DYNAMIC REPRESENTATION OF INFORMATION FOR A DECISION SUPPORT SYSTEM

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Abstract: This paper presents a system designed to help deciders manage cases of crisis. The system represents, characterises and interprets the dynamic evolution of information describing a given situation and displays the results of its analysis. The core of the system is made up of three multiagent systems (MAS): one MAS for the static and dynamic representation of the information (current situation), the second MAS for dynamically regrouping sets of agents of the former MAS and the upper MAS for matching results between the second MAS and scenarios stored in the persistent memory of the system in order to have a deeper analysis of the situation. The case based reasoning of this last MAS sends its results to the user as a view of the current situation linked to some views of similar situations. In this paper, we will focus on the representation of information MAS. This MAS is dynamic in order to be able to take into account the changes in the description of the information. Current information is represented by a layer of factual agents which is fed by the composite semantic features constituting the atomic data elements of information. The aim of the set of factual agents is both to be a real snapshot of the situation at any time and to model the evolution of information dynamically.

1 INTRODUCTION

This paper presents a global system designed to help deciders manage cases of crisis with an original representation of information. The system could either be used to prevent a crisis or to deal with it. In both cases, the main internal aim of the system is to detect a crisis (Borodzicz & al.1993). From the system point of view, detecting a crisis implies representing a crisis, characterising a crisis and comparing a crisis with other crises permanently stored in scenarios. The result of this comparison is provided to the user as the answer of the global system. Our *decision support system* chooses to highlight parts of scenarios close to the current information also called situation. The information thus obtained will help deciders analyse the current crisis and its possible evolutions.

The core of the system which is made of three multiagent systems (MAS) will be detailed in the second paragraph. A common characteristic of these three MASs is the use of intelligent agents. Wooldridge and Jennings define these intelligent agents (Wooldridge and Jennings 1995, 1998) which are the only kind of agents we will consider in this paper. Factual agents – which are our implementation for intelligent agents for the representation of information MAS – will also be explained in the second and third part. The third paragraph will focus on the design and the implementation of the composite semantic features and ontology, in order to measure semantic proximities in the information representation MAS. In the fourth part, we present some of the graphic analysis tools we use. We will conclude our paper with a presentation of the analysis of the choices we made about all the parameters and strategies we had to deal with. Some perspectives and relative works will be considered in the last part.

Historically, the objective of the representation of information MAS was to interpret the speech of human actors during a crisis (Cardon 1997), (Durand 1999), (Lesage 2000). Then we applied the system to a preventive vigil system (Boukachour & al. 2002). Its global architecture used semantic features (SF), proximity measure, ontology, dynamic clustering and case-based reasoning (Boukachour 2002). We wrote the software in Java for testing purpose on some parts of real situations. Since then, we have deeply redesigned new specifications. We

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implemented the prototype with an added goal: being generic; generic is used here with a different meaning from (Wooldridge and Jennings 1998). We postulated that some parts of the architecture and, at a deeper level, some parts of our agents were independent on the subject used as application. Today, we apply this global system to different topics such as:

– e-learning, we started collaboration with specialists in didactics (Bertin and Gravé 2004) to build a "pedagogical agent" (Hubbard 2000);
– crisis management, this architecture was tested on a scenario taken from an emergency exercise at an oil plant in Le Havre (Boukachour & al., 2001, 2002). The ontology of the specific domain was created to allow comparisons between semantic features in this context (Boukachour & al., 2003);
– logistics and information systems (work in progress);
– games (Person & al., 2005); the chosen game was the game of Risk®.

Risk (Risk game, 2006) is a commercial turn-based strategy board game produced by Parker Brothers, a division of Hasbro. Risk shares many characteristics with wargames, yet relative to other war games, it is simple and abstract. It makes little attempt to accurately simulate military strategy, the size of the world, the logistics of long campaigns or real-world luck. Risk is a turn-based game for two to six players. It is played on a board depicting a stylized political map of the Earth, divided into 42 territories, which are grouped into 6 continents.

The game is played by allocating armies to the territories that the player controls, and then attacking neighbouring territories in order to conquer them. The outcome of battles is decided by rolling dice.

Some versions of the rules specify a lower winning target or allocate a random, secret, "mission" to each player at the beginning of the game. Possible missions include gaining control of all territories in two or three specified continents, or eliminating another specified player. One of the goals of our system is to deduce the missions of the opponents.

Examples and figures in this paper are taken from the game of Risk. Here are the reasons for our choice:

– instead of depending on experts for knowing the validity of the results, we can be experts ourselves;
– it is easy to evaluate the quality of the advice given by the system: we know if the system helps us win;
– we can make the assumption of a closed-world;
– the time of execution is "reasonably" short thus allowing the system to loop and produce enough examples to test;
– the game of Risk is not a toy problem and it is particularly well suited for crisis management;
– information in the game of Risk always changes and dynamism has to be taken into account.

2 ARCHITECTURE OF THE DECISION SUPPORT SYSTEM

The *decision support system* (DSS) is a tool whose main objective is to help deciders manage decision process in the case of a crisis or before a crisis occurs. What this DSS offers users is to analyse the current situation dynamically and compare it to past situations. The past situations are permanently stored in a *scenario base* and can be viewed as one part of the knowledge we have on the specific domain.

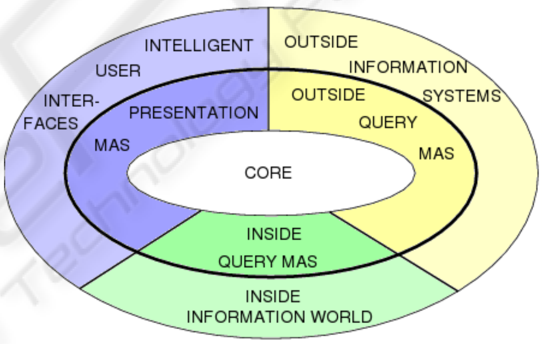

Figure 1: Global Architecture of the DSS.

In order to be helpful for the decider, the analysis of the current situation must be of great accuracy. Therefore it is essential for the analysis:

– to present a synthetic view of the salient aspects of the situation in accordance with the role and personal interests of the given decider;
– to present possible evolutions of the current situation with the associated consequences;
– to respect a temporal constraint according to the time scale of the problem.

Figure 1 shows the global architecture of this DSS. The *inside query MAS* and the *inside information world* are in charge of all the knowledge the *core* needs. The knowledge includes the scenario base we mentioned before. The knowledge also contains the ontology of the domain and the proximity measure which is specific to the domain.

The *outside query MAS* and the *outside information systems* refer to the extraction and presentation to the core of the external information the latter could need and find in network distributed information systems. The *presentation MAS* will allow dialogues between all the users authorised to access the DSS and the core of the DSS. This MAS also presents users with the final results of the core.

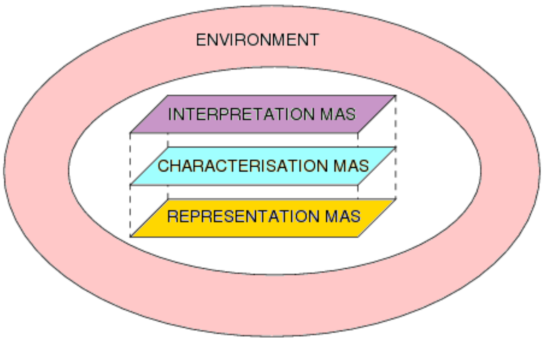

Figure 2: Architecture of the Core of the DSS.

Figure 2 shows the architecture of the core of the DSS. The *environment* provides a layer between the outer MASs presented in figure 1 and the three MASs of the core. The three internal MASs of the core communicate with each other and communicate with the environment. Each MAS has one and only one role.

The *representation MAS* must reflect an accurate static view of the whole current situation and its dynamic evolutions. The main components of this MAS are factual agents (FA). A detailed presentation of the architecture and the internal structure of FAs could be found in (Person et al, 2005). The graphic analysis tools of our last part will focus on FAs.

The *characterisation MAS* is an active observer of the representative MAS. The characterisation MAS clusters FAs both incrementally and dynamically according to the evolution of their internal indicators. The set of synthesis agents of the characterisation MAS is the internal view of the system, its internal representation of the current situation.

The *interpretation MAS* takes that view, that observation and compares the current observation with past ones known as scenarios. The interpretation MAS is composed of dynamic prediction agents. A prediction agent is associated to a given scenario or to a whole family of scenarios, depending on the applications. Prediction agents permanently try to match parts of their own scenario to the view of the current situation offered by synthesis agents. Through the environment, the activity of prediction agents is sent to the presentation MAS, and finally to the users.

3 INFORMATION REPRESENTATION MAS

3.1 Environment Design

As we wrote in the introduction, to detect a crisis implies representing a crisis and characterising it. After this stage, we must be able to compare a crisis with other crises. The result of this comparison is provided to the user as the global system answer.

The observed environment is analysed and designed as an object oriented world. That is to say that we consider all incoming information as object oriented messages describing states or behaviours of objects. These objects are a viewpoint to represent environment commonly used in object oriented analysis and design (Barber & al, 1999). From the object, semantic features (SF) are sent to our system.

An SF is a basic property of the environment or, in other words, an indication that a state is changing. In a state diagram, the state transition is used to show the state space of a given class, the events (messages) that cause a transition from one state to another, and the actions that result from a state change (Harel, 1987). Each transition occurs due to the occurrence of an event or action from one state to another. An event/action is directly linked above a transition that it causes. The observed system sends the events represented by semantic features.

We consider five parameters to identify our SF: the object, the attribute, the value attached to this attribute, the occurrence time of this event, and the location (dedicated to moving objects). A SF translates elementary information coming from the environment both particular and partial aspects of an observed situation. This SF design allows to obtain a homogeneous structure. This one allows us to establish comparisons between SFs.

3.2 Proximity Measures, Semantic Features and Ontology

With these comparisons, the system is able to evaluate a current situation by comparing it with referred situations (called scenarios).

These situations of reference result from passed experiments, studied situations, deductions, analyses or extrapolations. We need to define the set of the observations sent to our system, which is the goal of the following section.

3.3 Composite Semantic Features

In this section, we focus on the design and the implementation of the composite semantic features. An SF (”simple” semantic feature) is an elementary piece of information coming from the environment.

The factual agents represent a part of information MAS. The creation of a factual agent is triggered by the reception of a simple SF. A new SF incoming in the system does not always provoke the creation of a new factual agent. A factual agent is closed to a simple SF when the proximity measure is strictly positive. In this case, this FA aggregates the given SF. This aggregation is called a composite semantic feature (CSF). The aggregation causes an update of internal indicators.

3.4 The Game of Risk Example

The game of Risk is used to test our model. At the beginning of our study, no type of object was defined *a priori*. This study allowed us to test our model and to define these types of objects. The origin of the information must be treated upstream (ontological treatment) of the creation of the semantic feature. The different types of objects issuing from the study can take four identified values: territory, player, army, and continent. Continents and territories are static objects. The other two have dynamic properties. So for these objects, it is necessary to associate complete temporal data.

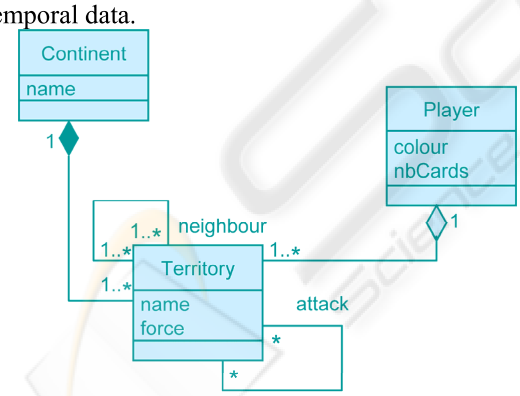

Figure 3: Class Diagram for the Representation of the Game of Risk.

Continents and territories are regarded as descriptions of a persistent situation. Continents are sets of territories; each territory has neighbours (other territories) and is occupied by armies owned by a player (see figure 3). Armies and players are activities respectively observed (occupying a territory) and driving the actions. An action is an attack by an army. It is an activity with a known origin and a determined immediate goal: to conquer a territory. We define qualifiers and their associated values for territories. For example colour indicates the owner (player) and force is the number of armies.

3.5 Internal Indicators of Factual Agents

We will now focus only on the internal indicators of FAs. How are they defined and computed and how could we interpret them?

An FA is the internal representation of a composite semantic feature inside the representation MAS. When an existing semantic feature is updated then the corresponding factual agent will update its internal indicators accordingly. The aim of internal indicators of an FA is to be a synthetic representation of the evolution of the current situation that the characterisation MAS will deal with. An FA has five internal indicators: *pseudoPosition* (PP), *pseudoSpeed* (PS), *pseudoAcceleration* (PA), *satisfactory indicator* (SI) and *constancy indicator* (CI). Figure 4 shows a partial description of the internal structure of a factual agent.

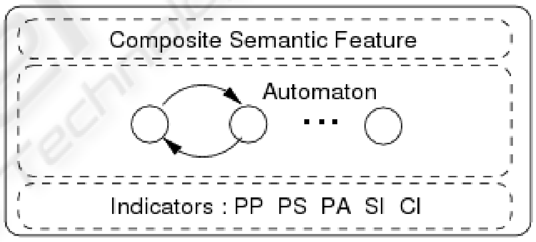

Figure 4: Partial Internal Structure of an FA.

The proximity measure between two CSFs returns a real number in [-1 .. 1]. This number is then multiplied by a coefficient specific to the given application. This result is the value of the *pseudoPosition* indicator:

$$PP_{t+1} = proximityMeasure(CSF_1, CSF_2) \times coef$$

The meaning of the *pseudoPosition* is to represent the current position of an agent in the agent representation space. We use the prefix *pseudo* because we choose a constant interval of time of one to simplify the computation of PP, PS and PA. Once the value of PP is known, consequently PS and PA are defined:

$$PS_{t+1} = PP_{t+1} - PP_t;$$

$$PA_{t+1} = PS_{t+1} - PS_t.$$

PS evaluates the speed of the evolution of PP and the semantic of PA is the estimation of the evolution of PS.

The internal automaton of an FA is an augmented transition network (ATN) whose transitions are functions of PP, PS and PA. From a generic five states ATN, each type of FA is assigned a specific ATN. Figure 5 shows the ATN of territories factual agents in the game of Risk. The internal aim of a factual agent is to reach state 4 (S4) and to stay in this particular state as long as possible. State 1 (S1) is the initial state and states 2 (S2) and 3 (S3) are intermediary states from S1 to S4. The transitions from a state to another state or to the same state are determined by predicates.

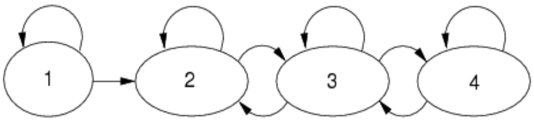

Figure 5: ATN of a Territory Factual Agent.

Table 1 shows some examples of predicates in the game of Risk.

Table 1: Example of Predicates for Transition from a State to another State of the Internal ATN of an FA.

From	***To***	***Predicate***
S1	S1	PP < 1
S1	S2	PP ≥ 1
S3	S2	PS ≥ 0 and PA ≥ 0
S3	S4	PS < 0 and PA < 0

The choice of a sub ATN from a general ATN and the definition of the predicates are specific to a given application. But the definition of the next two indicators is generic; these indicators must reflect the kind of evolution of the internal ATN of an FA.

The *satisfactory* indicator is a valuation of the success of an FA in reaching and staying in state 4 which is, by design, the ultimate aim of an FA. Figure 6 presents the calculation of this indicator.

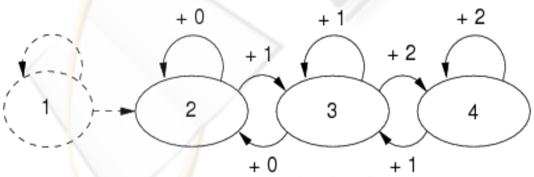

Figure 6: Calculation of Satisfactory Indicator of an FA.

The last ten transitions are summed to obtain a value in [0 .. 20]. The higher the value, the closer to the aim is the FA. In case of the maximal value of 20, the FA is said to be *fully satisfied*.

The *constancy* indicator will represent the tendency of a given FA to transit both from a state to a different state and from a state to the same state inside the internal ATN. Figure 7 explains how this indicator is computed.

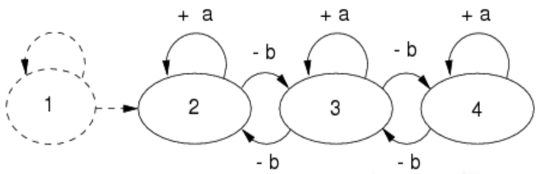

Figure 7: Computation of Constancy Indicator of an FA.

Positive values of CI must reflect the stability into a given state and negative values must reveal transitions between states. Experiments led us to choose the value of 1 for *a,* and the value of 9 for *b* to have an indicator balanced at around 0.

4 GRAPHIC ANALYSIS TOOLS

We have created and tested some specific graphic tools for analysing the behaviour of the representation MAS. We plan to include parts of these tools later in the intelligent user interface. We will successively present a dynamic internal view of the representation MAS, a static view of the same MAS, a dynamic Gantt chart focusing on the *satisfactory* indicator and an animated cartogram which is a fusion of the static view of the MAS with the *pseudoPosition* indicators of FAs.

A MAS could be perceived as a "black box". Another option is to trace the dynamic evolution of each agent. Figure 8 displays the evolution of both automaton and five indicators of a few FAs in the game of Risk.

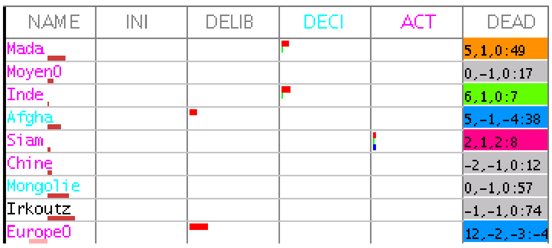

Figure 8: Partial Internal View of the Representation MAS.

The first column is the name of territories FAs. The other five columns are the possible states of the internal automaton, with state 1 called "Ini" for "initialisation", state 2 "Delib" standing for "deliberation", state 3 "Deci" for "decision", state 4 "Act" for "action" and finally "Dead" which is part of the generic automaton but is not used for territories FAs. The colourisation of names indicates when a given FA has reached a particular state in the automaton: cyan for state 3 and magenta for state 4.

Positive values of PP, PS and PA are represented by a coloured rectangle area in the column of the current state of the automaton (red for PP, green for PS and blue for PA). The last column is also used for displaying exact values of PP, PS, PA and CI. The coloured rectangles below the name of an FA graphically represent CI with pink for negative values as in “EuropeO” and red for positive values.

Each background colour in the last column corresponds to a given interval of values of a *satisfactory* indicator as specified by table 2.

Table 2: Colour of Satisfactory Indicator.

IC	[0 .. 4]	[5 .. 9]	[10..14]	[15..19]	20
colour	grey	blue	green	orange	red

Figure 9 displays the static view of the representation MAS in the game of Risk. This picture represents the board of the game with the updated corresponding CSF used as input of the MAS.

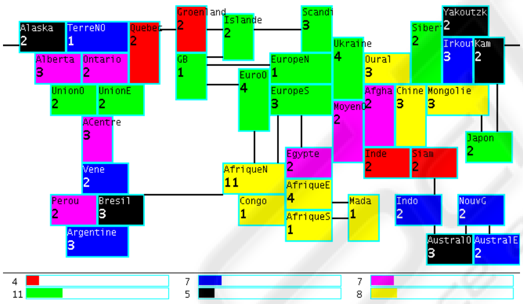

Figure 9: Static View of the Representation MAS.

A Gantt chart shows the timing of activities as they occur over time. The diagram presents to our expert the selection of factual agents whose internal satisfactory indicator is maximal as shown in figure 10. X axis is the time and Y axis is the name of the factual agent. We can note that only a few factual agents are fully satisfied, for a different interval of time and that some factual agents could be fully satisfied a few times. We are currently designing complementary views of this internal satisfactory indicator.

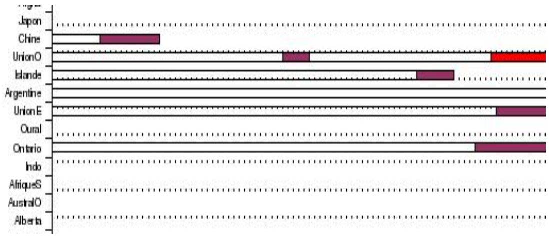

Figure 10: Partial Gantt Diagram of Fully Satisfied FAs.

The last analysis tool is *animated cartograms*. Using cartograms begun in the early days of computer science. The basic idea is to distort a geographical area according to a complementary criterion you want to represent on the same map. Tobler (Tobler, 2004) gives the following definition: “A value-by-area cartogram is a map projection that converts a measure of a non-negative distribution on the earth to an area on a map.” 1960 U.S. Population cartogram and 1981 equal population cartogram of Britain are examples taken by Kocmoud and House (Kocmoud & House, 1998) to compare their algorithm with a number of existing methods. It took about 20 hours of computer time to produce a single cartogram. 2002 French presidential election (Andrieu, 2002) is another example of cartogram where the time of computation was 33 hours for a small area. These cartograms share three common characteristics:

– the use of static data: there is only one set of data to work on;
– the topic in which cartograms is applied: geography in a broad sense;
– the time to compute a cartogram.

We offer two complementary views to the users: the static view which is the current representation of the situation and the dynamical view with the evolution between successive static views as perceived by our agents. The aim of animated cartograms is to provide users with only one synthetic view of the situation. To do so, we face three challenges:

– we do not have a “natural” criterion such as density of population to compute the cartogram;
– the data are dynamic: the set of data to be used to construct a given cartogram is permanently updated;
– we have to compute the resulting cartogram in quite a short span of time because we need to provide users with the results as soon as the data have changed.

The last two challenges could be summarised as finding a computational method quick enough to provide the end users with valid information. The answer was the use of the algorithm of Gastner and

Newman (Gastner & Newman, 2004) who propose a new method for constructing cartograms which is simpler than many other methods, and therefore the quickest to compute. They illustrated the method with applications on the results of the 2000 U.S. Presidential election, lung cancer cases in the State of New York, and the geographical distribution of stories appearing in the news. Gastner, Shalizi and Newman (Gastner, Shalizi & Newman, 2004) applied the same method to maps and cartograms of the 2004 US presidential election results.

The last challenge was to find a representative non negative distribution from internal indicators of our agents. We called *pseudoDensity* the distribution that we compute from the values of the p*seudoPosition.* As this internal indicator could have negative or positive values, we use the following formulae to transform this indicator to a strictly positive value:

$$pseudoDensity = 1 + Ln\left(1 + \frac{PP}{\max|PP|}\right)$$

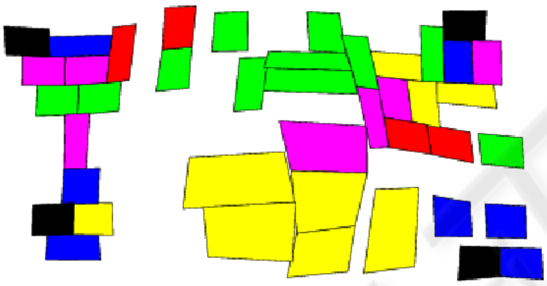

Figure 11: Cartogram of Step 118 of the Game of Risk.

We use morphing between two successive cartograms to alert the user that the current view will be updated. Figure 11 shows the new shape of a cartogram computed with *pseudoDensity*.

5 CONCLUSION

In this paper we describe a system designed to help deciders interpret information of a current situation. The system can represent information with its dynamic evolution. The core of the system is made of three MASs, and we have focused here on the first layer, because it has to represent, and to store information. The initial goal of the system was to help deciders prevent crises by analysing the information they have. We think that the main part of the system is generic and can be re-used for different applications. This is why we are testing our system on various types of applications (prediction crisis, game of Risk, E-learning, representation of information). The heart and soul of the system is, with an original representation of information and a particular treatment of it, to be able to prevent or/and predict (depending on the kind of application) something will (or is) happen(ing). Representation of information is done in the first layer we described, by the factual agents which contain the composite semantic features constituting the atomic data elements of information. Some graphic tools we use for helping the decider (but also debugging in fact), are described in this paper. These tools help us understand the parameters of the factual agents which are the most accurate to characterise information and what are the essential data to transfer to the second layer of the global system.

We are currently working on some complementary directions:

- developing new tools for a deeper analysis of the MASs;
- generating a full set of scenarios for the game of Risk. The game of Risk is an example we use to adjust the generic aspects of the core. Other applications will prove the genericity of the architecture;
- connecting the representation MAS to the characterisation MAS which is our immediate objective.

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