Coping with complexity

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Publication date:
1981

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Rasmussen, J., & Lind, M. (1981). *Coping with complexity*. Risø National Laboratory. Risø-M No. 2293

RISØ-M-2293

COPING WITH COMPLEXITY

J. Rasmussen and M. Lind

Abstract. In the report we discuss how computers can be used to assist the process plant operator in coping with complex situations during plant disturbances. The main idea is to use the computer for integrating plant measurements into information related to different levels of abstraction and aggregation. The basis for the data transformations is a hierachical multilevel plant description which identifies the variables and processes which are relevant to consider at the different levels. At the same time, the multilevel description provides a representation of the functional organization of the plant. This makes such a description useful for design of information displays which can be used by the operator in diagnosing disturbances.

The multilevel description is closely related to plant descriptions derived from analysis of verbal protocols. Accordingly the approach leads to a design of the man-machine interface which can support an advanced dialogue between the operator and the plant computer in diagnosis.

UDC 65.015.1 : 681.333

June 1981
Risø National Laboratory, DK-4000 Roskilde, Denmark

Presented at the European Conference on Human Decision and Manual Control, 1981. Delft, The Netherlands.
Revised reprint.

ISBN 87-550-0769-4
ISSN 0418-6435

Risø Repro 1981

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INTRODUCTION

A major topic in a discussion of safety aspects of modern industrial installations is invariably the complexity of the plant operators' work situation during abnormal plant operation. A situation is painted of a control room with thousands of instruments and indicators offering potentially important information, while hundreds of alarms assisted by a couple of screaming horns try to guide the operators' attention. The situation in highly automated plants has very picturesquely been characterised by 99% boredom and 1% horror (Bibby et al. 1975).

The conclusion of such discussions is typically one of two: Either it is argued that operators need more effective training, or it is concluded that modern information technology should be used to assist the operator in coping with complexity by using computers for analysing disturbances and presenting information by advanced displays. The present paper aims at a discussion of the potential for assisting the operator in coping with complexity by means of computerized situation analysis. However, before turning to computer support, it will be helpful to discuss the concept of complexity and to analyse how people cope with complexity without the assistance of computers.

THE CONCEPT OF COMPLEXITY

What is complexity and how is it measured? In a discussion of complexity of diagnostic tasks, Rouse et al. (1980) distinguish between subjective complexity and objective complexity, which can be defined and quantified. The literature review of Rouse et al. mentions a number of attempts to quantify complexity in terms of number of items to consider during analysis, or the number of alternatives to choose from. But what does this complexity measure describe? One may argue that objective complexity of a physical system does not exist. The complexity observed depends upon the resolution applied during information search. A simple object becomes complex if observed through a microscope. Objective complexity can only be defined for a given representation of a system, not for the system itself.

For industrial plants, the complexity faced by operators is determined by the representation of the internal state of the system which the interface allows the operator to develop for the various work conditions. This means that the complexity perceived by the operators is determined by the technology of the interface system. During a period when instrumentation is governed by the one sensor - one indication technology, only one level of resolution of the representation is available to the operator, and this has to be the most detailed one needed in any situation. In that case the interface must be complex by the law of requisite variety (Ashby 1960). However, if the resolution of the representation and the focus can be selected to suit a given situation, complexity need not be a fact of reality. To do this is precisely what is possible by use of computer processing of the measured data. However, great care should be taken when a computer is used to generate task specific displays in order to match the representation used for displays to the operators' preferred work strategies and understanding of the processes. If this match is not successful operators may be left with the even more complex situation of having to evaluate the information processes of the computer.

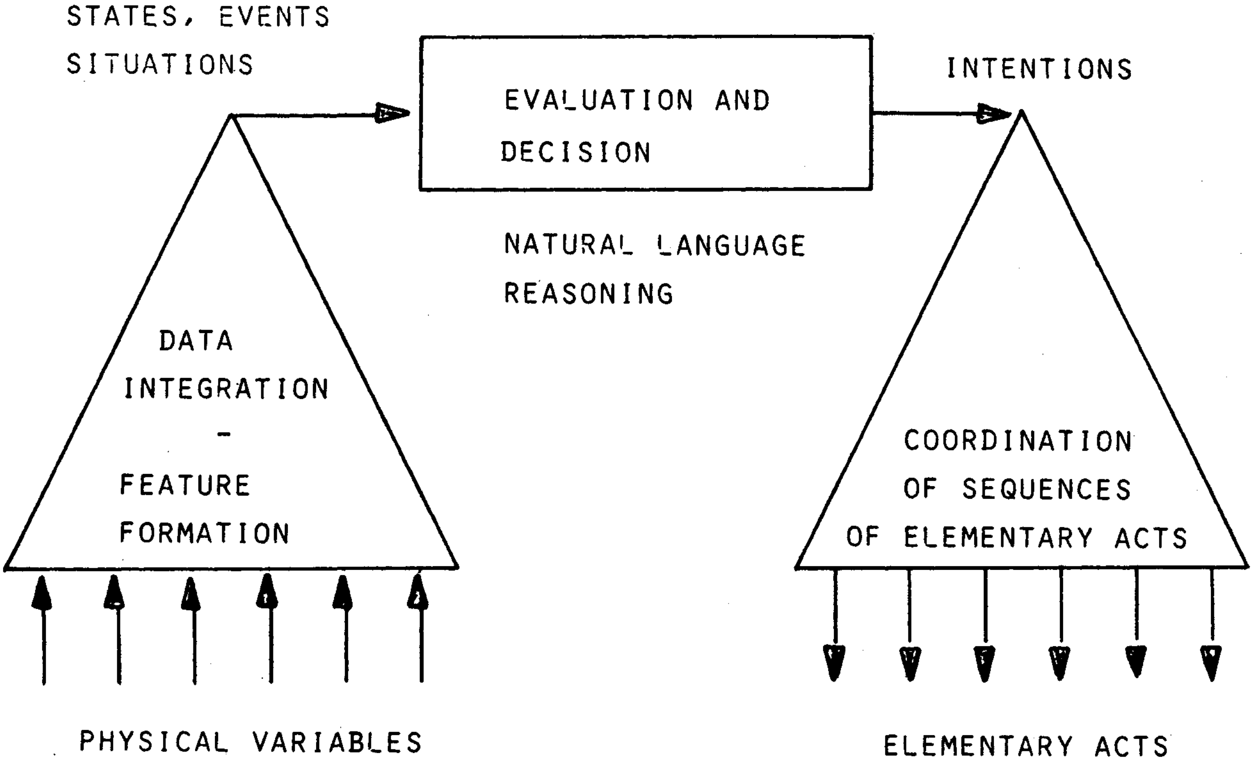
OPERATORS' TRICKS IN COPING WITH PRESENT COMPLEXITY

Since the human capacity for analysis and decision in a non-routine situation is notoriously limited to consideration of a very limited number of items of information, the only way to cope with the high number of information sources and of devices of elementary actions (e.g. switches and valves) found in an industrial plant, is to structure the situation and to transfer the problem to a representation at a level with less resolution. The total data processing task then is: To structure the information at a higher level representation of the states of the system; to make a choice of intention at that level; and then to plan the sequence of detailed acts which will suit the higher level intention, see fig. 1.

Humans are very well equipped for this tripartite task in the everyday concrete environment when navigating their body or manipulating objects - be it physical objects or symbols on paper which behave like artificial objects. This capability depends on the possibility of direct perception of higher level states and values as features in the information patterns received from the environment, and on the possibility of forming integrated motor patterns which can be activated by higher level intentions or orders. Both are depending on direct operation in a time-space world where movements are controlled by signals which have no symbolic or indirect meaning, and which can be treated simultaneously by data driven transformations in a parallel processing network. This processing also depends on quantitative (analogue) representation of the time-space signals for the control of movements.

The higher level conscious decision-making is related to states, values, and intentions for acts. This depends on another human trick in coping with complexity: Common sense natural language reasoning is based on qualitative representation of (large) sets of physical variables in terms of objects and functions which are characterised by states and properties rather than by physical variables and their quantitative relationships.

In both respects, the work situation in a traditional control room is posing problems to the natural human way of processing the data. Only in special and very familiar situations can operators operate directly on the time-space aspect of the display devices - only in some tracking and feedback adjustment tasks can they operate from the "expressions of the face of the system". In most cases, however, they have to consider the information to be symbols of the internal state of the system.



CHARACTERISTICS RELATED TO WORK ENVIRONMENT:

	DATA INTEGRATION	COORDINATION OF ACTS
EVERY-DAY CONCRETE, PHYSICAL ENVIRONMENT	PERCEPTUAL FEATURE FORMATION AND INDENTIFICATION	AUTOMATED SENSORI-MOTOR PATTERNS
CONTROL ROOM WITH ONE-SENSOR-ONE INDICATOR TECHNOLOGY	CONSCIOUS, FUNCTIONAL ANALYSIS OR SHORT CUTS FROM STEREOTYPE SIGNS, EXPECTATIONS AND PROCESS-FEEL	PROCEDURALISED ACTION SEQUENCES

Figure 1. Characteristics of human data processing depend on work situation.

Basically, this means that the relevant set among the physical variables presented should be selected and integrated by a functional diagnosis, since traditional display techniques do not allow for efficient perceptive identification. In this case humans exercise another efficient way of coping with the most frequent situations: They notice correlations and select one or a few convenient indications as signs of internal states. Generally a very efficient trick, but disastrous when faults change the system's behaviour, since the convenient but not defining signs then lead operators into traps. The basic feature of signs is that they refer to actions and are not one to one representations of system states.

A few other tricks assist the operator in the less familiar work situations. An efficient one is not to operate on absolute data, but to base the judgements on deviations from normal or familiar situations and system states. This is of course tightly connected to the use of qualitative information, since unfamiliar situations are qualitatively most conveniently labelled by referring to known familiar situations or system states. Another efficient trick is not to start every decision by collecting all the information needed. A skilled operator who cooperates with a system has very firm expectations regarding the state of the system, and therefore only looks for signs which are suitable to confirm or disprove his expectations - and only when he has doubts. A simple input-output model of an operator is therefore not acceptable for less familiar situations.

Decisions based on signs are only effective for situations for which the necessary conventions have had the chance to evolve. For new or unfamiliar system state caused by infrequent conditions or faults, the operators' identifications and decisions must be based on observations treated as symbols, i.e. representations for concepts related to the system's internal causal structure. The operators' symbolic data processing then depends on an internal or mental model of the causal structure of the system, and again humans have a number of ingenious ways to circumvent complexity by transfer of the problem to a representation suited to treat the present problem (Rasmussen

1979). The major tools are hierarchical aggregation/decomposition to change the resolution of the attention applied to the problem - which is very often coupled to a change in the level of abstraction used for the causal representation. Another tool is transformation into a representation for which solutions are ready from previous occasions. Hierarchical decomposition/aggregation is related to the span of attention of the operator, to the level of detail or resolution applied for data processing. A change in the level of abstraction is, however, related to the type of concepts used for representing the system and is basically independent of the level of hierarchical decomposition applied, although in practice there seems to be some correlation in the two concepts, as illustrated in fig. 2. Aggregation and abstraction hierarchies play an important role in human problem structuring and for systematic computer support, and will therefore be discussed in more detail. Fig. 3 gives illustrations of aggregation and abstraction.

AGGREGATION AND ABSTRACTION HIERARCHIES

The internal representations of the system's functional properties which are necessary for causal reasoning are available to operators in very flexible variations, and can be fitted to the problem at hand by varying the span and resolution of the model and the level of abstraction of the concepts used for modelling.

The resolution of the model is controlled by aggregation/decomposition of the elements used for representing the system. For example, the system can be considered as a hierarchy of parts ranging from elementary parts and components - nuts and bolts - to the complete plant while fig. 3 illustrates, among other things, a decomposition/aggregation in the functional domain.

Thus the hierarchy can be structured in many ways. However, in the context of control system design and operator decision

AGGREGATION/DECOMPOSITION

- PLANT
- SUB-SYSTEMS
- EQUIPMENT
- COMPONENTS
- PARTS, NUTS AND BOLTS

ABSTRACTION

- PRODUCTION FLOW
- ABSTRACT FUNCTIONS, SYMBOLIC FUNCTIONS
- GENERALIZED FUNCTIONS
- PHYSICAL (MECHANICAL, ELECTRICAL, CHEMICAL) FUNCTIONS
- PHYSICAL FORM, MATERIAL

TYPICAL COUPLING BETWEEN AGGREGATION AND ABSTRACTION

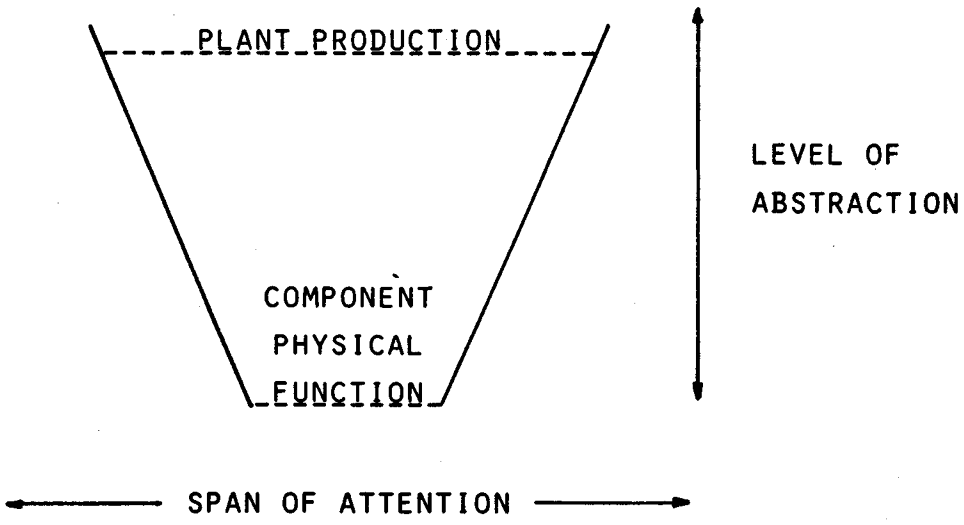


Figure 2. Illustration of the aggregation and the abstraction hierarchy and their typical coupling.

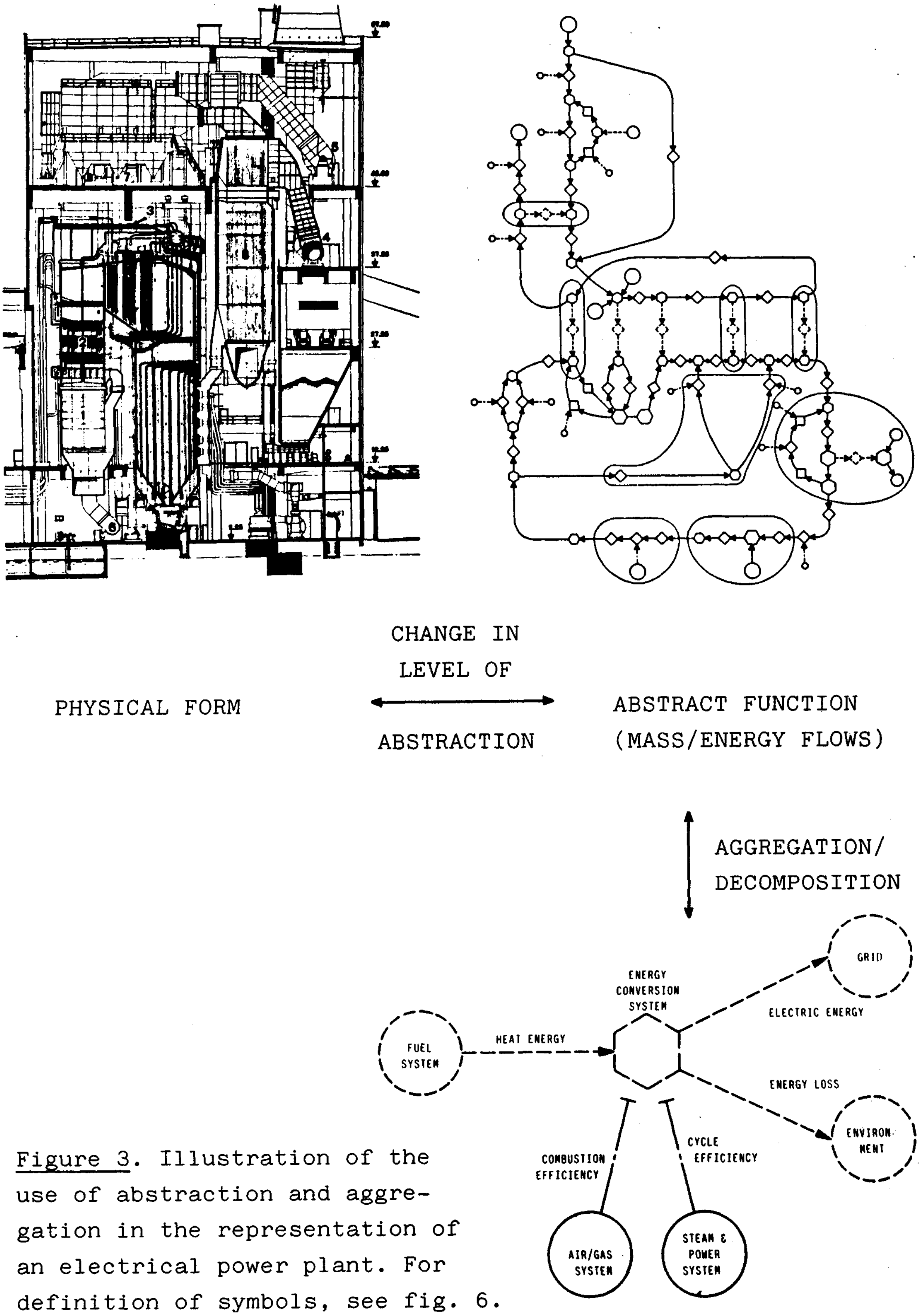


Figure 3. Illustration of the use of abstraction and aggregation in the representation of an electrical power plant. For definition of symbols, see fig. 6.

making, the hierarchy is naturally structured by the way in which the components are connected into functional units. In order to have an orderly synthesis of overall plant function during start-up, it is necessary to establish a number of autonomous functional units at one level before they can be connected to one functional unit at the next higher level; compare Simon's watch maker (Simon, 1969). This definition of autonomous functional unit at several levels is likewise important for orderly breakdown of system functions for shutdown or emergency actions. It immediately appears that a set of generic operator tasks during start-up can be defined: Coordination of functional states in a number of autonomous functional units; a network task of switching and valving to integrate into one higher unit; an adjustment of the operation of the unit to stabilize and optimize the total function of the unit.

In the abstraction hierarchy, the system's functional properties are represented by concepts which belong to several levels of abstraction, see fig. 4. The lowest level of abstraction represents only the system's physical form, its material configuration. The next higher level represents the physical processes or functions of the various components and systems in a language related to their specific electrical, chemical or mechanical properties. Above this, the functional properties are represented in more general concepts without reference to the physical process or equipment by which the functions are implemented, and so forth. At the lower levels, elements in the process description match the component configuration of the physical implementation.

When moving from one level of abstraction to the next higher level, the change in system properties represented is not merely removal of details of information on the physical or material properties. More fundamentally, information is added on higher level principles governing the co-function of the various functions or elements at the lower level. In man-made systems these higher level principles are naturally derived from the purpose of the system, i.e. from the reasons for the configurations at the level considered. This involves a shift

LEVELS OF ABSTRACTION

FUNCTIONAL PURPOSE

PRODUCTION FLOW MODELS,
CONTROL SYSTEM OBJECTIVES ETC.

ABSTRACT FUNCTION

CAUSAL STRUCTURE, MASS, ENERGY &
INFORMATION FLOW TOPOLOGY, ETC.

GENERALISED FUNCTIONS

"STANDARD" FUNCTIONS & PROCESSES,
CONTROL LOOPS, HEAT-TRANSFER, ETC.

PHYSICAL FUNCTIONS

ELECTRICAL, MECHANICAL, CHEMICAL
PROCESSES OF COMPONENTS AND
EQUIPMENT

PHYSICAL FORM

PHYSICAL APPEARANCE AND ANATOMY,
MATERIAL & FORM, LOCATIONS, ETC.

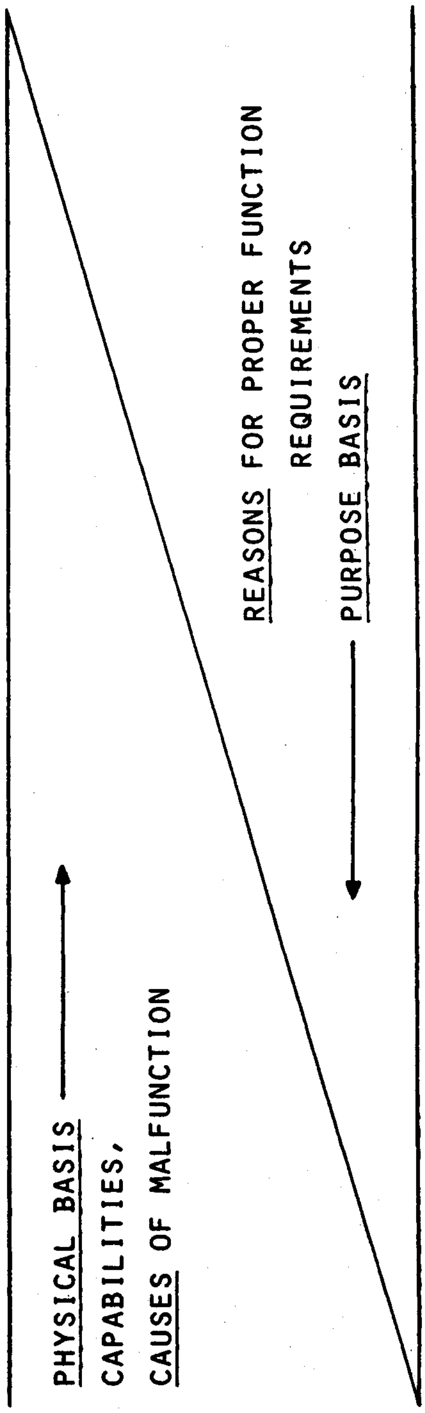


Figure 4. The abstraction hierarchy used for representation of functional properties of a technical system.

in concepts and structure for representation as well as a change in the data suitable to characterise the state of the function or operation at the various levels of abstraction. For display design this means that matching the presentation to the most effective level of abstraction is not only a question of changing the format for arranging measured data (bar-graphs, curves, mimic diagrams), but the data must also be converted and integrated to match the relevant abstract concepts. Some of these variables can be measured directly, as for instance liquid flows and levels of a mass balance for a flow representation, whereas energy flows and the levels of an energy balance must be derived by means of computations based on the measured data.

To us, a systematic use of this abstraction hierarchy seems important for formulation of the information needed by an operator to be able to identify and perform the proper control task in a given situation. At each level of abstraction, the reasons and specifications, i.e. the requirements for proper function, are formulated from above, and the means for control and potential for function, i.e. the physical capabilities and limitations, are coming up from below. In case of disturbances due to technical faults, the causes of malfunction are propagating bottom-up through the hierarchy of abstraction, at the same time as rules for proper functions are derived top-down (Polanyi 1958). Depending upon the situation, the operator's immediate task is related to one or another of the levels in the hierarchy - as will be discussed below - but in any case the task will be formulated from an identification of the discrepancy between the "top-down" proper function and the "bottom-up" actual function.

RELATIONSHIPS BETWEEN AGGREGATION AND ABSTRACTION

As already mentioned, there is generally a close correlation between the processes of abstraction and aggregation, between the span of attention applied when considering the system and the abstractness of the concepts used for representation. A design process is well suited for illustrative purposes, in particular since the task of an operator dealing with an unfamiliar system malfunction will be to design a control algorithm to close the gap between the proper function and the actual function of the system. In case of an idealised, systematic design, i.e. a design process which is not performed by updating a previous design and not merely based on accepted standard practices, the process will be a systematic top-down realisation or materialisation of the stated overall functional purpose of the system; through a selection of a suitable production flow structure, a selection of appropriate physical processes for the production, identification of the relevant equipment, and finally selection of the components suitable for the equipment. This process is ideally an orderly change of view by concurrent change of aggregation and abstraction. For the design of control algorithms for normal operation and for plant protection, this process will generally be an iterative one. When means for realisation of a function or process have been selected at the next lower level, the implications and possible side effects at the level above must be evaluated, and causal links (for instance control loops) must be introduced to remove unwanted degrees of freedom which were added by the physical reality introduced when moving to lower abstraction levels. The aim of a design process is to coordinate and constrain the possible states and functions of a physical system to those appropriate for the purpose of the system, by means of proper system configuration and proper control links. At each functional level, reasons and requirements for the function are obtained from above, whereas support and potential for functions as well as causes of malfunction propagate from below.

The basic concepts used for describing the system at the various levels of abstraction do not depend much on the specific system considered. However, the way in which the aggregation and abstraction are coupled is very much related to the way in which proper operation is synthesized during start-up and is, consequently, very much depending upon the specific type of system.

Such control of the physical degrees of freedom by system reconfiguration and control action is exactly the task of the human operators in case of disturbances not properly responded to by the automatic control systems. Design of a relevant control strategy for fault management depends on the identification of a discrepancy between the specified or target state of operation and the actual state. This discrepancy can be formulated at each level of the abstraction/aggregation hierarchy. The one to select depends on the specific situation and the priorities of the different relevant operator tasks. The natural way to judge priorities and to select the proper level of abstraction/aggregation in order to formulate control strategies will be a top-down evaluation of the situation. This is partly so because the highest priority is generally related to the highest levels: First, judge overall consequences of plant production and safety to see whether the plant mode of the operation should be switched to a more safe state - for instance, standby or emergency shutdown. Next, consider whether the situation can be counteracted by reconfiguration or use of alternative resources. This is a judgement at a lower level of physical equipment and function. Finally, find the basic cause of the disturbance and determine how it can be corrected. This implies a search at the level of physical function of parts and components.

Another reason for the top-down evaluation is the simultaneous change towards more material, physical properties of the system and the narrowing down of the span of attention which enables a direct zooming-in on the discrepancy between actual state and target state. This, however, depends on the availability of information about the "actual state" of the system at each level which can only be obtained by an evaluation of the measured data and of the actual system configuration. This state identification by a bottom-up data integration must be based on functional analysis of the measured, quantitative data; not on a combinatorial analysis of off-normal signals for the measured data individually followed by a state identification from reference to stored symptom patterns for known disturbances. Since disturbances are propagating bottom-up through the hierarchy, bottom-up detection of abnormalities is necessary in order to give early warnings announcing the need for top-down identification of the proper task.

This approach immediately leads to several data processing tasks which are well suited for computers: First, storage and retrieval of technical specifications for production and safety, and of information regarding the purposes and reasons related to the various operating modes of the plant, together with the requirements and target states for each level of the hierarchy. This information can only partly be obtained by measurements on the plant (collection of data patterns defining "normal states"); much information must be made available by the system's designer. Secondly, identification of the actual state of operation at each level derived by data integration of measured values and information on systems configuration. And thirdly, presentation of information in properly formatted displays.

The way to assist operators to avoid complexity is then to make a repertoire of display formats available to him, structured in a hierarchy with a small number at the high levels of abstraction/aggregation, and a larger number at the low detailed levels, together with an orderly and structured way to seek through the hierarchy to "zoom-in" on the relevant display. The properties of the individual displays and the quality of cross references to related displays at higher and lower levels of abstraction are, however, important for the perception of complexity.

INFORMATION STRUCTURE FOR DISPLAYS

An operator actually faced with the proposed hierarchical set of displays will probably not be aware of the multilevel structure of the representation of the total system. In a given work situation, an operator will have only a certain part of the plant within his span of attention. This part is to him "the system" to be represented in the actual situation, and the rest of the plant is part of "the environment" of this "system". Considering only this more restricted "system" in a specific situation, generally only three levels of abstraction are relevant to the operator, viz. the process or function under consideration (the "what" level); the purpose of this process for the next higher level (the "why" level); and, finally, the level below representing the more physical properties (the "how" level, i.e. the implementation level). These relations between a functional representation and the adjacent levels are independent of the actual location in the abstraction hierarchy (fig. 4) and are, therefore, well suited as a basis for organizing plant information into a set of displays, see fig. 5.

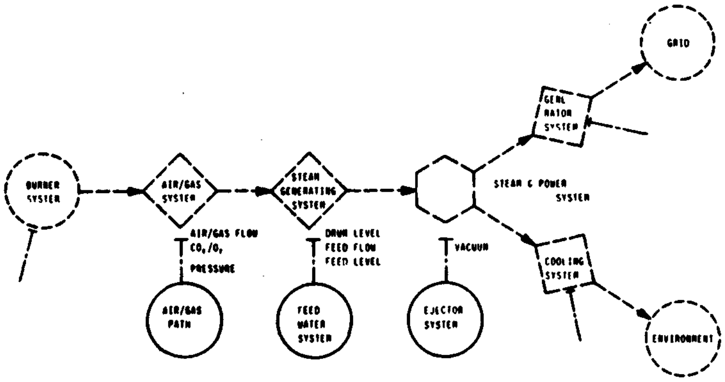
When the focus and span of attention change in accordance with the requirements of his work situation, the typical coupling between aggregation and abstraction will lead to the effect that these three levels of abstraction - purpose, process, and implementation - as the operator sees them in a specific situation, will generate the full abstraction hierarchy of the designer (see fig. 4) by recursion as his attention shifts. This means that the system properties which are represented in the three levels and used by an operator in a specific situation will vary, and to keep the complexity of the interface low as perceived by the operator it is important to identify a consistent and uniform language to express the functional relationships represented in the displays. Similarly, the links used to refer operators to the display levels above and below the one in use should be standardised, and the typical operator tasks should be identified, i.e. the designer must realise explicitly the types of control task he wants the operator to perform. The effect of this will be to make the concepts and structures used by the operator's higher level analysis and decision making as shown on fig. 1 more uniform and situation independent. The language used in this report for describing the process of the system is based on a flow representation (mass, energy and/or information flow; Lind

PURPOSE
("WHY" LEVEL)

REQUIREMENTS

Consult to judge effects of disturbances and to prioritize goals

PROCESS REPRESENTATION
("WHAT" LEVEL)



INFORMATION REQUIREMENTS:

- Actual states and target states of process
- Critical variables and limits for supporting systems

SUPPORT:

- FUNCTION, SUB-PROCESS
- SUPPLIES, MATERIAL, ENERGY
- CONDITIONS, PARAMETERS

IMPLEMENTATION
("HOW" LEVEL)

CAPABILITIES,
LIMITATIONS,
POTENTIAL BACK-UP

Consult to find causes and to select alternative resources and means for action

Figure 5. Schematic illustration of the relationship between the three levels of abstraction to be considered for a control task.

1981) of a physical system, which in addition to its generality has the quality of being easily visualized (Rasmussen 1980). This may be used for displays which allow direct perception of system states and related operator tasks (Goodstein et al. 1980). It should be realised, however, that the question of the properties of the system at the various levels of abstraction which should be represented in the content of the related displays, and the question of the language to be chosen for the representation, are two separate issues. The use of flow-models has proven to be a very consistent tool for analysis of the properties of energy production or conversion systems at several levels of abstraction, even through the language and symbols used for flow-modelling may not be the language to choose to represent the results of the analysis in information displays for system operators at all these levels.

The relationship between the three levels to be considered by an operator is illustrated in fig. 6. In the example we have described a conventional power plant. The first level describes the plant as an energy conversion system which distributes energy from the fuel to two sources, the electric grid and the environment (cooling tower etc.). The purpose of the conversion process is to act as a distributor of energy and it is conditioned by two support systems indicated by two critical variables related to the efficiency of the conversion process. At the next level below we have described the processes going on in the energy conversion system. But the air/gas system and the steam generating systems are again supported by the "air/gas path" and the feedwater system. If the air/gas flow is not established, the air/gas system does not exist as an energy transport system. If the feed flow is not established and the levels are not proper, then, in a corresponding way, the steam generating system does not exist as an energy transport system.

This example shows how the linkage between descriptions of different abstraction levels is established. In the representation, a change from one level to the level below includes both a shift from "what" to "how", but also a shift in focus of attention such that support systems are described in terms of what they do; i.e., in terms of their processes. This example

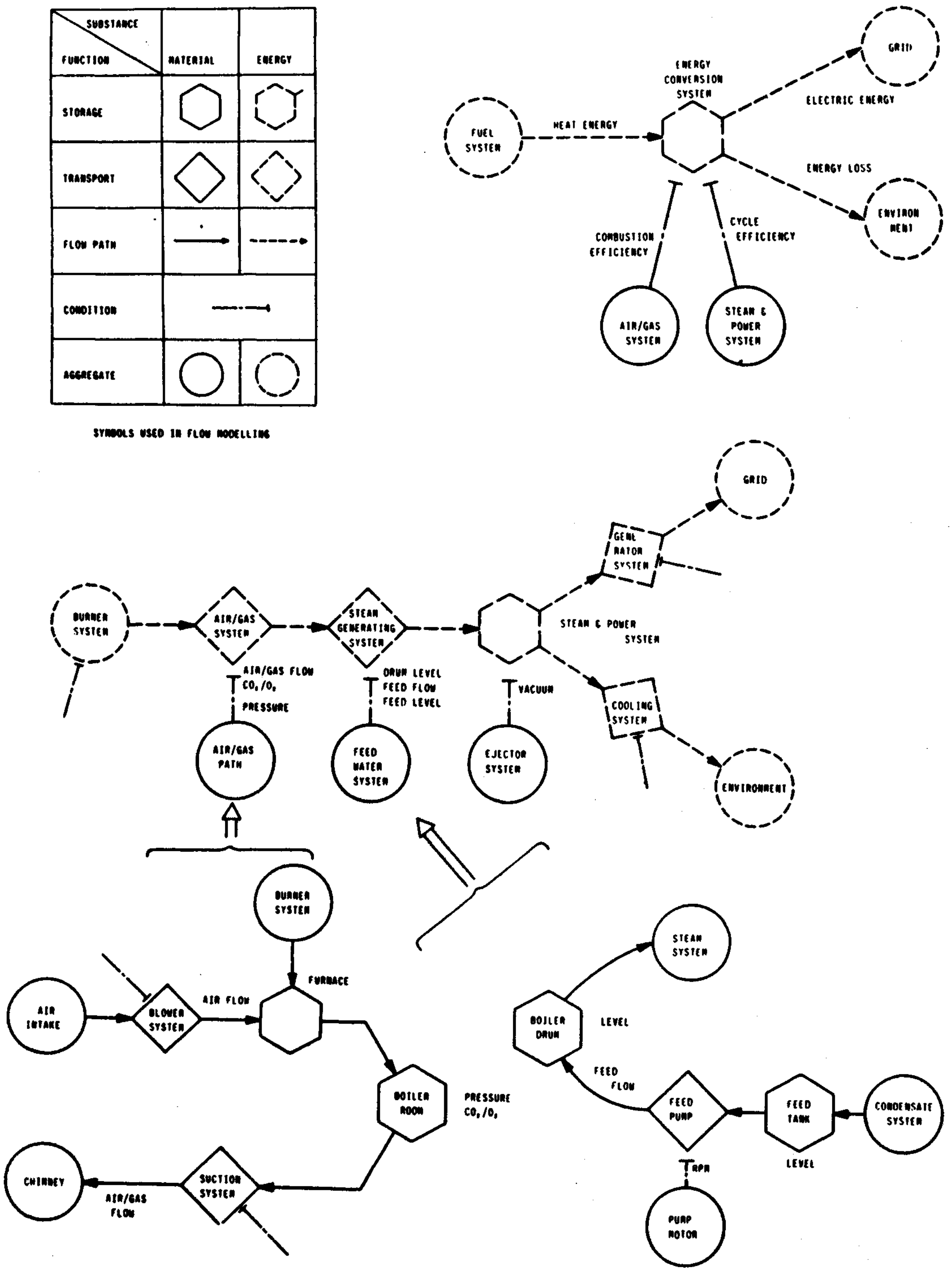


Figure 6. Example of three levels of representing the functional properties of a power plant in terms of flow structures.

illustrates that the purpose of a process, i.e. its role in support of the level above, can in general be described by a few categories: First, the process may serve to implement part of the function at the level above, for instance a mass flow system can serve as carrier for an energy transport at the next higher level. Secondly, the process may serve to supply energy or material necessary for the function of the next level. Thirdly, the process may serve to maintain a condition within proper limits to support the function above, for instance to maintain a pressure constant in order to convert an energy balance condition to a pure transport condition; or to maintain bearing conditions of a pump. When the role of a process for the next higher level has been identified, the information necessary to characterise the exchange of requirements and capabilities across the boundary can be determined immediately. This exchange of requirements and capabilities also identifies the cross reference path between the levels of the display hierarchy which should be used to guide the operator through the information available to him, see fig. 5. Considering a disturbance of a process at a given level, he has to move to the level above to judge the effects and to prioritize; to explain and to find causes, or to find alternative functional capabilities and means for action, he will need to consult the level below.

In the individual displays, details are ignored which are irrelevant for the task at hand and which could only lead to an increase of the apparent task complexity. In addition to ignoring details (aggregation), processes are described in a language convenient for design of control strategies. In this type of model, the effects of the different automatic control systems often reveal themselves as conditions (fx. parameter control). These simplifications allow for a considerable reduction of the number of basically different tasks which the operator has to learn and distinguish.

The linkage of processes and support systems also describes the decomposition of the overall control task. Support systems should be started up and be in proper state (target state) before the processes on the next level can be carried out, etc.

CONCLUSION

This kind of information processing would lead to a system in which the operator can consult a computer to obtain information with the degree of resolution matching his immediate need. The computer is used to store and process a large number of measured variables and other data available from the design process. It is also used to make this information available to operators at that level of detail and in terms of those higher level concepts which are necessary for system's monitoring and supervisory control. Data integration used in this way will serve to counteract the tendency to use subsets of data as stereotype signs. Thus, the operator will not have to spend mental resources for complex, but elementary functional deductions to integrate information contained in the numerous measured variables. This is especially important during stressed situations.

The multilevel modelling framework provides a knowledge base which can be used as a common denominator for the computations in the computer and the activities of the operator. Such a base is necessary in order to establish an advanced dialogue between the operator and the computer during, for instance, diagnosis. Furthermore, the modelling framework is a basis for the specification of the functions to be performed by the computer, i.e. serve as a tool for design of the information processing system supporting the operator. This means that the framework is used by the system designer to cope with the complexity in specifying the functions to be performed by the information interface. The model framework defines the proper way of thinking of the process plant, i.e. the logic of its functional organisation.

An additional advantage with the multilevel approach in coping with complexity is that it leads to structured problem solving in diagnosis. The repertoire of strategies used in diagnosis is limited to a small number of generally applicable methods. This facilitates the transfer of diagnostic skills obtained by the operator during normal operation to diagnosis of infrequent incidents involving high risk.

In diagnosis using these models, the computer will guide the operator in a top-down search through several levels of abstraction. In response to early warnings indicating a plant disturbance, the operator/computer starts at the highest level of abstraction describing plant overall function and the systems supporting the process on that level. The search may then continue, supported by the computer, in deeper levels by picking out one or several subsystems for investigation. Although the effect of plant disturbances always first appears at a low level as early warning signals, the efficiency of a top-down approach will help the operator in quickly performing a plant state identification.

The depth of the search depends on the nature of the actual disturbance and of the task of the operator. In disturbance compensation it is only necessary to identify the plant state to a level of detail where proper control actions are known to the operator/computer.

In conventional alarm systems the problem of diagnosis is left completely to the operator. The alarm patterns are situation dependent and do not include any clues as to how to interpret the available data. In this way the operator has to perform a very complex inference process where measured plant data and alarms are combined with his knowledge of process functions and properties. This bottom-up approach to diagnosis excludes the explicit consideration of plant information which is known to the designer, such as the purpose of subsystems. Conventional alarm systems are situation dependent and their design requires specification of patterns which are virtually infinite in number. The approach described here is function-oriented and provides a formal method of relating different types of plant information so that it is operational to the operator and the computer. Furthermore, the models constitute a closed set since their limitating can be clearly defined.

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Abstract

Abstract. In the report we discuss how computers can be used to assist the process plant operator in coping with complex situations during plant disturbances. The main idea is to use the computer for integrating plant measurements into information related to different levels of abstraction and aggregation. The basis for the data transformations is a hierachical multilevel plant description which identifies the variables and processes which are relevant to consider at the different levels. At the same time, the multilevel description provides a representation of the functional organization of the plant. This makes such a description useful for design of information displays which can be used by the operator in diagnosing disturbances.

The multilevel description is closely related to plant descriptions derived from analysis of verbal protocols. Accordingly the approach leads to a design of the man-machine interface which can support an advanced dialogue between the operator and the plant computer in diagnosis.

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