An introduction to multilevel flow modeling

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Abstract: Multilevel Flow Modeling (MFM) is a methodology for functional modeling of industrial processes on several interconnected levels of means-end and part-whole abstractions. The basic idea of MFM is to represent an industrial plant as a system which provides the means required to serve purposes in its environment. MFM has a primary focus on plant goals and functions and provide a methodological way of using those concepts to represent complex industrial plant. The paper gives a brief introduction to the historical development, introduces the concepts of MFM and presents the application of the concepts in detail by a water mill example. The overall reasoning capabilities of MFM and its basis in cause-effect relations are also explained. The appendix contains an overview of MFM concepts and their definitions.

Keywords: complexity; functional modeling; risk analysis; supervision and control

1 Introduction

Multilevel Flow Modeling (MFM) is a methodology for modeling of industrial processes on several interconnected levels of means and part-whole abstractions. The basic idea of MFM is to represent an industrial plant as a system which provides the means required to serve purposes in its environment. MFM has a primary focus on representation of plant goals and functions and provide a methodological way of using those concepts to represent complex industrial plant. MFM belong to the group of AI modeling techniques for qualitative reasoning called functional modeling.

The basic idea of MFM was conceived by the author and has been developed and used over the years by his research group and by research groups in several other countries including Sweden, USA, Japan and China. The early research in MFM originated in problems of representing complex systems in Human Machine Interfaces for supervisory control. But it has since developed into a broader research field dealing with modeling for analysis, design and operation of automation systems for safety critical complex plants.

The basic ideas of MFM were formulated by the author [1-3] and the conceptual foundations, the MFM modeling language, the tools and the applications have then been developed over more than two decades [4-14] and is still ongoing [15-20].

The development of MFM has involved several steps of refinement based partly on experiences from its application to supervision and control of industrial processes. In recent years the refinements has also been motivated by action theoretical foundations [18, 21].

There is currently a need for an up to date introduction to the concepts of MFM, its philosophical and theoretical foundations and its application. The purpose of the present paper is to present an introduction to the core concepts of MFM which previously was scattered in several reports and papers published by the author and other researchers between 1990 and 2000. An important aim of the paper is to propose a notational standard for MFM models such that the tendency of diversified notations in the past can be reduced in future development and applications of MFM.

1.1 Overview of the paper

MFM can be introduced in many ways. It has here been decided to present the core ideas in a quite direct way to avoid too many reflections on philosophical and theoretical foundations. These aspects of MFM will be discussed in companion papers to be published in the future. Actually, the philosophical and theoretical foundations of MFM are very important both for understanding the nature

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of MFM and for using it. MFM is not just another modeling language. It is a powerful tool for thinking and reasoning about complex dynamic systems and is complementary in its concepts to more traditional techniques for modeling dynamic systems in control and systems engineering, such as differential equations.

The paper will introduce the reader to the core elements of the MFM modeling language by a water mill example. The water mill is hydraulically powered flour grinding process and illustrates well the basic principles of MFM. It is not more complex than most readers without specific process knowledge can understand how MFM is used to represent its goals and functions. MFM has been used for modeling much more complex processes like conventional and nuclear power plants and distillation columns. Modeling such systems require deep knowledge about the process and its operation and more complex examples like these would therefore be more difficult to understand by the general reader.

The main purpose of the example is accordingly to help the reader to understand the type of knowledge which is represented by MFM and the principles for model building. The example can also serve as a “design pattern” which can be reused or adapted to other modeling problems in other domains or more complex systems.

2 Multilevel Flow Modeling

MFM is a methodology for functional modeling of complex industrial processes and belong therefore in its thinking and methodology to the branch of Artificial Intelligence called qualitative reasoning. The purpose of qualitative reasoning is to be able to represent and reason about knowledge of physical phenomena and systems which cannot be done by quantitative approaches based on first principles such as differential equations. An important goal of AI is also to apply computers to automate the reasoning. The MFM modeling language has been developed to realize these aims within the general domain of industrial processes and their automation systems. A particular challenge is here to develop qualitative modeling and reasoning techniques that can handle the complexity of large scale dynamic processes.

The concepts of means-end and whole-part decomposition and aggregation play a foundational role in MFM. These concepts enable humans like systems engineers and plant operators to cope with complexity because they facilitate reasoning on different levels of abstraction. The power of means-end and part-whole concepts in dealing with complexity has roots in natural language. But natural language is not efficient for representing and reasoning about means-end and part-whole abstractions of complex physical artifacts. MFM development draws on insights from the semantic structure of natural language but is designed as an artificial language which can serve modeling needs of complex engineering domains which cannot be handled within the common sense limitations of natural language.

MFM represent goals and functions of process plants involving interactions between flows of material, energy and information.

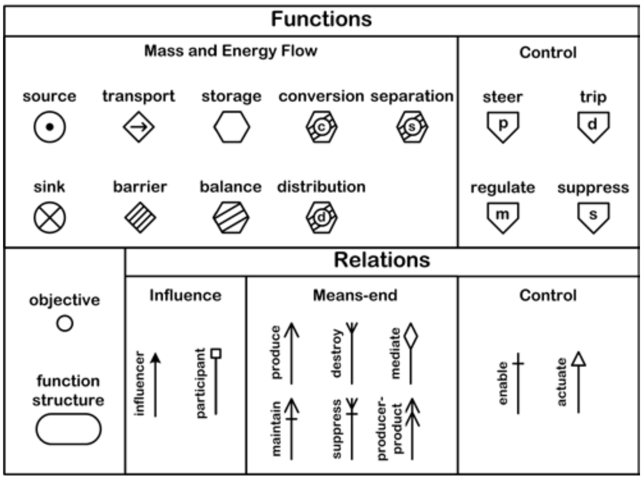


Fig. 1 The basic MFM symbols.
(see appendix for definition of MFM concepts)

Functions are represented by elementary flow and control functions interconnected to form functional structures representing a particular goal oriented view of the system. The action theoretical foundation which is under development see MFM functions as instances of more generic action types (see *e.g.* [18, 21]). The views represented by the functional structures are related by means-end relations and comprise together a comprehensive model of the functional organization of the system.

The basic MFM modeling concepts comprise objectives, flow structures, a set of functional primitives (flow functions and control functions), a set of means-end and influence relations representing purpose related dependencies between functions and objectives and among the functions themselves. The functions, the functional structures and the relations are interconnected to form a hyper-graph like structure. The symbols used to represent functions, objectives, functional structures are shown in Fig. 1 together with symbols used for representing means-end and influence relations. The concepts are defined in detail in the appendix.

An easy way to understand how these concepts are used is to consider the modeling of the water mill presented below. By this example we can explore a large fraction of the concepts shown in Fig. 1 (see also appendix). We will not consider the use of control functions in this paper. The interested reader can find an example in [18].

2.1 Principles for building MFM models

There are two overall principles for building MFM models.

According to the first principle, the building of a model takes its departure in the definition of objectives of the modeling object or system. System functions provided to achieve the objectives are then identified. The purpose of this top down procedure is to ensure that functions are defined in the context of system objectives. The procedure is suitable in particular for modeling systems where the physical realization is not known in detail or taken into account such as in the early phases of system design or in supervisory control.

The second principle is to associate functions with system components *i.e.* the physical realization. These functions are then aggregated so that they match with the objectives of the system. This bottom up the procedure is suitable when the objectives are unknown or vaguely defined. The aggregation process serve here to suggest possible objectives and higher levels functions in the system which cannot be directly associated with physical components or subsystems.

In most cases the two overall principles are combined into an iterative procedure. The model of the water mill presented below is the result of such an iterative procedure. The presentation will not explain the details of the model building process which obviously is highly dependent on the background knowledge of the model builder.

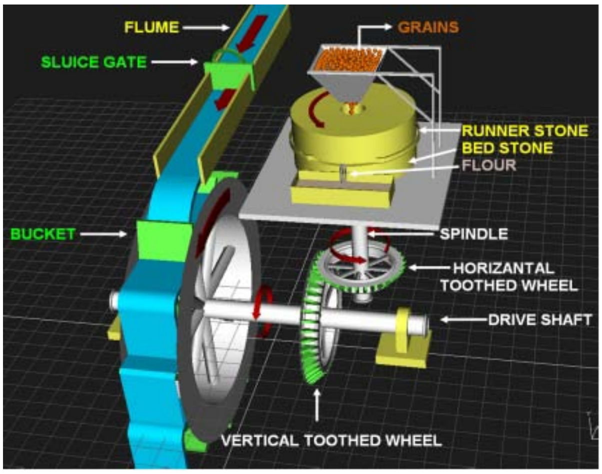


Fig. 2 Sketch of the water mill used to introduce key MFM concepts.

3 The water mill example

The overshoot water mill shown in Fig. 2 is a hydraulically powered flour grinding process and will used to illustrate the basic ideas of MFM.

A water mill is machine that uses running water to drive a mechanical process such as grinding. Water is diverted from a river along a channel known as the flume. On the flume, a sluice gate controls the water flow rate. A wheel is rotated by the momentum of the falling water striking and filling the buckets of the wheel. The weight difference between the side with water filled buckets and the side with empty buckets turns the wheel, which in turn rotates a drive shaft with a toothed wheel. By means of the horizontal toothed wheel, the angle of rotation changes and rotates a spindle on which a runner stone is mounted. The runner stone spins above a stationary bed stone to create the grinding action.

The runner stone has a hole at the center into which the grain is fed. As the grain is ground between the two stones, it moves towards the outer edge, and passes as flour into the casing. The grinding process also separates the grain shells from the flour through a sieve. This hydraulic process only has two control possibilities available to the miller: 1) to adjust the water flow rate by means of the sluice gate, and 2) to adjust the grain feeding rate to the runner stone. A simple MFM model of the water mill is shown in Fig. 3. Note that the millers control possibilities (NOT shown in the model.

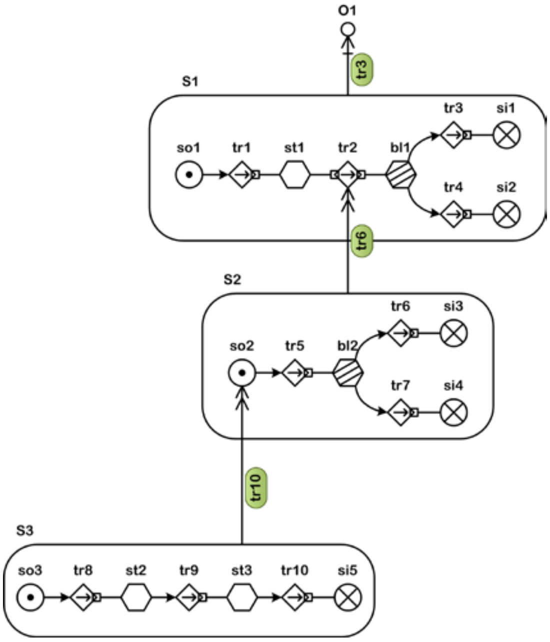


Fig. 3 MFM model of the water mill in Fig. 2.

3.1 The MFM model explained

The MFM model can be subdivided into three functional levels indicated in Fig. 3 by the functional structures S1, S2 and S3. These structures are examples of flow structures and are distinguished from control structures which contain only control functions and not flow functions.

The three flow structures S1, S2 and S3 represent functions of the water mill related to

- grinding of the grain (a mass flow structure - S1)
- conversion of potential energy of the water to kinetic energy (an energy flow structure - S2)
- water delivery and transport (a mass flow structure - S3)

The MFM model show how these functions of the water mill can be organized in levels as means to achieve ends. The functional levels are connected by two means end relations of the producer-product type representing the fact that the transportation of water to the wheel (S3) is a means of converting energy (S2) and that the conversion and consumption of energy is a means of transporting the grains through the grinding stone and the bed and the grinding of the grains into flour (S1).

The miller can control the operation of the water mill by changing the feed of grain to the grinding stone or by the manipulation of the sluice gate. The control functions of the operator can be represented by the concepts shown in Fig. 1 and defined the appendix but will not be discussed in this paper.

3.1.1 The grinding

The flow functions belonging to flow structure S1 represents the functions involved in grinding the grains. The grinding process supports the achievement of the objective O1 which is to deliver flour to the miller.

The provision of grain is represented by the source function so1 and the transportation of the grains from the source to the storage st1 in the funnel above the grinding stone is represented the transport function tr1. From the funnel the grain is transported (tr2) to the grinding stones.

The balance function bl1 represents the conversion of grains into flour and shells and the transportation of flour (tr3) and shells (tr4) to two sinks (si1 and si2). The means-end relation from flow structure S2 connects the transport function tr2 with the means of transportation represented by the flow structure S2 discussed below. The grinding can be controlled by adding more grains to the funnel i.e. by increasing the transportation of grains represented by tr1.

3.1.2 The energy conversion

The flow functions belonging to energy flow structure S2 represents the functions of the water mill involved in the conversion of the kinetic energy of the running water (so2) into rotational energy of the wheel, the connecting mechanical linkages and the stone (bl2) and subsequent consumption of the energy in the grinding (tr6) and the production of heat by friction (tr7).

The means-end relation connects the energy source so2 with the means used for energy conversion *i.e.* the functions involved in leading the water from the flume to the wheel. These functions are represented in flow structure S3.

3.1.3 The water transport

The flow functions belonging to flow structure S3 represents the functions of the water mill involved in the delivery and transport of water from the flume to the wheel and away from the wheel.

The water source located upstream the flume is represented by the source so3 and the transportation to and storage of the water in the flume is represented by tr8 and st2. It is accordingly assumed that the river (or lake) supplying the water has a sufficient capacity for the present purpose so that it can be represented as a source.

Flow functions tr9 and st3 represents the functions involved in transporting the water to the wheel and the water in the buckets of the wheel and tr10 represents the transportation of water away from the wheel to its downstream destination represented here as a sink (si5). The flow of water through the water mill can be controlled by the sluice gate (tr8).

3.2 Adding lubrication functions

The MFM model shown in Fig. 3 illustrates the use of some of the most important MFM concepts. However, we have not yet used the enable relation which represents an important aspect of control. We have therefore for illustration of this concept added a lubrication system to the water mill.

The purpose of the lubrication system is to ensure that the mechanical linkages of the mill can rotate and thereby support the transfer the rotational energy. This support function of the lubrication system is represented in the extended model shown in Fig. 4 by an enable relation connecting an objective O2 with the balance function bl2. Objective O2 is a representation of the lubrication requirement which is related to the lubrication functions shown in the flow structure S4 by the means-end relation called maintain.

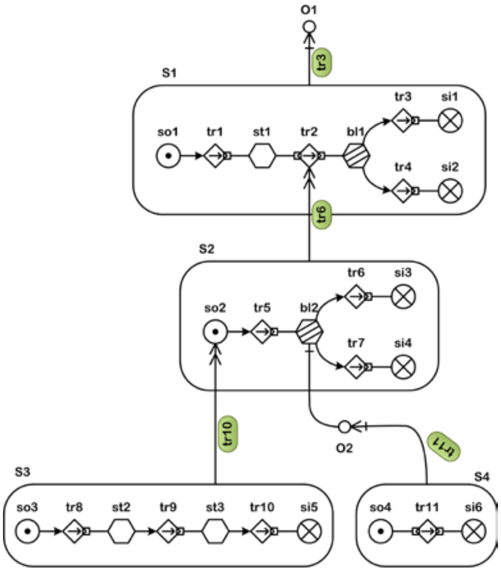


Fig. 4 MFM model of water mill including lubrication functions.

The node so4 in S4 represents the source of lubrication oil and the transport function tr11 is the transport function performed by *e.g.* a lubrication pump. Enabling is an important aspect of control and it is seen that MFM has a concept for its representation. Other aspects of control are discussed in [18].

4 MFM reasoning

The participant and influencer relations shown in Fig. 1 (and defined in the appendix) are used extensively in the two MFM models of the water mill model but were actually not discussed above. This was intentional because they are best explained in relation to how MFM is used for reasoning. Influence relations, the means-end relations and the principles of mass and energy conservation related to the balance functions are the three aspects of MFM which makes it powerful for reasoning about causes and consequences in *e.g.* diagnosis and management of plant failures.

4.1 Cause effect relations

Reasoning with MFM models is based on cause-effect relations which are generic *i.e.* independent of the particular modeling object. MFM is therefore very effective for building knowledge bases for model based expert systems. The need to develop rules for reasoning about causes and effect which is a characteristic of rule based systems is eliminated entirely and the effort is reduced to building the MFM.

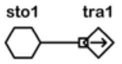
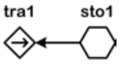
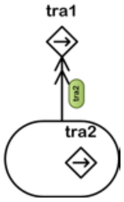
The cause-effect relations are associated with goal-function and function-function patterns in MFM models. These patterns are defined by:

- relations of influence interconnecting the flow functions within the flow structures
- the means-end relations making connections between flow structures

For each of the influence relations and the means-end relations there is a corresponding set of cause-effect relations relating a state of a function or goal with the state of another function or goal in the model. These generic cause-effect relations are implemented as a rule base in the MFM workbench which is a model development and reasoning system for MFM (see below).

Examples of goal-function patterns and associated cause-effect relations used in the reasoning system are shown in Table 1.

Table 1 Example MFM patterns and cause-effect relations

Pattern	Cause-effect-relation	
	cause	effect
	tra1 is hiflo	sto1 is lovol
	tra1 is loflo	sto1 is hivol
	sto1 is lovol	tra1 is hiflo
	sto1 is hivol	tra1 is loflo
	tra1 is loflo	sto1 is lovol
	tra1 is hiflo	sto1 is hivol
	tra2 is loflo	tra1 is loflo
	tra2 is hiflo	tra2 is hiflo

4.1.1 Influence relations

Flow functions are interconnected within a flow structure by two types of influence relations called direct and indirect influences. These two types of influence determine the cause-effect relations between states of the flow functions.

Direct influences

A direct influence between two flow functions is exemplified in Fig. 5 by considering the effects of a changed flow in transport function tr8 on its neighboring storage function st2.

If we assume that the flow provided by tr8 is increased it will influence the storage st2 by increasing its content *i.e.* the hivol condition shown in Fig. 5. And conversely, if the flow is reduced it will reduce its content. These influences on the state of st2 caused by changes in tr8 are called direct influences and are expressions of mass and energy balance constraints governing flow systems. The arrow inside the transport function tr8 is an explicit representation of the direct influence. The meaning of this arrow is implied by the ontology of flow systems. Note that the direct influence is in both the downstream and upstream directions.

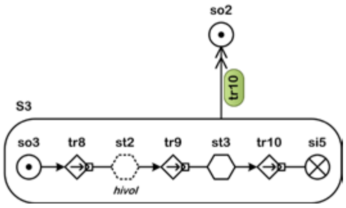


Fig. 5 A hivol deviation from normal in st2 in flow structure S3 in the water mill MFM.

Indirect influences

The indirect influences are represented explicitly by two relations (influencer and participant) between transport functions and its neighboring flow functions. They represent interaction between flow functions which are connected with relations between *potential* and *actualized* flows.

As an example, if the content of st2 increases it may influence the transport tr9 by increasing its associated flow. The accumulated content in st2 represents a potential for flow and the resulting increase in the transport tr9 is its actualization.

This indirect influence of st2 on the state of tr9 is represented by an arrow pointing from st2 towards tr9. Since the storage actively influences the transport the relation is called an influencer.

In other situations, a storage function will not influence the state of the transport *i.e.* it will not be active but passively delivering or receiving the flow(s). This type of indirect influence is indicated in MFM models by a participant relation depicted by a directed relation with a box connecting to the transport function, as between tr9 and st3 in Fig. 5. Note that the arrow head and the box are always pointing towards a transport function. But they can both be connected to either the upstream or the downstream side of a transport function.

4.1.2 Means-end relations

The means-end relations also give rise to cause-effect relations between states of functions, goals and objectives. The relations can be divided into two main groups.

The first group of relations connects *objectives* with flow structures. This group comprises the relations produce, maintain, destroy and suppress. Their definition are very similar (see appendix) and we will therefore only discuss the maintain relation which used in the model of the water mill.

The maintain relation in the MFM model of the water mill in Figs. 3 and 4 connects the objective O1 (end) with the transport function tr3 included in S1. The connection with tr3 is indicated by the label associated with the maintain relation. This means that tr3 is the function of the grinding wheel which directly contribute to achieving the objective which is the delivery of flour.

The second group of means-end relations connects *functions* with flow structures and comprise the producer-product and the mediate relations. These relations are of particular interest because they involve a shift in perspective on the object of modeling which is triggered by the corresponding change of goal context. Such shifts in perspective are not associated with the produce, maintain, destroy and suppress relations which do not involve change in goal context but merely specify temporal aspects of goal achievement. Goal achievement takes time whereas producer-product and mediate relations indicate concurrency of the “end” function and the “means” functions in the flow structure.

The causal aspects of the producer-product and the mediate relations are connected with the asymmetry of the relations they define between the main function of a flow structure and a flow function in another flow structure. If they did not have this asymmetrical nature they would not give rise to cause-effect relations.

The producer-product relation and the mediate relations are asymmetric because in both cases the existence of the flow function in another flow structure is conditional on the existence of the main function (the function indicated in the label attached to the means-end relation), but not the reverse.

The shifts in perspective are different for the producer-product and the mediate relations.

In case of the producer-product relation the process transformation represented by the flow structure and identified by the main function is *seen under another aspect* in the flow structure containing the flow function pointed to (*e.g.* from being transformation of energy to being transformation or transportation of mass).

In case of the mediate relation the shift in perspective is a *shift between two roles of the same system* which is connected with two different goal contexts. And, as mentioned above the relation is asymmetric so that the role related to the flow function in the other flow structure is conditional on the role related to the main function.

MFM has therefore a distinction between two different types of cause-effect relations depending on whether they are connected with shifts in aspect or in roles.

The concept of role is also important for understanding the relations between the structure and the function of a system and is a subject for further research. It will not be discussed further here (see [19]).

Thus it can be inferred from the MFM model in Fig. 3 that the miller can cause a change in the flow of water from the flume (tr8). This change will subsequently change the amount of water stored in the wheel buckets (st3) which again will result in a changing outlet flow from the wheel (tr10).

The changed outlet flow will result in a changed energy supply to the mill (so2) which again (following the influence relations in S2) will lead to a changing rotational speed (st3) and energy delivery to the grinding (tr6). Furthermore, the changed energy delivery to the grinding will change the amount flour and shells produced (tr3 and tr4).

4.2 Cause-effect relations and control of the mill

The influence relations connecting the flow functions within each of the flow structures as well as the means - end relation connecting the functional levels are accordingly important for understanding how MFM support causal reasoning and thereby also reasoning about abnormal situations.

4.3 Overall reasoning principles

The principles for reasoning in MFM can be summarized in Fig. 6. Here two reasoning paths are shown.

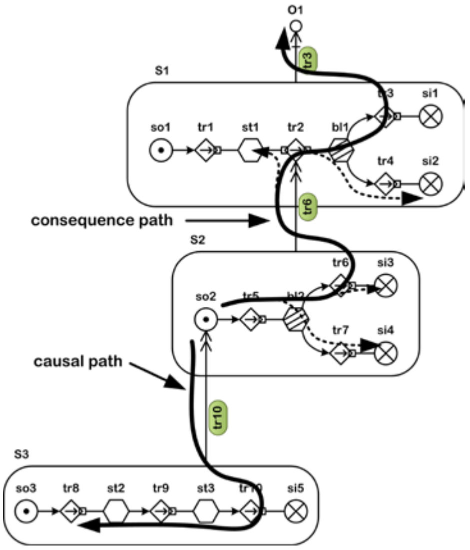


Fig. 6 Reasoning about causes and consequences of a disturbed source so2 in the MFM model.

One path follows the propagation of consequences of a disturbed source so2 and another trace the disturbance back to its possible root causes.

One consequence path goes directly to the objective O1 whereas other paths (the dotted ones) show the propagation of the disturbance to other functions. The paths traverse the model in both a horizontal direction following the functions and their interconnection within a flow structure (*e.g.* so2, tr5, bl2 and tr6 in S2) and in a vertical direction following the means-end relations connecting flow structures with functions (*e.g.* S2 and tr2 connected by the producer product relation). The reasoning paths can be generated automatically by the set of rules in the MFM Workbench expressing the basic rules for reasoning about flow disturbances both within and across flow structures which are illustrated by a few selected examples in Table 2.

5 The MFM workbench

An integrated computer aided environment for development and use of MFM models, called the MFM Workbench, has been developed by integrating commonly available commercial software, such as Microsoft Visio, with components developed in platform independent Java.

An MFM model builder has been implemented in Microsoft Visio by using stencils for implementing the MFM functions and other symbols shown in Fig. 1 in order to facilitate interactive model building. The MFM model is saved in a text format.

The MFM Reasoning Engine, which reads the model from the MFM Model Builder, allows the user to experiment with reasoning in the MFM model by setting a variable high or low, and let the engine discover causes and consequences of this. The MFM reasoning engine is based on the java based expert system shell Jess [22].

6 Summary

The paper provides an introduction to Multilevel Flow Modeling (MFM) which is a methodology for functional modeling. MFM represent an industrial plant as a system which provides the means required to serve purposes in its environment. The plant is modeled by MFM on several interconnected levels of means-end and part-whole abstractions. MFM has its primary focus on plant goals and functions and provide a methodological way of using those concepts to represent complex industrial plant. The paper introduces a central core of the MFM concepts and presents their application in detail by a water mill example. The overall reasoning capabilities of MFM and its basis in cause-effect relations are also explained.

Control functions and their use in building MFM models is a large subject which is outside the scope of the present paper. It will be explained in a separate publication.

The material presented in the paper is the result of several decades of research. It is the authors hope that the paper can serve as a reference for future applications and development of MFM.

Acknowledgements

The current Multilevel Flow Modeling language is the result of a long term research effort by many people including PhD students and co-workers at DTU and a group of international researchers. Students following MFM classes have also contributed by pointing out obscure formulations which needed clarification. The contribution of all these people to the present maturity of the MFM language is acknowledged but it is difficult to list the names of all of them. However, a handful of people stand out. In particular I will mention the early efforts of Prof. Akio Gofuku in considering the relations between structure and function in MFM and his continued interest in MFM. Ass. Prof. Johannes Petersen contributed also significantly by the development of influence relations in MFM (at that time called causal roles) which has proved to be essential to the reasoning power of MFM. Also the contributions to MFM applications by Prof. H. Yoshikawa are highly appreciated. Finally the author is grateful to two colleagues at DTU Prof. Sten Bay Jørgensen and Ass. Prof. Niels Jensen for their continuing interest and great support in MFM development, for their current contributions to the application of MFM for risk analysis and alarm management and for their support in development of modeling examples.

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Appendix: Definitions of MFM

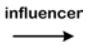
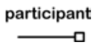
The MFM concepts shown in Fig. 1 are defined in detail below.

objective ○	An objective represents a state which should be produced, maintained, destroyed or suppressed. Objectives are related to function structures by means-end relations.
function structure ▭	A function structure represents a set of functions connected by influence relations. A function structure can contain either mass or energy flow functions or control functions. Three subtypes of are therefore distinguished: mass flow structures, energy flow structures and control flow structures.

Functions

Mass and Energy Flow	
source ⊙	A source represents the function of a system serving as an infinite reservoir of mass or energy. No physically realizable has in principle unlimited capability to deliver mass or energy. However, the source function is used to provide an adequate abstraction of the physical phenomena considered.
sink ⊗	A sink represents the function of a system serving as an infinite drain of mass or energy. As for the source function, this function can be used in many cases as an adequate abstraction.
transport ⟐	A transport represents the function of a system transferring mass or energy between two systems or locations. A transport function has one upstream and one downstream connection to an influence relation. The downstream connection point is indicated by the arrow head representing the direction of flow. Note that the flow direction is not identical to the directions defined by the influence relations.
barrier ▨	A barrier represents the function of a system that prevents the transfer of mass or energy between two systems or locations. Typical examples of systems which implement barrier functions are the cladding on nuclear fuel rods, heat isolating material and a trap in water systems.
storage ⬡	A storage represents a system which serves as an accumulator of mass or energy. A storage function can have any number of connections and any number of enablement conditions. An example could be the function of a tank when used as a device for accumulation of a fluid, in this example we are dealing with a mass storage. Another example could be the storage of energy in a boiler by heating the water.
balance ⊘	A balance represents the function of a system which provides a balance between the total rates of incoming and outgoing flows. Each balance function can have any number of connections and any number of conditions.
conversion c	A conversion represents the function of a system whose purpose is to convert between two forms of mass or energy.
separation s	A separation represents the function of a system whose purpose is to separate different flows of mass or energy.
distribution d	A distribution represents the function of a system whose purpose is to divide a flow of mass or energy among between several flow paths.
Control functions	
steer p	To steer is the function of a system S_1which is producing (p) a new state in the controlled system S_2.
trip d	To trip is the function of a system S_1 which is destroying (d) the actual state of the controlled system S_2.
regulate m	To regulate is the function of a system S_1 which maintain (m) the actual state of the controlled system S_2.
suppress s	To suppress is the function of a system S_1 which is suppressing (s) a potential new state of the controlled system S_2.

Relations

Influence	
	A flow function F (source, sink, storage or balance) is connected with a transport T upstream or downstream with an influencer relation if it has the role of influencing the amount of substance transported by T.
	A flow function F (source, sink, storage or balance) is connected with a transport T upstream or downstream with a participant relation if the system realizing F has the role of passively providing or receiving substance for the transport T.
Means-end	
	A produce relation connects an objective (end) with a function structure if one or several functions F (means) in the structure contribute to produce the objective. F is indicated by a label on the relation.
	A maintain relation connects an objective (end) with a function structure if one or several functions F (means) in the structure contribute to maintain the objective. F is indicated by a label on the relation.
	A destroy relation connects an objective (end) with a function structure if one or several functions F (means) in the structure contribute to destroy the objective. F is indicated by a label on the relation.
	A suppress relation connects an objective (the end) with a function structure if one or several functions F (the means) in the structure contribute to suppress the objective. F is indicated by a label on the relation.
	A mediate relation connects a function F_1 (the end) with a function structure if one or several functions F_2 (the means) in the structure contribute to mediate the function. F is indicated by a label on the relation. This relation is used when a system has the role of being an intermediate between an agent and another system that serve as an object of action
	A producer-product relation connects a function F_1 (the end) in a function structure S_1 with one or several functions F_2 (the means) in another structure S_2. F_2 is indicated by a label on the relation. This relation is used when the interactions between functions in structure S_1 result in a transformation that serves a function in the context of the objective related to S_2.
Control	
	An enable relation connects a function with an objective. It is used when the function is enabled when the objective is satisfied. All functions can be enabled.
	An actuation relation connects a control function F_1 with a function structure containing a function F_2 which is the direct object of control. F is indicated by a label on the relation.