of object-oriented. UML does not support a topological view of a system. Furthermore, experience with the method has shown that with set time constraints, the POA toolbox is sufficiently accurate to analyse production systems.

STATIC ANALYSIS

The first step in analysis is the system specification, which is carried out using a static model called the Flow Diagram that shows the processes and flows of production systems. This brings initial insights into the interfaces between the processes. The topological analysis is the first step for every type of process analysis. In Figure 1, box A1 depicts the Flow Diagram, which is the starting point for the other analysis paths.

The economical analysis of a process chain is introduced by drawing a Flow Diagram made of processes and flows. Each flow has a value that is used to calculate the value of the product and is read from the diagram. This makes the Value Flow Diagram a graphic value analysis tool. In Figure 1, box A2 represents the Value Flow Diagram. Value flows within a company are matched graphically with the product flow. By this, the value added is followed step by step along the production process, and the origin of the costs is immediately visualised. The values are then added to the flows, and calculations are carried out to achieve the economical analysis.

The ecological analysis is based on the static Flow Diagram. It is supplemented with resource values for the resource flows. The Resource Flow Diagram is depicted as box A3 in Figure 1. The analysis includes the calculation and balancing of natural, technical, and human resources. Energetic and exergetic balance and efficiency are introduced and visualised as a tool for ecological valuation. The exergy is focused upon because it is the technically relevant parameter concerning energy reuse. A ranking table is used for a quantitative environmental analysis within industrial process chains. Human resources are included in this diagram to highlight the relationship between machinery work and the human workforce. In the context of partially automated production lines, this relationship differs. A calculation and optimisation step based on the flow values results in recommendations for improvements of the production system.

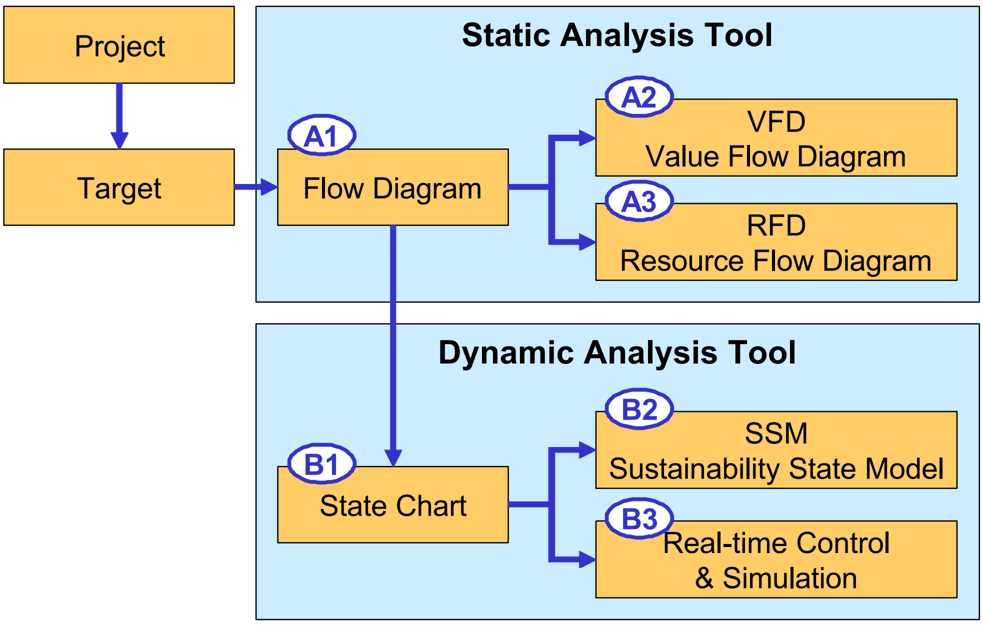

Figure 1. Toolbox of Process-Oriented Analysis

Dynamic analysis

The system behaviour analysis is based on a dynamic view of the system depicted by a State Chart. The State Chart is made for a process of the Flow Diagram and is represented in box B1 in Figure 1. Processes are modelled and optimised on a time-dependent basis. The State Chart specifies the state-based behaviour of the system by defining states and transitions for a process. To change a state, the transition must be triggered by fulfilling a condition.

The sustainability and efficiency of an industrial production line is measured and calculated compared to other production systems. This is done using benchmarking in the Sustainability State Model. Box B2 of the POA toolkit in Figure 1 represents the Sustainability State Chart. The process of interest is analysed by a Sustainability State Chart. Benchmarks are set for the system in order to transit to a more beneficial sustainability state of the system. The Sustainability State Chart is a two-level diagram. The top, strategic level imposes the new benchmarks. On the operational level, the behaviour of the production processes towards the new benchmarks is modelled.

Within design and coding, POA attempts to control a machine and model its behaviour, or to model the interaction of a production. A computer program based on a State Chart of a process performs this. Box B3 of Figure 1 depicts the part simulation and coding. The states of the dynamic model are the basis for program modules, and result in a real-time control for a machine or a simulation of a system. A simulation is programmed in order to investigate a production line and scenarios for alternative processing; it is also used to check the performance of machines. Control systems are programmed to enable the set-up and operation of production machines.

Case study 1: Ecological analysis and comparison of four cotton products

Subject of the study

The goal of the study is a production comparison of four cotton products, which fulfil the same functional specification. The production alternatives are compared by the Resource Flow Diagram. The system boundary is set by the context diagram, which is the same for all the production alternatives. The system boundary contains the spinning, knitting and finishing processes. The product specification is a natural-coloured cotton-knitted fabric with low hairiness and therefore reduced pilling. By eliminating much of the hairiness of the fabric, pilling is reduced and therefore the life of a textile is prolonged. The production alternatives are shown in Table 1. The analysis is carried out for a production goal of 1000 T-shirts with a cloth weight of 150 g/m2.

Table 1. Specification of the compared cotton products

Product	Spinning	Knitting	Finishing
Product 1	20 tex ring yarn	Single Jersey Normal knitting tension	Singeing Washing
Product 2	10 tex ring yarn 2 x 10 tex twist	Single Jersey Normal knitting tension	Washing
Product 3	20 tex compact yarn	Single Jersey Normal knitting tension	Washing
Product 4	20 tex ring yarn	Single Jersey Normal knitting tension	Washing Enzymatic treatment

The resource flow diagram in Figure 3 shows the resource flows and values for the production of Product 3. The resource flows carry a flow specification, which consists of the flow values mass, total energy, embodied energy, exergy and eco-index. The diagram displays the flow values mass and total energy. The flow colours indicate which flow types are balanced in the same mass balance. The energy balance is calculated on the basis of the total energy of every energy and material flow.

Results

The energy consumption for the production of the four products varies significantly, as shown in Figure 4. Surprisingly, the processes with highest energy consumption are the spinning processes and not the finishing. It is obvious that Product 2 has the highest energy consumption because of the additional twisting process, which consumes a great deal of energy. The spinning process for the compact and ring-spinning consumes approximately the same electric energy. However, the compact yarn does not require an additional process for the elimination of the hairiness in the finishing process, because compact yarn has already a low hairiness. Therefore Product 3 is more beneficial regarding energy consumption. Products 1 and 4 are both ring yarns and undergo a different finishing process for the elimination of the hairiness. Product 1 undergoes a chemical burning process, and Product 2 undergoes a biological-enzymatic process. From the point of view of energy, the biological-enzymatic treatment requires more energy because of the necessity to heat a considerable amount of water for a period of time.

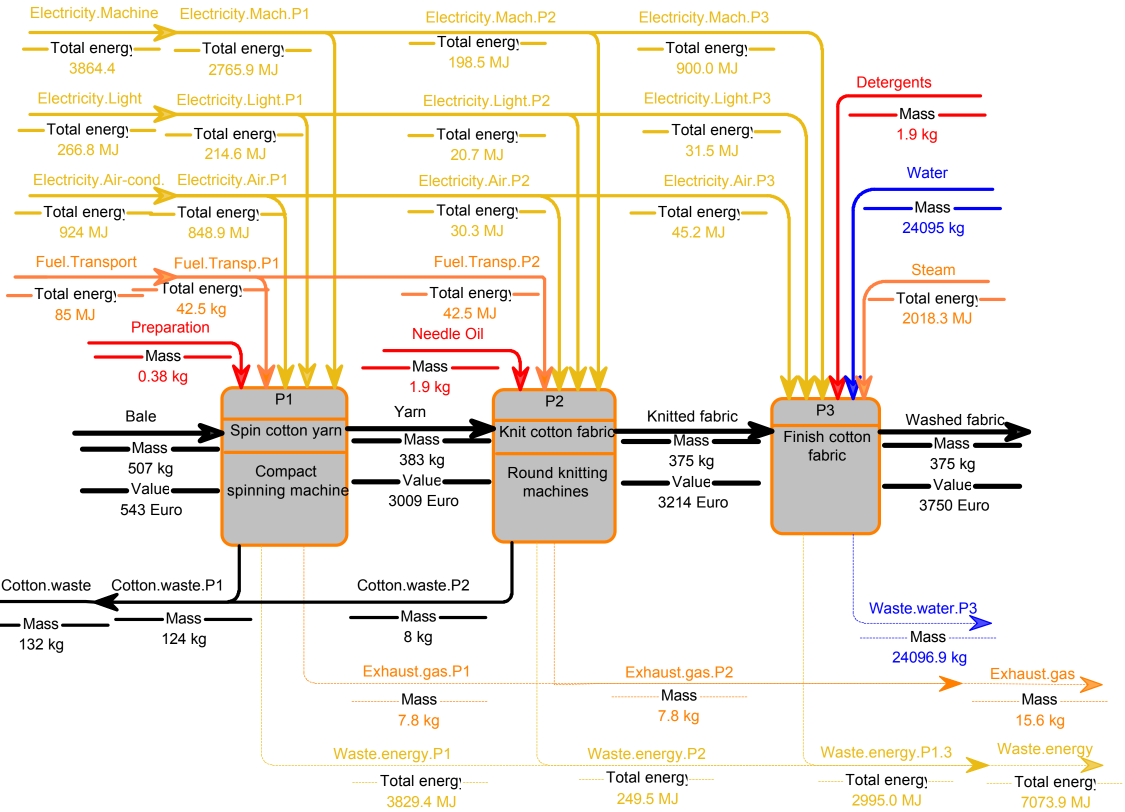

Figure 3. Resource Flow Diagram for the production of Product 3

The four production alternatives to producing a product with the same property concerning the hairiness have different environmental impacts. Typically for the textile production chain, a required property of a textile can be implemented by different production alternatives at various stages in the production. As regards energy consumption and production of emissions to water and air, Product 3 is the most environmentally friendly fabric. It is favourable in meeting the properties concerning hairiness already in the spinning stage by producing a compact yarn, without additional processes such as twisting.

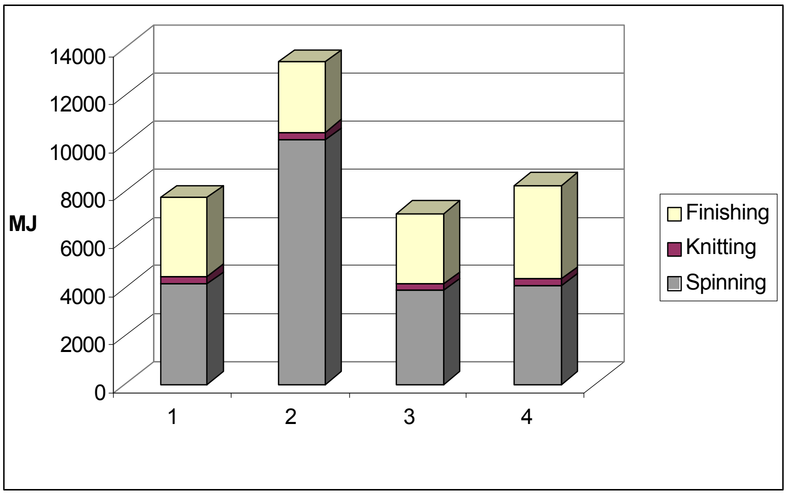

Figure 4. Energy consumption of the alternative production lines

In this way the emissions to water and air in the finishing process can be reduced. Within the finishing process the biological-enzymatic treatment causes considerably more emissions to water and also more emissions to air than the singeing and washing process. The cost analysis shows that Product 3 is also the cheapest production alternative. Product 1 has low production costs; the costs for the additional singeing process are only slightly higher than the costs for the compact yarn compared to the ring yarn. The costs for the twisted ring yarn are the highest, even higher than the costs for Product 4 with the additional enzymatic treatment.

Case study 2: Simulation of future high performance weaving

Subject of the study

The objective of this study is to simulate the personnel interaction needed with a new efficient weaving machine. A new efficient weft insertion principle is implemented in the M8300 weaving machine. At the same time, four parallel ??[[timely]] graded weft yarns are introduced into the warp, which tremendously increases the production speed compared to a common weaving machine with just one weft insertion at a time. This analysis is a new concept of the weaving process based on the new technology. It is carried out by programming a simulation which aimed at previewing further production scenarios with the M8300.The first step is to depict a Flow Diagram for the weaving process. The processes then are analysed on their behaviour by a State Chart. The State Chart for the weaving process is depicted in Figure 5.

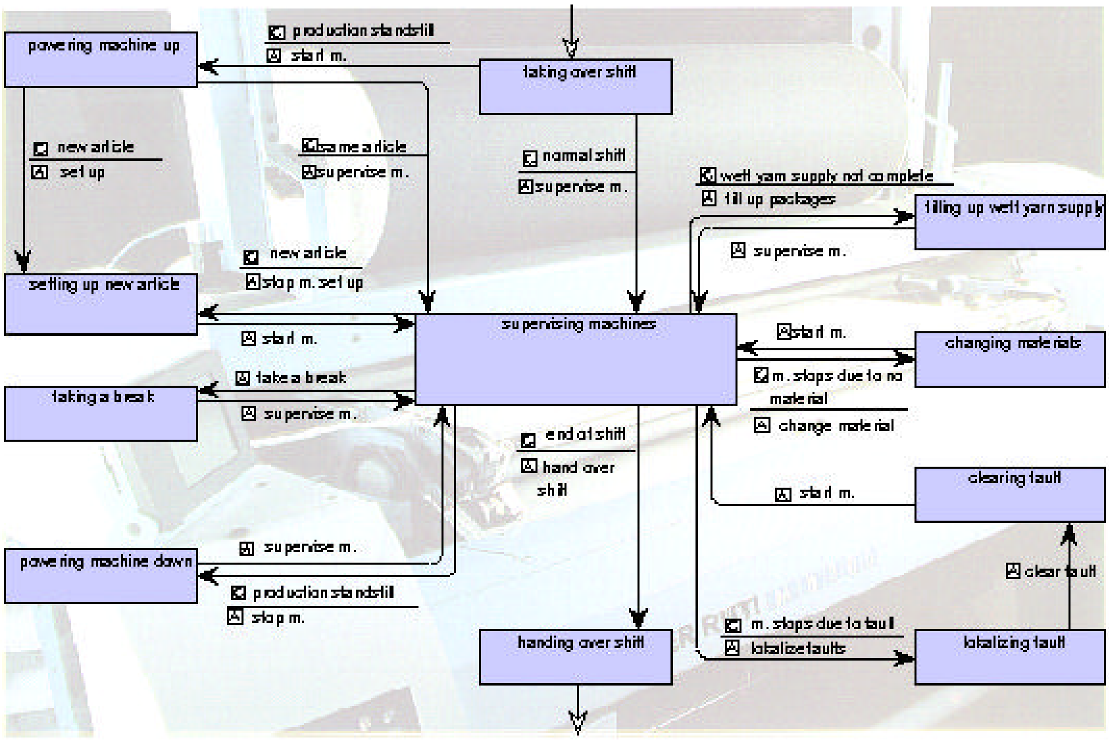

Figure 5. State Chart of the weaving process

Results

The states depicted by the State Chart are specified until they represent an uninterrupted activity in reality as well as in the computer model. These states are collected in the state list. The numbers of the states are a unique identification and may only be used once. The program is elaborated on the basis of this state list. In the program part called ‘parameter input’, the user sets all the needed variables in different masks. The core of the simulation program is composed of nine modules. Before starting the simulation cycle, the ‘initiate’ module is passed once. At that stage, several start configurations of the machine are set concerning the amount of warp already woven and the amount of used weft bobbins. The goal of the simulation is to investigate the optimal use of the new M8300 weaving machine in the plant. The question evaluated by the simulation is the optimal number of operators needed for the new machine.

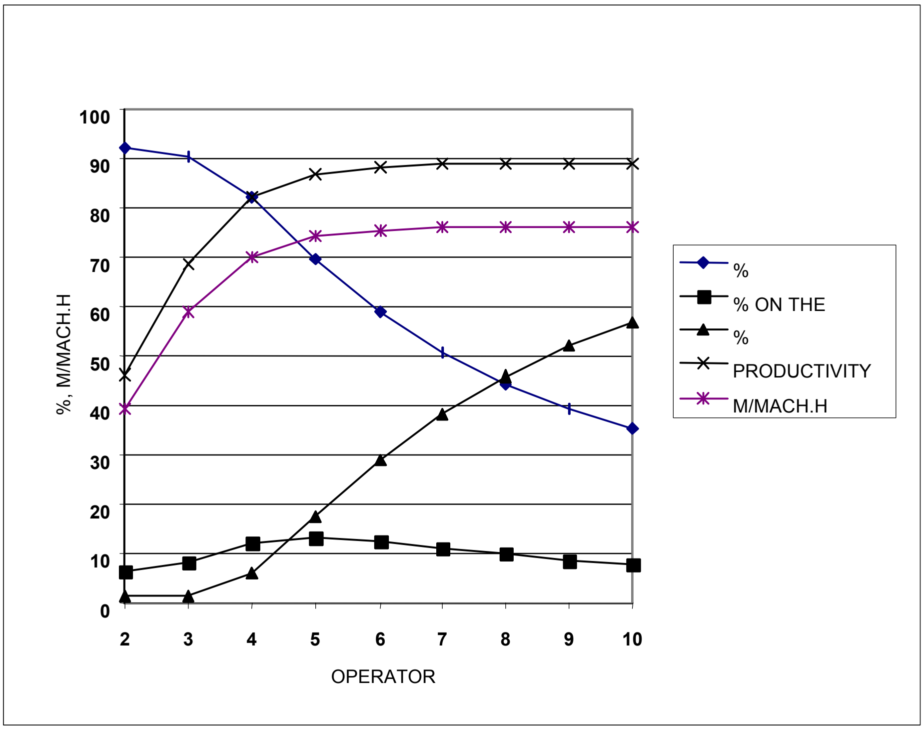

Figure 6. Result of simulation run of M8300

The best relationship between efficiency of the operator and the machine is reached by six operators. Figure 6 shows that the saturation zone of the productivity and machine efficiency is reached with between 5 and 6 operators. At that point, the percentage of work is between 60 and 70%.

Conclusions

Process-Oriented Analysis is a useful method for education in and research into complex production systems. The step-by-step procedure and the consistent relationships between the diagram types allow a straightforward set-up and execution of a project. Applying this method in education and projects with students showed that first results based on models and programs were achieved within a few weeks. The strength of this method is that simple and complex processes can be analysed at the same time in a static and dynamic way. Carrying out various projects and case studies, it became clear that POA is applicable in every production situation: new conception, reengineering and reverse engineering.

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