Towards a framework for enhancing Qualitative Simulation with Explanation

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Abstract
To validate systems represented by a computing model, engineers often use simulation. On the other side, qualitative reasoning, an artificial intelligence field, allows prediction of possible behaviors of a system, modeled by using imprecise or incomplete knowledge. Each behavior is a series of qualitative states. Transitions from one state to another lead to a behavior tree.
In this paper, we propose to enhance qualitative simulation with an explanatory module, in order to:

- Justify each transition
- and, eventually, show why an expected behavior is not present in the behavior tree.

The explanatory module proposed is modeled at the knowledge level. This approach is based on an abstract description of the knowledge and the resolution process using it. For that purpose, an emergent concept, conceptual model, is used.
A proposition to represent explanatory knowledge identified, is then suggested.
Keywords: Qualitative simulation, behavior tree, explanation, knowledge level, conceptual model.

1. Introduction

Artificial Intelligence has been used in simulation field since the end of the seventies with qualitative reasoning leading to qualitative simulation (**[DEKL77], [KUIP84], [KUIP86]**).
Qualitative simulation guarantees to find all possible behaviors consistent with the knowledge in the observed model. This expressive power and coverage are important in problem-solving for diagnosis, design, monitoring and explanation.
More recently, explanation, another field of artificial intelligence, has been integrated in simulation(**[FOFA90], [GAGR93], [GRGA93]**). We have proposed to integrate an explanatory module to an environment of simulation(**[BELA97], [LARA99]**). We propose to extend and adapt this module to an environment of qualitative simulation.
This paper is structured as follows: after this introduction, we will introduce the problem of integrating explanation in qualitative simulation in section 2. Sections 3 and 4 will contain general principles of qualitative simulation and explanation. Functional and structural description of the explanatory module will be presented in sections 5 and 6 and be followed by a proposal for explanatory knowledge, and then the conclusion..

2. Problematic

In all of qualitative modeling and simulation packages, the simulation process begins with a qualitative description of the behavior of the system and its initial state, using physical parameters and relationships between these ones. Each parameter is defined as a physical quantity expressed by a real function, continuously differentiable ,
$f: [a,b] \rightarrow R$. Simulation thus produces a description of the behavior of the system. Each behavior is a series of qualitative states through which the physical system may move over time. Qualitative states are unique descriptions of the physical system. Each stata, **QS(f,t)**, defined for a function f at an instant t, is characterized by a landmark value **qval** and the sign of its derivative **qdir** as follows:

$\forall t \in [a,b] \quad QS(f,t) = (qval, qdir)$ with

qval = { l_j if $f(t) = l_j$ — l_j being a member of a totally ordered set
{ (l_j, l_{j+1}) if $f(t)\ ]l_j, l_{j+1}[$ — called quantity set.

Qdir = { inc if $f'(t) > 0$
{ std if $f'(t) < 0$
{ dec if $f'(t) = 0$

transitions from one state to another are obtained by continuous changes in parameters, creating a behavior tree. An explanatory module is needed to justify each transition and eventually the absence of an expected behavior in the behavior tree.

3. Qualitative Simulation

Before discussing explanation principles, let's introduce qualitative simulation. Its interests are multiple**[HATO91]**:

- parameters controlling a system change qualitatively even they are defined quantitatively
- in problem resolution, quantitative data are always lacking
- complete quantitative models construction is not always possible

When running according to the constraint propagation approach, qualitative simulation process proceeds using propagation/prediction cycle.

Propagation phase allows completion of current state qualitative description by constraint propagation.

Prediction phase determines which state to be inferred using transitions(P-transition from time t_i to time $]t_i, t_{i+1}[$ and I-transition(from time $]t_i, t_{i+1}[$ to time t_i and external constraints. The result is a successive sequence of qualitative states defining possible behaviors of the system, as shown below:

time t_i	**P-trans**	**time $]t_i, t_{i+1}[$**	**I-trans**	**time t_i**
< lj, std >	p1	< lj, std >	i1	< lj, std >
< lj, std >	p2	< (lj, lj+1),inc >	i2	< lj+1, std >
< lj, std >	p3	< (lj-1, lj), dec >	i5	< lj-1, std >
< lj, inc >	p4	< (lj, lj+1), inc >	i3	< lj+1, inc >
< (lj, lj+1), inc >	p5	< (lj, lj+1), inc >	i4	< (lj, lj+1), inc >
< lj, dec >	p6	< (lj-1, lj), dec >	i6	< lj-1, dec >
< (lj-1, lj), dec >	p7	< (lj-1, lj), dec >	i7	< (lj-1, lj), dec >
		< (lj, lj+1), inc >	i8	< l*, std >
		< (lj-1, lj), dec >	i9	< l*, std >

Figure 1: successive qualitative states inferred

4. Explanation

Let's now discuss explanation. Recent researches in this Artificial Intelligence field, consider explanation as a task of reasoning necessitating its own knowledge.

Explanation is based on a contextual and cooperative approach. The cooperation is motivated by the fact that an explanation has for finality a human user with his own knowledge, his habits, his doubts**[LESA91]**. Explanations whose elaboration has not taken into account the user**[BREZ92]**, or has considered him as novice**[BREZ95]**, have not reached their objectives. Indeed, the explanation being considered as a transfer of knowledge of the explanatory model to the user, a common effort between them is necessary for the production of a satisfying explanation. The final explanation is then the result of a progressive refinement of the first explanation produced, by considering new additional knowledge provided by both of the explanatory module or the user. It is therefore necessary that the former and the latter interact in the same context. The notion of context, although always badly defined, remains however representable**[BAHA95]**. Explanatory knowledge, the dialogue, characteristics of the user are its elements**[BREZ93]**.

5. The knowledge level

AI community discovered the term *knowledge level* in [NEWE82]. This approach was introduced to describe a system as owning some knowledge without considering its representation or implementation. A knowledge level modeling concerns then the behavior of the system in terms of its knowledge, goals and actions it can perform. A conceptual model is then built

A conceptual model is an abstract description of the problem solving process and the knowledge it uses. A such description is based on three concepts:

- the task: describes what must be done and shows goals and sub-goals of the system
- the method: shows how these goals are realized

- the domain model: describes necessary knowledge for performing these methods.

As a consequence of using knowledge level modeling, explanatory module would be described in a higher level of abstraction, driving a better characterizing of its behavior

6. Explanatory module modeling

Considering explanation as a reasoning task, we will first identify knowledge necessary for constructing explanation and its generation by the explanatory module. Then, we will describe explanatory reasoning.

6.1 Explanatory knowledge modeling

Explanatory knowledge may be of different types:

- **explanatory strategies**: that represent methods of implementation resolution during the construction of the explanation.
- **explanatory principles**: that represent heuristic knowledge that contribute to the improvement of the explanation proposed by explanatory strategies.
- **knowledge of the simulation area**: that are useful to the explanation.
- **knowledge elaborated during the explanatory reasoning**: such as explanatory reasoning trace, and the historical of the dialogue between the explanatory module and the user.
- **cooperative knowledge**: that allow to consider specificities of both explanatory module and the user
- **control knowledge**: composed of constraints and evaluating knowledge serving to choose between different explanatory strategies or different explanatory principles.
- **linguistic knowledge**: necessary for the generation of the explanatory text.

These different types may be regrouped in many classes according to their
roles in elaborating the explanatory discourse. We can then distinguish:

- **contextual knowledge:** which improve other classes knowledge efficiency eventhough not directly involved in explanation elaboration. These are knowledge elaborated during explanatory reasoning
- **constructive knowledge:** which participate actively in the explanation building, using contextual knowledge. This class includes explanatory strategies, explanatory principles and control knowledge
- **generative knowledge:** that generate constructed explanatory text. This class includes linguistic knowledge and the content of the first explanatory text
- **contextualized knowledge:** that have participated previously to the explanation elaborating process. These are object reasoning trace and knowledge of simulation area
- **cooperative knowledge**

According to these classes, a three layers conceptual model may be built and is shown below:

Constructive Explanatory Conceptual Model CECM
Domain Explanatory Conceptual Model DECM
Cooperative and Contextual Explanatory Conceptual Model CCECM

Figure 2: Explanatory Knowledge Model

The model illustrated in Figure 2 is based on the three layers model of the KADS (**K**nowledge **A**cquisition **D**esign **S**tructure) design methodology, developed at Amsterdam university[WIEL92]. Its three layers are:

- Constructive Explanatory Conceptual Model(CECM): that models constructive knowledge
- Domain Explanatory Conceptual Model(DECM): that models generative and contextualized knowledge
- Cooperative and Contextual Explanatory Conceptual model: that models contextual and cooperative knowledge.

6.2 Explanatory reasoning modeling

All of knowledge presented above collaborate to be used by explanatory reasoning as described in the following.

At the end of simulation process, explanatory module intervenes to eventually justify any transition or absence of an expected behavior. When responding to a user, it associates this latter’s question to an explanatory strategy in the explanatory knowledge base. A first explanation is then generated which may not satisfy the user. A dialogue can then take place between the explanatory module and the user. Each actor must consider new knowledge acquired by the other. The process is stopped when explanation provided by explanatory module is finally accepted by the user.

Figure 3 illustrates this running principle

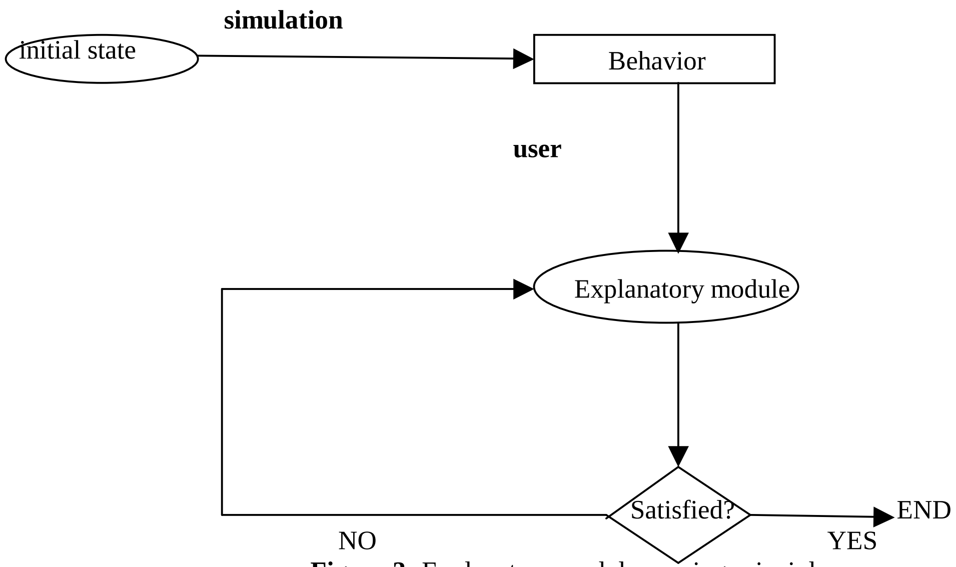

Figure 3: Explanatory module running principle

In order to construct the explanatory reasoning model on a particular domain, one has to model explanatory methods to be applied for that domain.

In qualitative simulation, an explanatory method may have two goals:

- To justify any state transition
- To justify why an expected behavior is not in the behavior tree

Thus, when receiving a question from the user, explanatory module analyses it to determine what explanatory strategy it will perform, according to whether the user is:

- asking for justifying any transition (such a question will begin by *why…*or *how…*)
- or asking for understanding why a behavior he expected is not in the behavior tree(such a question is thus beginning with *why not…*).

It then initiates a dialogue with the user to provide a satisfactory explanation to this latter. Final explanatory text will then be constructed and generated.

Many tasks are thus performed. These are:

- **Analque:** that analyses user question.
- **Why-How:** that answers why or how questions.
- **Why not:** that answers why not questions
- **Consexp:** that constructs intermediate explanatory texts
- **Genexp:** that generates final explanatory text to be provided to the user.

The explanatory reasoning conceptual model may then be represented as shown in Figure 4 below:

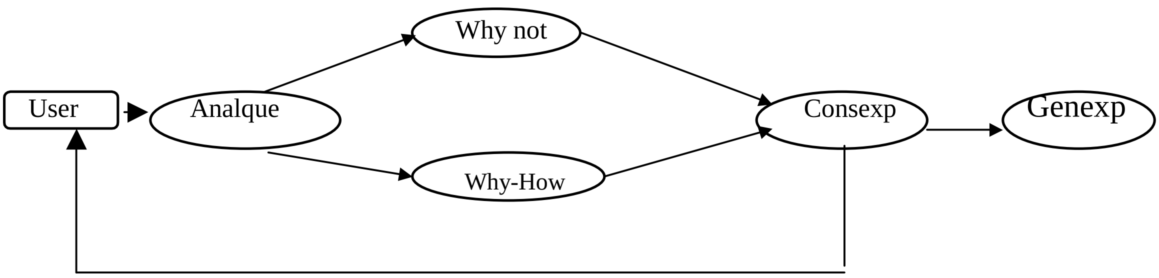

Figure 4 : Explanatory module architecture

This figure shows the tasks performed by the explanatory module to provide final explanatory text. *Analque* task analyses user question. *Why-How* task is performed to answer why or how questions. In the other hand, *Why not* task answers why not questions. *Consexp* task constructs intermediate explanatory texts and *Genexp* task generates final explanatory text to be provided to the user.

7. Representation of an explanatory text

Since we have been interested by the form of explanatory text representation presented in**[BOUR94]** , we propose to adapt it. In fact there is nothing made natural than the fact that an explanatory text may be divided into many propositions linked by argumentative relations. This may be illustrated by the example below, where the absence of any behavior from the behavior tree may be justified as: that behavior doesn't appear in the behavior tree, despite that I transition's prediction, because qdir's change corresponding to the change of the derivative sign, has not been executed correctly. This explanatory text is divided into three propositions:

P1: That behavior doesn't appear in the behavior tree

P2: That transition anticipated it

P3: The qdir change corresponding to the derivative sign hasn't been executed correctly.

These propositions are then related by argumentative links ***Inspite of*** and ***For.***

SOWA conceptual graphs**[SOWA84]** are well adapted to this kind of propositions. Those are bipartite graphs. Concepts and conceptual links are their two kinds of nodes.

The three propositions above may then be represented as follows:

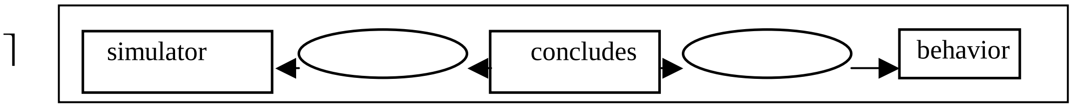

Figure 5: conceptual graph corresponding to P1

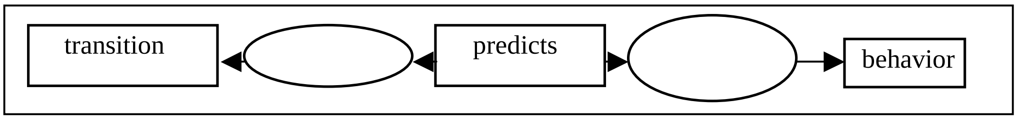

Figure 6: conceptual graph corresponding to P

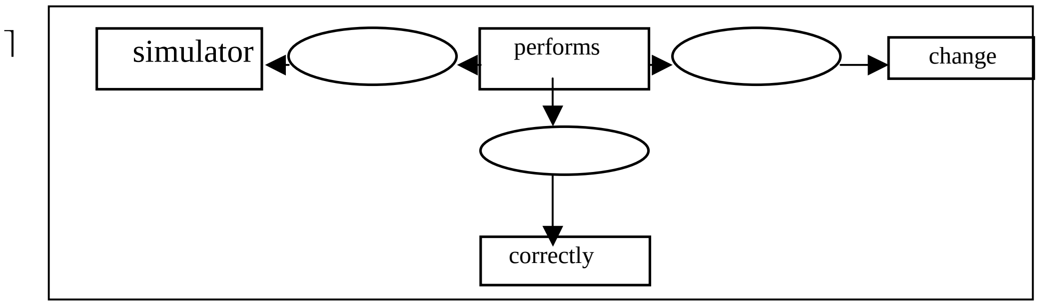

Figure 7: conceptual graph corresponding to P3

8. Conclusion and Future Work

In this paper, we presented multiple interests of qualitative simulation and proposed to improve qualitative simulation process with an explanatory module.

We proposed modeling it at the knowledge level. Explanation , viewed as a problem solving process, is then described at a higher level of abstraction. This drove to a better characterizing of the behavior of the explanatory module.

A three layers explanatory knowledge conceptual model has been constructed. Different explanatory knowledge types were identified. These were: explanatory strategies, explanatory principles, knowledge of the simulation area, knowledge elaborated during the explanatory reasoning, cooperative knowledge, control knowledge and linguistic knowledge.

An explanatory reasoning conceptual model was also built. It consisted of many cooperative explanatory tasks. These were: *Anal*yzing *Que*stion task, *Cons*tructing *exp*lanation task, *Gen*erating *exp*lanation task, *Why not* task and *Why-How* task.

Designed at a such high level of abstraction, the explanatory module will provide satisfactory explanations. Qualitative simulation is then enhanced
Such an affirmation is obviously worth of validating. That is our main concern at the present time. An implementation framework is thus planned in the immediate future.

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