Support for problem formulation and evaluation in manpower planning problems

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ABSTRACT

We are developing a system to support a manpower planner in the decision making process. The functional structure of this system consists of two main components. One component, the problem solver, generates the consequences during the planning period of specified problem situations. The other component, the problem interpreter, is responsible for the communication of the planner with the system. In this paper we focus on this last component. The problem interpreter must support a planner in a rather active way in the formulation of the problem situations and in the evaluation of their consequences, generated by the system. So, from the actions that take place in the communication of the planner with the system, we come to a set of tasks that must be provided by the problem interpreter.

1. Introduction

We are developing a system to support a manpower planner in the decision making process concerning the medium and long term manpower planning. The functional structure of this system consists of two main components, a problem interpreter and a problem solver. The problem interpreter is responsible for the communication with the planner. The problem solver computes to a specified problem situation its consequences during the planning period. An extended description of this structure can be found in [1]. In this paper we will consider the tasks of the problem interpreter. The tasks and structure of the problem solver are described in [2] and [3].

In the medium and long term manpower planning a planner has to deal with a variety of problem situations. Several aspects can play a role in the problem situations, such as the occupations, the salary costs, the mean passage time of the personnel in a part of the organization, the man-woman distribution, etc.. On behalf of the mathematical algorithms in the problem solver, the problems are modeled using a network structure, reflecting the distribution of the personnel in the organization (the nodes of the network, called the categories) and its evolution possibilities (the arcs of the network, called the transitions). This format, suitable to the algorithms in the problem solver, is called the formal specification. However, this format will in general not coincide with the terminology of the planner. Furthermore the formal specification is stated on a low level of detail, while the planner will mostly refer to more aggregate terms. Therefore the problem interpreter must offer the manpower planner the possibility to specify the problems in a terminology that is used in the manpower planning world. Of course, also the results generated by the problem solver must be presented to the planner in this terminology. This format, used to communicate with the planner is called the informal specification. So the interpreter must be able to convert the aspects that may occur in the planner-specified problems, stated in the informal specification, to objects that are known in the formal specification and vice versa.

The interpreter must thus take care of the communication between the manpower planner and the system. Important tasks of the interpreter are to support the planner with the formulation of problem situations as well as with the evaluation of their consequences during the planning period. Except for support in the sense of a "user friendly interaction language" we would like to offer the planner some more intelligent support. The interpreter should assist the planner in the evaluation of the specified problems and their consequences. For instance, check if apparent contradictions occur in the problem specification of the planner or trace the reasons why some planner-specified goals are not satisfied in the computed results.

In section 2 we will describe some properties that influence the way the problem situations must be specified and are dealt with. These properties are depending on the functional structure of the system and the way the solver acts. In section 3 we will come to a classification of the tasks of the interpreter. In section 4 we will describe the possible actions during a session of the planner with the system. From these actions we come to a set of tasks, grouped according to the classification described in section 3. This set of tasks will be described in section 5. Finally in section 6 we will discuss possible strategies to realize these tasks and the problems that arise.

2. General remarks concerning the problem situations

In general, a decision maker is interested in the consequences of modifications of the present policy and of external influences, or is searching for new policies slightly differing from the present one. Furthermore, a complete problem specification includes a great amount of data. Therefore we assume that at least one problem situation is available with respect to which the planner can specify alternative problem situations by specifying modifications and new policies and goals. As mentioned before, the problem specifications are modeled using a network structure. Therefore, a problem specification is defined by the specification of the network structure, the network instance (i.e. the start occupation numbers and the transition strengths) and possibly (aggregate) goals and constraints that influence the evolution of the personnel in the organization.

As a result of the way of modeling, the evolution of the network is completely described by a mechanism that controls the flow possibilities in the network. For that reason, the transition strengths are the decision variables in the planning problems. Therefore a planner may indicate the transitions that will be subordinate to the specified goals and constraints. These transitions are treated as the decision variables by the problem solver. Of course a planner can also indicate that for some transitions the specified flow strengths must be satisfied and are not subordinate to specified goals.

We don't want to worry the planner about all kinds of details, necessary to specify the mathematical models completely. Therefore a planner may specify the modifications of an existing planning problem and new goals and constraints in terms of the aspects that are defined in the informal specification and on an aggregate level. Furthermore, the system assumes that aspects not specified by the planner are to remain unchanged. The planner can thus restrict the problem description to the relevant changes.

The problem solver computes the development of the personnel in the organization during the planning period just on basis of the problem stated in the formal specification. If it is only possible to satisfy a part of the objectives in the formal specification, the solver generates an outline of the personnel evolution in which the competing objectives are realized as close as possible, taking into account the mutual priorities.

In the case the problem specification contains aggregate objectives, the system assumes that the desired results, computed on a detailed level, should be similar to the results following from the specification of the detailed state and policy (i.e. the network instance). This is achieved by trying to preserve the distribution of occupation numbers and transition strengths resulting from the detailed information.

3. Classification of the tasks of the interpreter

As mentioned in the introduction, internally in the system the problems are modeled in network terms, while the communication with the planner occurs in a terminology more according to the manpower planning world. The interpreter must thus take care for the conversion of information between the formal specification and the informal specification.

Except for support in the formulation of problem situations and the evaluation of the results via a suitable language, we also would like to offer a planner some more active and intelligent support with respect to the meaning of the problem situation and its consequences. For instance by recognizing relations between the several aspects in the problem situation, or relations between these aspects and the computed consequences of the specified problem situation. It is also desirable that the interpreter can give explanations to the generated consequences, such as mismatches between the planner-specified goals and the computed realization.

Naturally, the interpreter must take care for the correctness of a newly defined problem situation. In the structure as developed in [1], we assume that the problem solver has no direct interaction with the planner. So, the formal problem specification, the result of the conversion of a specified problem into the formal specification by the interpreter, must be correct. The problem solver must be able to compute the consequences during the planning period just on basis of this information.

These considerations result in the following classification of the tasks of the interpreter:

- *Conversion and representation:*
  The interpreter must take care for the representation of the specified problem(s) and their consequences during the planning period in terms of the informal specification. The interpreter must also take care of the conversion from informal specification into formal specification and vice versa. The choice for the way of representation has influence on the conversion process.
- *Evaluation:*
  The interpreter must be able to analyze a specified problem as well as to interpret the consequences during the planning period of a problem, that are computed by the problem solver. The analysis will refer to the "intention" of the aspects that occur in the specified problem, such as mutual relations between the several aspects in the specified problem, the acceptance level for changes in numbers and distributions, etc..
- *Verification:*
  The check for correctness of a formal problem specification is of a different type as the other tasks. It operates on a more elementary level.

4. The course of a session

The different actions during a session can be divided into three stages: the formulation stage, the computational stage and the report stage. And of course, the planner can instruct the system to save a problem situation. However, to a manpower planner, this distinction in stages will be partially masked. For instance, it is possible that during the formulation of a new problem a presentation is asked of a certain aspect, which requires a computation by the solver. So it seems to the planner that the system is in the formulation stage, while the system itself has been in the computational stage for a while.
The following actions can occur during a session:

Formulation stage:

1 The planner selects an existing problem situation. New problem situations are always specified as modifications of an existing one.

2 The planner can ask for presentations concerning the selected problem specification itself and concerning the new problem specification, as far as specified at that moment. The presentations can refer to:
  - the network structure at different levels of aggregation
  - different aspects of the problem situation at different levels of aggregation, such as mean salary costs, the evolution of the occupation in certain grades, the mean passage time from one grade to another, the personnel policy following from the problem specification, etc.. Also the time dependence during the planning period of these aspects can be presented

- the actual set of goals and constraints, and the degrees of freedom.

The interpretation of the data with respect to the formal problem specification itself can be hard, because not all data with respect to the individual transition strengths reflect the actual situation. They are only needed for the underlying mathematical algorithms as a kind of guide lines, while computing the resulting evolution. For instance, in the case goals and constraints are specified, it is possible that for certain groups of transitions, the specified strengths for the individual transitions are subordinate to the goals and constraints. The transition strengths that result from the complete specification will mostly not equal the strengths as specified in the network instance. Therefore, the presentations that are shown to the planner will always refer to the situation that follows from a specified problem situation and not to the formal problem specification itself.

3 The planner specifies a new problem situation by modifying the selected problem situation. To this end the planner can make use of the generated presentations. The planner can specify a new problem situation by adapting the values, shown in the presentations, or by adapting the set of goals and constraints. Except for the specification of the new values, the planner must also be able to specify the changes and goals in more qualitative terms.

As a result of the way of modeling it can be guaranteed that certain planner-specified changes can always be satisfied. Other changes can only be handled as "target values" by the system and may therefore be competing with other specified goals and constraints.

Each modification, specified by the planner, will directly be converted to the formal specification. A reason for this is that the presentations with respect to the problem at hand will always refer to the problem, as specified so far. Therefore it is necessary that each individual change results in a correct problem specification (otherwise the problem solver cannot compute the resulting evolution, if necessary to generate a presentation that is asked for).

The planner can adapt the set of goals and constraints by specifying new goals and/or constraints and by changing or removing old ones. In the case the planner is adapting this set, the system shows the complete set of actual goals and constraints. In this way, the planner can take care of mutual relations or influences between the goals and constraints, in particular in the case the goals and constraints refer to the same area of the organization (thus of the network).

4 The defined problem can be adapted in consultation with the planner.

After a planner indicates that the new problem situation is specified completely (for instance by asking for an evaluation of the problem situation), the interpreter will perform a global analysis of all specified changes in respect of the original problem situation. To this end both the changes with respect to the values of the generated representations and with respect to the changes in the set of goals and constraints are considered. The interpreter will point out to the planner the changes and goals that seem to be in conflict with each other. For instance, lengthening of the mean passage time in a grade and decreasing of the wastage fractions for that grade will probably not agree with each other. Also relations between the different aspects that are most likely, and that are not made by the planner in the specification will be pointed out. For instance, if the planner specifies a lengthening of the mean passage time in a grade without changing the wastage from that grade, it will be brought into the planners attention that probably the wastage will also change. On basis of this information a planner can choose to adapt the problem specification.

5 Conversion.
As mentioned before, each formulation of the planner will directly be converted to the formal specification. This conversion is done autonomously by the system, without any interaction with the planner.
The formal specification consists of a set of object types in terms of which the planning problems are modeled. The formulations in terms of the informal specification must be converted to these object types. To this end the aspects appearing in the formulation of the user will be related to so called elementary aspects that are directly related to the object types in the formal specification. Qualitative statements must be converted into quantitative data.
The specifications stated in the elementary aspects are converted to the object types in the formal specification. At this moment we can only imagine specifications stated in terms of elementary aspects. The part of the system that implements more intelligent interaction would allow a specification at a higher level of abstraction.

Computational stage:

6 Computations.
The problem solver generates to a problem situation, stated in the formal specification, the resulting evolution of the personnel in the organization during the planning period. The level of detail of the results depends on the problem situation itself.
The computations are performed whenever the resulting evolution is needed to answer the questions of the user, for instance when the planner asks for presentations during the formulation of a problem or when the planner likes to see an evaluation of the specified problem.

Report stage:

7 Indicating conflicts:
- the interpreter compares the planner-specified goals and constraints and their realizations. Goals and constraints that are not satisfied (within certain margins) will be reported to the planner
- the interpreter compares the expected values and distributions for some aspects of the planning problem, derived from the values and distributions, that follow from the original selected problem situation, and their realizations. The interpreter will

report the differences between the expected and the realized values or distributions if they exceed some pre-described margins. The reason for this check is that even when the planner-specified goals can be satisfied, the solution can be of bad quality because of undesirable effects, such as an imbalance in the distribution of the personnel over the grades.

8 the planner can ask for all types of presentations concerning the problem specification and its consequences (the same as in action 2).

9 Analyzing the conflicts:
- the planner can ask for an explanation concerning the indicated conflicts (the result from action 7). The interpreter will try to answer these questions in a qualitative way by indicating the aspects in the problem specification that influence each other.
- the planner can ask for suggestions to reduce the appearing conflicts. The interpreter will answer these questions also in a qualitative way by indicating which type of changes should probably reduce the conflicts. An obvious extension will be that the interpreter is able to produce quantitative proposals, together with their consequences.

10 The planner can ask explanations with respect to:
- the generated results
- the generated proposals in order to reduce the conflicts.

Save a problem situation:

11 A planner can instruct the system to save a problem situation.
There are two obvious ways to save a problem situation:
- the network instance and the specified goals as specified in the original selected problem situation, adapted with the planner specified changes and extensions
- the network instance (especially the transition strengths) reflects the values as generated by the problem solver from the specified problem, together with the planner specified goals and constraints.

We have to decide in which way a new problem situation will be saved. In the first way the original transition strengths, reflecting target values and target distributions, are saved. In the second way the transition strengths correspond with the specified goals.

5. The tasks of the interpreter

From the possible actions during a session, described in the previous section, we come to the following tasks of the interpreter:

Representation and conversion:

1 *construction* of reports concerning the problem situation itself and its consequences computed by the problem solver (corresponds with the actions 2 and 8):
the results are converted from the formal specification into the informal specification

2 *assistance* for the formulation of policies and objectives on basis of a selected problem specification in informal and qualitative terms (corresponds with action 3)

3 *conversion* of the user-specified problem formulation (corresponds with action 5):
- division of the informal and qualitative terms appearing in the informal problem specification in subaspects that have a 1-1 correspondence with the object types in the formal specification
- conversion of the subaspects to the formal specification

Evaluation:

4 *support of the problem formulation* by giving hints and/or warnings in case of mutual influences, such as the relation between the adaption of career patterns and the wastage numbers (corresponds with action 4).

5 *detection of undesirable effects* with respect to aspects that did not appear in the problem specification but that can be of importance to the quality of the generated solution both during the planning period and on the long term. For instance, an imbalance in age distribution or a shift in the personnel distribution in a part of the organization that was not concerned in the objectives appearing in the problem specification (corresponds with action 7).

6 *analysis of the results in relation to the specified objectives* (corresponds with actions 7, 9 and 10), such as
- detect the bottle-necks, i.e. show which goals are in conflict
- make proposals to handle the conflicts
- answer why-questions, such as why is this policy proposed
or why is the number of recruits that small.

Verification:

7 *verification* of the resulting formal problem specification:
- correctness
- consistency
- completeness.

The verification of the problem situation is done by the interpreter after each conversion of a statement of the planner.

6. Side-notes to these tasks

6.1. Representation and conversion

In this subsection we will consider some problems that arise in the conversion process. Of course, the conversion process is mainly dependent on the format of the informal and the formal specification. The measure to what extent the correctness of a new problem situation will be satisfied is also dependent on the way te statements of the planner are interpreted and influences thus also the way the conversion is performed.

The correctness of the problem situation requires nonnegative occupation numbers and transition flows. It is easily to check whether the start occupation satisfies this requirement. The transition flows must satisfy the condition that the total amount of flow from a category may not exceed the available occupation in that category. So, the change in one transition flow can easily induce incorrectness, especially because a planner may specify changes on an aggregate level. For instance, an increase of the promotion flow from a grade to another can easily induce incorrectness for the categories from which also early-retirement flows are defined, and it will induce incorrectness for the categories with a retirement flow (which already consumes the total amount of personnel in that category). This problem can be avoided by introducing precedence orders for the several transition types. The specified transition strengths are then interpreted as fractions or numbers of the remaining occupation, after the transitions with a higher precedence order are performed. For instance, a precedence order could be:

- retirement and early-retirement
- wastage and promotion (i.e. the transition that result in a change of the grade)
- the other transitions.

Of course, for transitions with the same precedence order, still the total amount of the flow numbers may not exceed the remaining occupation at the moment these transitions are evaluated.

The question remains to what extent the precedence orders must penetrate into the system:

- only into the interpreter, thus into the way of interpretation and conversion
- also into the formal specification (this only influences the way the fractions and numbers in the formal specification must be interpret)
- or must even the problem solver keep this precedence order strictly, when computing the problems.

An other point to be considered with respect to the conversion process is the way the mutual priorities of the goals and constraints, specified by the planner, must be interpreted and converted to the weight factors in the formal specification. Will the weight factors be chosen once and be fixed during a session or can they be adapted by the interpreter for instance on basis of the results of the solver, after which again a solution is computed by the solver. Also in the case new goals and constraints are added it could be useful to reassign the weight factors for all goals and constraints.

6.2. Evaluation

Now we will consider the tasks with respect to the evaluation, both with respect to the interpretation of the planner specified problem as to the interpretation of the results, computed by the problem solver. With respect to the problem formulation, the system supports the planner in the formulation stage by showing the relevant causal relations concerning the aspects that occur in the statements of the planner and give the planner qualitative hints with respect to unexpected combinations or neglected aspects in the

complete problem specification.
The system supports the planner also with the interpretation of the results, computed by the problem solver. The system will identify the not satisfied goals, examine which goals are in conflict and detect undesirable effects. The system must be able to produce proposals to reduce the conflicts. The proposals will be stated in a qualitative way. No concrete quantified proposals or hints will be given. In a later stage of the development of the interpreter, it could be considered to extend this part of the system with facilities that can give quantitative hints and make quantitative proposals.
The following points have to be considered:

- What is the basic set of causal relations between the different aspects that can occur in the problem specifications. This set of causal relations will be used to support the planner with hints and/or warnings during the problem formulation as well as in the analysis of the results of the problem solver. The set of causal relations will exist of a general part, independent on the organization the system is used for and a specific part, tailored to the organization in question.
  Also the grounds upon which the hints and or warnings are produced must be considered. For instance, what changes of the mean passage time in a grade will result in a warning that they can influence the wastage fractions from that grade.
- For the detection of undesirable effects a number of checks will be performed on the results computed by the solver. The checks that will be performed and the conditions they have to satisfy must be considered. Also a part of this set of checks and conditions will be general operative for each organization, another part will be tailored to the organization in question.
- An inference mechanism is needed that controls the set of causal relations in relation to a specified problem. Also an inference mechanism is needed that results in an explanation why goals are not satisfied, that is able to construct proposals to handle the conflicts and that is able to explain the behavior of the system. Such an inference mechanism will operate by combining the causal relations, the not satisfied goals and constraints, and the shifts or imbalances in the evolution of the personnel. It must be considered to what extend the proposals are concrete or to what extend they just will indicate the way the conflicts can be handled and leave it to the planner to make these proposals concrete. In the case the interpreter also makes concrete proposals, the interpreter must be able to instruct the solver to make some test computations to confirm the proposals.
- Although the sets of causal relations and checks that have to be performed are static during a session, the planner must be able to adapt these sets.

6.3. Verification

The test for verification will take place on basis of the formal problem specification. *Correctness* deals with references to existing categories, transitions and objects. This can be done immediately when the planner refers to non-existing aspects. Correctness also deals with the uniqueness of the specification of the object instances referring to the description of the detailed state (for instance, for each transition the strength must be uniquely defined).

Consistency deals with contradictions in the problem specification that cannot be handled by the problem solver. However the problem solver can handle competing objectives, for instance the case that several objectives refer to the same categories. So a problem specification will always be consistent from the point of view of the solver.

A *complete* formal problem specification consists of a specification of the detailed state and possibly the specification of (aggregate) objectives. At this moment we do not allow changes in the network structure. A new formal problem specification is obtained by specifying mutations and/or by the addition of goals and constraints to a (complete) existing problem specification. So newly specified problem specification will always be complete. When also changes in the network structure can be formulated, it depends on how these changes are implemented whether the detailed state will remain complete with respect to the new network structure.

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