Some considerations concerning the problem interpreter of the new manpower planning system formasy

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1. Introduction

This paper is an extension to paper [1] in which the tasks of the problem interpreter, the component of the manpower planning system that is responsible for the communication with the planner, are considered. In this paper we will go further into the difficulties that arise and the choices that have to be made in the development of the problem interpreter. For an introduction into the concerning issue see paper [1].

As mentioned in [1] the tasks of the interpreter can be classified in:
- conversion and representation,
- evaluation,
- verification.

The problem situations are modeled in terms of a network. This format is called the formal specification. However, this format will in general not coincide with the terminology of the planner. The representation tasks must offer the planner a suitable terminology to communicate with the system. This terminology is called the informal specification. The conversion tasks depend on both the informal and the formal specification.

The evaluation tasks operate on the basis of the stated problem situation itself and on forecasts produced by the system. Problems are formulated within the context of an existing description of the present organization. The planner-specified problem itself will be analyzed on basis of the differences compared to the original problem situation. The interpreter will detect the changes that seem to be in conflict with each other and the relations between aspects that seem to be neglected by the planner. The results, generated by the system, will be related to the specified goals and restrictions. The interpreter detects the goals and restrictions that are not satisfied. Also the bottlenecks and the conflicts between the goals and restrictions are detected. In this analysis the interpreter will use knowledge concerning the causal relations between the aspects that can occur in the problem specifications. Furthermore the problem interpreter will perform a set of checks with respect to aspects that also influence the quality of the generated evolution during the planning period.

In section 2 we consider the format of the formal specification and the considerations that play a role in the choice for this format. In section 3 we consider the several
presentation possibilities that determine the format of the informal specification. In section 4 we consider some consequences of these choices for the conversion of informal to formal specification and vice versa. Finally in section 5 we will make some general remarks concerning the evaluation.

2. The formal specification

2.1. Introduction

The planner-specified problem situations, stated in the informal specification, are modeled into the formal specification. A problem, stated in the formal specification is called a formal problem specification. As mentioned before, a new problem situation is specified by modifying an existing one. Because modifications to a problem instance often only affect a limited number of aspects, a problem instance is subdivided into a collection of object instances, where each object type corresponds to a different type of aspect. The set of object types in the formal specification must be chosen such that the manpower planning problems can be described in terms of those object types. Furthermore it must be rather easy to incorporate changes into a formal problem specification, especially with respect to correctness and consistency of the consequent problem specification. This requirement has a strong impact on the format of the object instances.

2.2. The object types

The formal specification is the format in which the manpower planning problems are modeled. The problem solver, the component of the system that generates the forecasts to specified problem situations, must be able to produce the evolution of the personnel in the organization just on basis of the formal problem specification. The manpower planning problems are modeled using network structures. The network model reflects the classification and the evolution possibilities of the personnel. The network nodes correspond with the classification of the personnel in a number of categories. The categories are defined by several characteristics of interest, such as grade, age, grade seniority, gender and level of training. The network arcs describe the possible transitions between these categories and to or from the environment. At this moment we assume that the network structure cannot be modified by the planner during a session. In order to be able to evaluate salary costs, a salary cost will be defined for each category.

We require that a problem instance at least contains a detailed description of the present organization and policy. This part of a problem instance, also called the detailed state, consists of an instance of the network structure, that is of the start occupation for each category and the transition mechanism, possibly time dependent, that describes the transition strengths for each transition in the network structure. In addition to the detailed state, the formal problem specification provides for object types in terms of which goals and restrictions can be specified. Goals and restrictions can be specified at an aggregate level, and may refer to the primary object types such as the occupation numbers for groups of categories and flow strengths for groups of transitions, as well as to object types that can be derived from these primary objects, such as the mean passage time in a
grade, the mean age of the personnel with a certain variance, the ratio between external recruitment and internal promotion into a grade, etc.

From these considerations we come to the following object types in the formal specification, grouped according to their purpose:

**Network structure:**
- the categories (network nodes)
- the start and/or end category to each transition possibility (network arcs).
The categories are defined by:
  - the characteristics (number and type is dependent on the concerned organization)
  - the range of values to each characteristic,
  - the categories are the elements of the resulting product set to or from which personnel flows are possible. The remaining elements of the product set are considered to be non-existing.

In addition, transitions have a type. The type of a transition defines the characteristics that it operates on. Examples of transition types are recruitment, retirement, early-retirement, wastage and promotion.

**Network instance:**
- start occupation to each category
- the transition strength to each transition.
- the salary costs to each category.

**Goals and constraints:**
- occupation numbers, both values for groups of categories and distributions for sets of groups
- transition strengths, both values for groups of transitions and distributions for sets of groups
- salary costs for groups of categories
- mean passage time
- mean values and variances for groups of categories with respect to characteristics with numerical values. For instance, mean age, if age is one of the characteristics.
- etc..

Goals and constraints are in the formal specification reflected by:
- the concerned group of categories or transitions
- the concerned object type
- the target value(s) or constraints
- possibly weight factors (derived from the planner-specified priorities).

As mentioned before, the transition strengths are the potential degrees of freedom. Degrees of freedom are in the formal specification reflected by constraints, derived from the default requirement that transition strengths and occupation numbers must be non-negative.
2.3. Consequences of aggregate modifications on the object instances

The format of the object instances is influenced by the requirement that it must be rather easy to incorporate changes into a formal problem specification, especially with respect to correctness and consistency of the consequent problem specification. Modifications can be specified with respect to:
- the detailed state, thus the start occupation and the transition strengths
- the goals and constraints.

Modifications with respect to the goals and restrictions will pose no problems concerning correctness or consistency. The modifications must be stated in the correct form and satisfy some elementary requirements, such as non-negative target values for occupation numbers or transition strengths. The same holds for modifications in the start occupation, specified in the network instance.

Modifications in the transition mechanism, described in the detailed state, are of a different type. Again, non-negative flows and occupation numbers must be guaranteed. However, usually several flows will leave from each category. So the change in one of these flows can easily cause a conflict. This problem comes up especially in the case modifications are specified on an aggregate level (a possibility that we want to offer the planner). However we don't like to bother the planner too often with this type of correctness problems during the formulation process. For instance, an increase of the promotion flow from one 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). For most other categories within the concerned grade, the increase of the wastage flow will cause no problem. To the planner this correctness problem will seem to be unimportant: retirement and early-retirement flows are expected to remain the same, the increase of the wastage is only intended for the personnel that does not (early-) retire. A possible solution to the problem of aggregate modification to the transition mechanism is to introduce transition precedences for the different types of transitions. Transition strengths are then evaluated on the basis of the occupation that is left after higher-precedence transitions have been evaluated. 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.

Some problems have to be considered:
1. the planner allowed to define the precedence order and to change it during a session
2. to what extent will a planner be able to handle precedence orders. In particular will a planner be able to handle the difference between fractions and numbers based on the total occupation in a grade and based on the remaining occupation in that grade after
some transitions are already performed

3 how must the transition strengths, defined by numbers, be interpreted. We require that transition strengths defined by fractions and defined by numbers are handled in the same way

4 to what extent must the precedence orders 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 problem.

Naturally, if precedence orders for the different types of transitions are used to support the planner in the formulation of the problems, the interpreter will use this in the interpretation and the conversion of the planner-specified problems.

It seems wise to reflect the transition strengths in the formal specification on basis of the precedence order. In that case the transition strengths are specified in relation to the remaining occupation, after the transitions with a higher precedence order are performed. An advantage of this way of specification is that, if a transition strength is changed, this only influences the transitions with the same precedence order that leave from the concerned category. If the transition strengths in the formal specification would be related to the start occupation itself, the change of one transition strength by the planner would cause a change of all transitions strengths with the same or a lower precedence order in the formal specification, which requires quite a lot of work. An other advantage of specifying the transition strengths in relation to the precedence order and not in relation to the start occupation is that much less information is needed, because in the first case the transition strengths can be specified on an aggregate level in the formal specification. A disadvantage to specify the transition strengths in relation to the precedence order is that the solver needs a mechanism that interprets the specified values in a correct way.

From this we come to the third point to consider: must the problem solver keep the precedence order strictly or not. Transition precedences may introduce a problem, because the precedence order may conflict with the priorities of the planner-specified goals. If the solver keeps the precedence order, a planner has no longer influence on the order in which the transitions are evaluated, unless the planner may define the precedence orders, not necessarily the same for the whole network. Each time the precedence orders are changed, it requires a lot of work to convert the new precedence orders into the formal specification. However, it is likely that this problem will rarely occur in practice, since different transition types usually operate on different classes of employees. For example, retirement and promotion operate on non-overlapping age intervals.
3. The informal specification.

3.1. Introduction

The informal specification is the framework in which the planner communicates with the system. This determines both the way the reports and the results of the analysis are presented to the planner and the way the planner can formulate the new problem situations. We will discuss now what has to be presented in the reports and what aspects may occur in the problem formulations of the planner. We will also consider the type of results of the analysis, performed by the interpreter, that are presented to the planner.

3.2. The reports

As mentioned before, a new problem formulation is specified by adapting an existing one. Therefore the interpreter must be able to generate reports with respect to all kinds of aspects concerning the (possibly partial) modified problem situation itself and the evolution of the personnel resulting from that problem situation. The planner must be able to indicate the aggregation level of the reports.

The aspects that can be shown in the reports, can refer directly to the object types in the formal specification as well as to aspects that can be derived from the information that is available in the formal specification, such as the actual mean passage time, an age distribution, salary costs, etc.. All these reports will show quantitative information.

The interpreter must also be able to show the actual set of goals and restrictions to the planner. In the case the planner wants to change this set, the complete set must be shown to the planner. In this way, it is brought to the attention of the planner which goals and restrictions refer to the same area of the personnel structure or are related otherwise.

3.3. The formulation

We assume that a new problem specification is also specified in quantitative terms by the planner. In a later stage of development of this system it could be considered to allow also more qualitative formulations. The planner may specify modifications of the problem situation by indicating desired changes in the generated reports or by adapting the set of goals and constraints. We prefer to enable the planner to indicate changes with respect to all aspects that can be shown in the reports. However, for most secondary aspects it can be rather hard to convert changes to the formal specification. On the other hand, the construction of the reports from the formal specification will mostly be easy.

The planner must specify, analogous to the way the information is stated in the formal specification:
- the concerned part of the organization (i.e. the concerned group(s) of categories or transitions)
- the concerned aspect (such as target occupation, mean age, mean promotion fraction, etc.).

In the case the values generated in the reports are modified:
- the modification, at choice as a fixed value, a scale factor, an increase or decrease, etc.
In the case a goal or constraint is specified or modified:
- the target value(s) or constraints
- possibly the mutual priorities in relation to other goals and constraints.
Furthermore the planner can indicate which groups of transitions are the decision variables.

3.4. The analysis

The interpreter produces evaluations both with respect to the formulated problem situation itself and to the forecasts generated to that problem situation. These evaluations will be stated in qualitative terms. The interpreter points out to the planner causal relations between aspects that play a role in the problem specification. The interpreter will also compare the realized values with the specified goals and constraints. For some aspects the interpreter will also compare the realized values with the values that would be expected from the original problem situation. The reason for this is that changes in certain distributions or values can influence the quality of a personnel policy too. Examples of such aspects are the change of the age distribution of the personnel in time, or an imbalance in the personnel flows which can cause an accumulation or a depletion of the number of personnel in certain grades.

With respect to the problem specification itself, 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. For instance, if the planner changes the opportunity for promotion without changing the wastage flows, the interpreter will warn the planner that the wastage will probably change in a certain direction as a result of the changed promotion. It is up to the planner to adapt the wastage as a result of this information or not. At this moment, this type of evaluations will be qualitative. Only the trend of an expected change will be indicated.

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 (within certain margins), examine which goals are in conflict and detect undesirable effects. In the case that not all goals and constraints are satisfied within certain margins, the interpreter will show both the realized value and the target value(s) or the constraints. In the case of undesirable effects the interpreter will show the realized values and the values, expected from the original problem situation.

The interpreter will also produce proposals to reduce the conflicts. The planner may also ask for explanations concerning the generated results and proposals. The proposals will be stated in a qualitative way. No concrete quantified proposals or hints will be given. For instance, the interpreter can advice to change a goal in a certain direction or to reject it. 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.
4. Conversion of informal to formal specification.

The planner can specify a new problem situation by modifying an existing problem situation and by specifying new goals and restrictions. Each statement of the planner will directly be converted to the formal specification. We assume that each modification of the formal problem specification must preserve the correctness. If a modification would result in an incorrect problem specification, the interpreter reports this to the planner and offers support to adapt the problem specification. As mentioned before, the only modifications that could cause real problems are the modifications of the detailed transition strengths. The other modifications and the formulation of new goals and restrictions must satisfy conditions that are rather straightforward to a planner. So these conditions will mostly not be violated and otherwise it will be easy to adapt the concerned statement in a proper way. Because of our choice to introduce precedence orders for the different types of transitions, the same will hold for modifications in the detailed transition mechanism. The actual conversion of changes to the transition mechanism will depend on the choice to what extend the precedence orders penetrate into the system, only in the interpreter or also in the formal specification.

Modifications with respect to goals and restrictions can refer to the concerned part of the organization, the target values or constraints and the priority. The conditions that this type of modifications have to satisfy are thus clear. Therefore they will mostly cause no problems. The deletion of goals and restrictions will also cause no problems.

The same holds for the conversion of new specified goals and restrictions. If they satisfy the proper format in the informal specification, the conversion can be performed directly. The only problem with goals and restrictions is the conversion of the planner-specified priorities. With the actual design of the problem solver, the priorities can only be taken into account by using the optimization algorithm. Therefore they have to be converted to weight factors. The conversion of the priorities, possibly quantified by the planner, is thus dependent of the format of the different terms in the cost function, used to evaluate the optimization problem. Because each object type is reflected in its own way in the cost function, the conversion of the priorities is dependent on the specified priorities as well as on the concerned object type.

5. The evaluation

The evaluations by the problem interpreter can refer to the stated problem itself and to the forecasts produced by the problem solver. The generated forecasts are analyzed to detect conflicts with the specified goals and constraints, possible bottlenecks, and undesired effects. The detection of conflicts is done by comparing the generated results with the specified goals and constraints. The detection of undesired effects is done by comparing resulting values and distributions for a predescribed set of aspects with the values and distributions that should be expected on basis of the original problem specification. A part of this predescribed set of aspects is common valid to all organizations, a part will be dependent on the concerned organization. Naturally, the planner can
also indicate aspects with respect to which must be examined whether significant shifts in relation to the original situation arise.

The evaluation of the problem specification itself, the generation of suggestions to reduce bottlenecks and conflicts, and the answering of questions concerning the reasons for the conflicts and bottlenecks or the origin of the generated results will be based on knowledge with respect to the causal relation of the aspects that play a role in manpower planning problems. A possible way to embody this knowledge into the interpreter is by a set of rules that describe the causal relations between the several aspects that play a role in manpower planning problems. Also an inference mechanism is needed to apply these rules to the problem specification and its results. Again, a part of this set of rules will be independent of the organization in question, a part will be organization dependent.

6. Final remark

As mentioned in the introduction, this paper is a refinement of paper [1]. It reflects some problems and choices that have to be made in the development of the problem interpreter. We describe the global exploration and some considerations we have made. We do not pretend that in this paper the first stage in the development of the interpreter is treated exhaustively.

References

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