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Value Based Argumentation using Formal Concepts

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Abstract **— We consider the problem of argumentation over actions for the development of new agent programs. The goal is to improve the representation of argumentation over actions by using Galicia, a tool based on Formal Concept Analysis and Relational Concept Analysis. The main objective of the paper is to show our findings in the advantage provided by a clear visualization of the interaction between the agents. While we are using here a simple scenario the end goal is a more complex one in which agents need a clear picture in their decision making encounter.**

Index Terms **— Cooperative systems, Distributed computing, Intelligent systems, Interactive systems, Knowledge representation**

I. INTRODUCTION

There is significant research on methods for complex decision making regarding inter-agent activities [2], including argumentation [3]. Among the many practical reasoning approaches we concentrate in this paper on agent decision mechanisms [2] and a formal concept representation of the knowledge the agents are using [6].

Value based Argumentation has been proven to be a powerful tool in practical reasoning, offering an argumentation approach based on the values promoted by a situation, action or event, or on a pre-established hierarchy of values. Formal Concept Analysis (FCA) provides a mathematical foundation for abstract concepts, while Relational Concept Analysis (RCA) [7] adds the relational dimension, offering a visualization support for the representation of complex problems.

In the next section we describe the basic notions related to Value based Argumentation Framework (VAF) and a classical application problem that we chose as example for our study. Then, we briefly explain the FCA and RCA notions used by Galicia[1], emphasizing the contribution to the VAF approach applied in practical reasoning. The conclusions and further work end our paper.

II. VALUE BASED ARGUMENTATION

Definition 1: An argumentation framework is a pair AF = {AR, attacks}, where AR is a set of arguments and attacks is a binary relation on AR, i.e. attacks $\subseteq$ AR × AR [4].

The relation attacks(A, B), where A and B are two arguments, is interpreted as an attack of A on B. An AF is represented as a directed graph, with arguments as vertices and attacks as edges between two arguments [4]. An argument A is considered as accepted if and only if each argument B, such that attacks(A, B) is defeated by an already accepted argument. However, it can be observed that in order to apply an argumentation framework for reasoning about different situations or facts, a mechanism is required in order to determine which arguments are acceptable. In order to define such a mechanism, a new notion is introduced and that is the value promoted by an argument, this type of argumentation being known as Value based Argumentation [2], [9].

Definition 2: A Value based Argumentation framework (VAF) is a 5-tuple: VAF = {AR, attacks, V , val, P}, where AR represents a finite set of arguments, attacks is an irreflexive relation on the set AR, V is a finite nonempty set of values, val is a function mapping the elements of AR to the elements of V and P is a set of possible audiences.

Moreover, an argument A relates to value v if accepting A promotes or defends v, where:

v = val(A), val(A) $\in$ V , for every A $\in$ AF [4].

In VAF, an argument A successfully attacks (defeats) an argument B only if the value promoted by B is not ranked higher than the one promoted by A, according to some pre-established hierarchy of values. Furthermore, arguments can promote (or demote) values to a given degree, meaning that if A and B would promote the same value v, A would defeat B if it promotes the value v to a higher degree.

II.1. Application

In order to exemplify the practical application of Value based Argumentation in real-life situations, a classical problem in the Artificial Intelligence field will be further analyzed. The scenario captures a situation in which a farmer, returning from the market with his dog, a chicken and a bag of seeds, must cross a river using a boat. The main constraint consists in the fact that he can cross the river with only one of his possessions at a time. Moreover, he must be careful not to leave on the same river bank the dog and the chicken as the dog will eat the chicken. Similarly, he cannot leave the chicken and the seeds as the chicken may eat the seeds. The reasoning consists in trying to find an appropriate sequence of actions required for crossing the three possessions and, also, to provide an appropriate justification for each of the selected actions.

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[1] Available from http://www.iro.umontreal.ca/˜galicia/

To apply the Value based Argumentation approach, the problem must be modeled first in order to allow reasoning about the joint actions of the farmer. For this, we represent the farmer problem as an Action Based Alternating Transition System (AATS) [2], [8]. An AATS is a state transition diagram in which the transitions represent joint actions, that is actions composed from the individual actions available to the agents in that state, each transition being labeled with the values promoted and demoted by moving from one state to another [2]. An AATS representation is composed of a set Q of states, a set of agents Ag and their corresponding set of possible actions Ai, a set of joint actions J, i.e. a 2-tuple with one element from Ai for each agent from Ag, and a set of promoted values V.

In the farmer problem, the set Ag is represented by the three agents farmer, dog, chicken, each of them being capable of performing a certain set of actions. For example, the farmer can perform one of the three actions carry dog (carryD), carry chicken (carryC), carry seeds (carryS). The dog and the chicken are able in this context to perform only one action, eat the seeds (eatCS), respectively eat the chicken (eatDC). Each action causes a change to the current state of the problem, which leads to the transition to a new state, promoting or demoting in the same time one or more values. The set of values associated to the mentioned actions is Progress, Chicken, Seeds, Friendship, DogHappy, ChickenHappy. The value Progress is associated to each of the three possible actions of the farmer: carryD, carryC, carryS. The value Chicken is associated to the situation in which the farmer eventually goes home with the chicken, similarly, the value Seeds corresponding to the one in which the farmer goes home with the seeds, while the value Friendship being associated with the situation in which the farmer continues his journey having his dog by his side. The value DogHappy is promoted by the action eatDC, while ChickenHappy is promoted by the action eatCS, the first action being performed by the dog, while the second one being performed by the chicken.

In order to find an appropriate sequence of joint actions for solving the farmer problem, we must first determine the final state of the AATS with the highest benefit for the farmer. For this, we must consider an ordering of the set of values, such that it reflects some kind of hierarchy in the importance of the possessions for the farmer. For example, if we were to consider the value Chicken having the highest importance, then the farmer will select to perform the action carryC, which promotes the mentioned value. Similarly, if the value Seeds would be considered as having the highest degree of importance, the action carryS will be performed by the farmer. In case that the value Friendship would have the highest importance for the farmer, then he could decide to carry the dog over the river and continue his journey back home without returning for the chicken and the seeds. Moreover, if the farmer carries the dog, then the chicken could eat the seeds, which will promote the value ChickenHappy. Similarly, for the situation in which the farmer decides to take the seeds, the dog could eat then the chicken, thus promoting value DogHappy. If we were to consider the situation in which the farmer would prefer to bring all three possessions home, then a reasonable sequence of actions would be to carry the chicken first, which promotes the values {Progress, Chicken} and prevents the dog eating the chicken or the chicken eating the seeds, thus demoting the values {DogHappy, ChickenHappy}, with a lower importance for the farmer. The next appropriate action would be to carry the dog and then the seeds, preventing this way to leave the chicken alone with the seeds on the right bank of the river, which could promote the value ChickenHappy, if the chicken was to eat the seeds, but this means that it could demote the higher ranking value, Progress, as the farmer would lose one of his possessions, in this case the seeds. However, this solution could be argued by considering the most important values for the farmer as being Friendship and Seeds, which would rule out the action of carrying the chicken. Similarly, if we were to consider the pair of values {Friendship, Chicken} or {Chicken, Seeds}, which will rule out the actions carryS, respectively carryD. The other possible cases considered in the reasoning process are detailed in [1].

For a better representation of the actions that should be considered for promoting a certain pre-established hierarchy of values, several argumentation environments were proposed, among which Casapi, included in the MARGO framework. This approach consists in determining first a set of goal rules specified in the order of importance, followed by a set of decision rules, which will lead to the application of the goal rule (figure 1).

```
goalrule(r01,use_boat(X),[raw_chicken(X),vChicken(X),
vProgress(X)]).
goalrule(r02,use_boat(X),[raw_dog(X),vFriendship(X),
vProgress(X)]).
goalrule(r03,use_boat(X),[raw_seeds(X),vSeeds(X),
vProgress(X)]).
goalrule(r04,use_boat(X),[raw_alone(X)]).

decisionrule(r20(X),raw_chicken(X),[d(X),vChicken(X),
vProgress(X)]).
decisionrule(r30(X),raw_dog(X),[d(X),eatsCS(X),
vProgress(X), vFriendship(X)]).
decisionrule(r40(X),raw_seeds(X),[d(X),eatsDC(X),
vSeeds(X), vProgress(X)]).
decisionrule(r50(X),eatsDC(X),[d(X),vDogHappy(X)]).
decisionrule(r51(X),eatsCS(X),[d(X), vChickenHappy(X)]).
%admissibleArgument(use_boat(X),PREMISES, SUPPOSITIONS).
```

Figure 1. Problem description in the Casapi Argumentation platform.

```
  admissibleArgument(raw_chicken(1),P,S).
  SENT=[d(1),wn(del(f01)),  wn(del(f10)), wn(del(r20(1)))]
 P=[d(1), vChicken(1),  vProgress(1)],  S=[d(1)]
```

Figure 2. Argumentation for one step transition solution.

After establishing the goal and decision rules, different arguments could be provided for justifying a certain solution for the problem. For example, for the case in which the farmer decides to carry the chicken, its decision may be sustained by the fact that performing this action would promote both the values Chicken and Progress (figure 2).

The above argumentation approach provides the possibility to justify a certain action, but it does not offer the possibility to reason about a sequence of actions that should be performed in order to promote a pre-established ordering of values. The main impediment consists in not having a clear representation of the resulted state after performing an action, an imperative step in selecting the next action to be performed. A solution can be given by combining the reasoning power of VAF with the visualization power emphasized by Formal Concepts Analysis, which will make easier the process of finding an appropriate sequence of actions that will lead to a desired result, thus promoting the pre-established ordering of values based on their importance for the farmer.

III. FORMAL CONCEPT ANALYSIS

Definition 3: A formal context $K := (G, M, I)$ consists of sets of objects G, attributes M, and a binary relation $I \subseteq G \times M$.

For $A \subseteq G$ and $B \subseteq M$, we have:

$$A^{I} := \{m \in M \mid \forall g \in A : (g, m) \in I\}$$

$$B^{I} := \{g \in G \mid \forall m \in B : (g, m) \in I\}$$

called the derivation operators for (G, M, I). (A, B) is a formal concept of (G, M, I) iff

$$A \subseteq G, B \subseteq M, A^{I} = B, A = B^{I}$$

with the extent A and the intent B.

Definition 4: Formal concepts can be ordered by
$(A_1, B_2) \le (A_2, B_2) \Leftrightarrow A_1 \subseteq A_2$ (equivalent to $B_1 \supseteq B_2$)
The set of all concepts of the formal context K, with this order, is a complete lattice, called the concept lattice of K.

Definition 5: With $A, B \subseteq M$ in the formal context (G, M, I), the implication $A \rightarrow B$ holds in (G, M, I) iff every object that has all the attributes from A also has all the attributes from B.

Formal Concept Analysis [6] is usually applied for representing complex problems or situations, offering a clear visualization of the context in which they were generated and of the parties involved. If we consider the farmer problem, FCA offers the possibility to contextualize the transitions between the states, such that the effects of the actions performed by the three agents can be linked to previous actions or events, creating this way a dependency relation between the possible states of the problem.

In order to obtain the concepts based representation, the first step consists in determining the most important aspects of the problem and, then, to represent them in terms of objects and related attributes. Similarly with the AATS representation, we must focus on emphasizing the set of possible states of the problem, the set of possible actions performed by each of the three agents: farmer, dog, chicken and the set of corresponding values promoted by the agents' actions. A state, defined as a conjunction of literal, must be represented in such a way in which it captures the possessions present on the left (L), respectively the right (R) bank of the river. To each literal (L and R) we further associate a tuple, consisting in an enumeration of the possessions present on the corresponding bank: dog (D), chicken (C), seeds (S). For example, the initial state of the problem, denoted by q1, and corresponding to the situation in which all the three possessions are situated on the left bank of the river, can be represented as L(D,C,S) R(none). From state q1, the system may be transited to states q2, q3 or q4 depending on the action performed by the farmer, respectively carryS, carryD or carryC. In this case, state q2 can be described by L(D,C) R(S), q3 by L(C,S) R(D) and q3 by L(D,S) R(C). The complete set of states is captured in the context named States (figure 3).

A second context was constructed for representing the set of all possible actions and the corresponding set of values promoted by each of them (table 1).

Table 1. The actions of the Transition System corresponding to the farmer problem

	Progress	Chicken	Seeds	Friends	DHappy	CHappy
carryC	×	×				
carryS	×		×			
carryD	×			×		
eatDC					×	
eatCS						×

As mentioned in the previous section and observed from the table 1, each of the actions performed by the farmer, by the dog or by the chicken can promote one or more common values, such that new relations may be established between the actions of the set Ai, not only based on the entity performing the action, but also on the values promoted by a subset of actions. This new dependency relation plays an important role when having to select a sequence of actions for promoting a subset of values, as it allows us to focus only on a reduced number of actions, rather than considering all the possible cases, thus contributing to the efficiency of the decision making process.

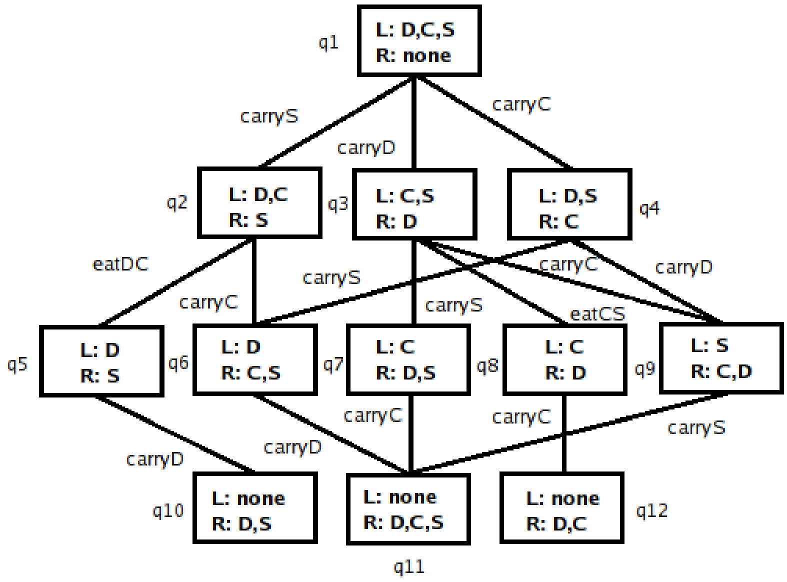

Figure 3. States of the Transition System corresponding to the farmer problem.

The new relations are better emphasized by the lattice based visualization of the Actions context (figure 4).

III.1. Relational Concept Analysis

In addition to FCA, Relational Concept Analysis (RCA) takes into account the possibility that links may exist between different objects that can represent at their turn relations between the connected objects. Regarding the farmer problem, a link can be established between the objects of the context States (figure 3), respectively the states q1, q2, ..., q12 of the AATS, and the actions: carryD, carryC, carryS, eatDC, eatCS corresponding to the set of objects of the context Actions, to which a modification was performed, each action being described also by the state from which it derives. The connection is based on the "reached by" relation, linking a state of the problem to another one, resulted by performing an action corresponding to the context captured by the first state. The "reached by" relation is emphasized by the lattice representation of the relational context connecting the States (figure 3) and the Action contexts (table 1). A second, reciprocal connection can be established this time between the set of all possible actions carryD, carryC, carryS and all possible states q1, q2, ..., q12, based on the "transit to" relation (figure 6), more precisely, on "what subset of states a certain action can transit to from a given state". For example, carryD(q1) (context #24) corresponds to the action of carrying the dog to the right bank of the river, when the system is in state q1 (L(D,C,S) R(none)), which will determine the system to transit to state q3 (L(C,S) R(D)), representing the extent of the context #12 in the lattice representation of the "reached by" relation. A similar reasoning can be applied vice-versa, the state q3 corresponding to the extent set of context #12, being reached by carryD(q1) action, which corresponds to the extent set of context #24 from the lattice representation of the transit to relation. Comparing the AATS and RCA based representation approaches, it can be observed that RCA offers a more complex representation of a problem, allowing us to capture and perceive more complex relations and aspects of a problem (in terms of states, actions and values), providing in the same time a clearer visualization of the links connecting them.

IV. VAF USING FORMAL CONCEPTS

VAF represents a powerful approach applied to practical reasoning, that is in deciding what it is best to do for a particular agent in a given situation. Reasoning about actions consists in providing a presumptive justification, which instantiates an argument scheme, representing an extension of the Walton's sufficient condition scheme [2]:

In the current circumstances R
We should perform action A,
Which will result in new circumstances S,
Which will realize goal G,
Which will promote value V.

It can be observed that the argument scheme is based on three elements: the states of affairs brought about by the action, the goal or the desired state of affairs and the value capturing the reason for which all the previously mentioned features are desirable [2].

In order to apply the Walton's scheme to a practical

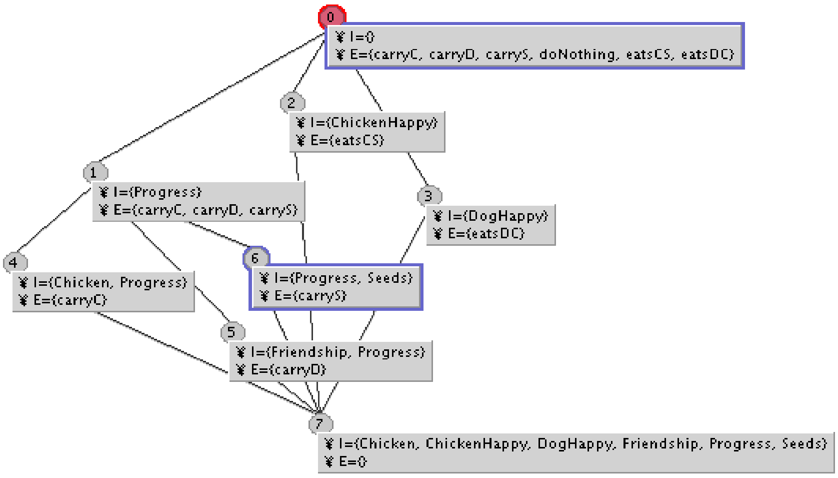

Figure 4. The lattice based representation of the Actions context.

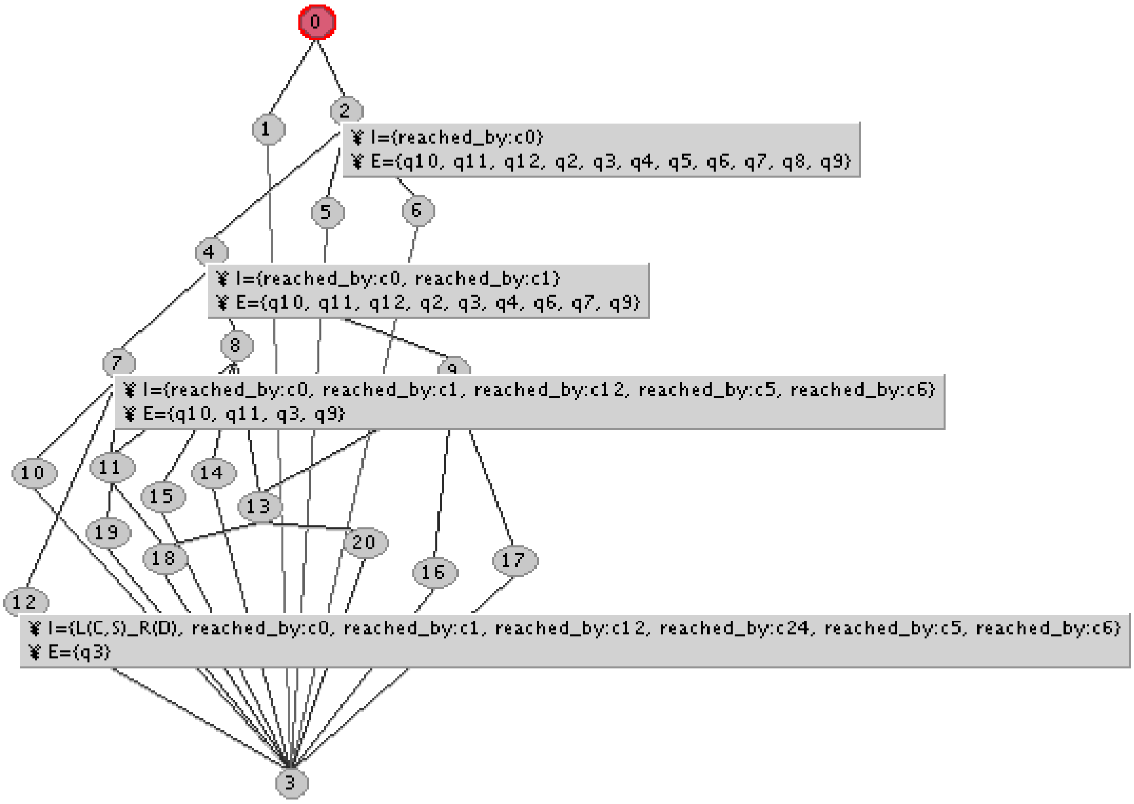

Figure 5. Part of the lattice based representation of the relation “reached by”.

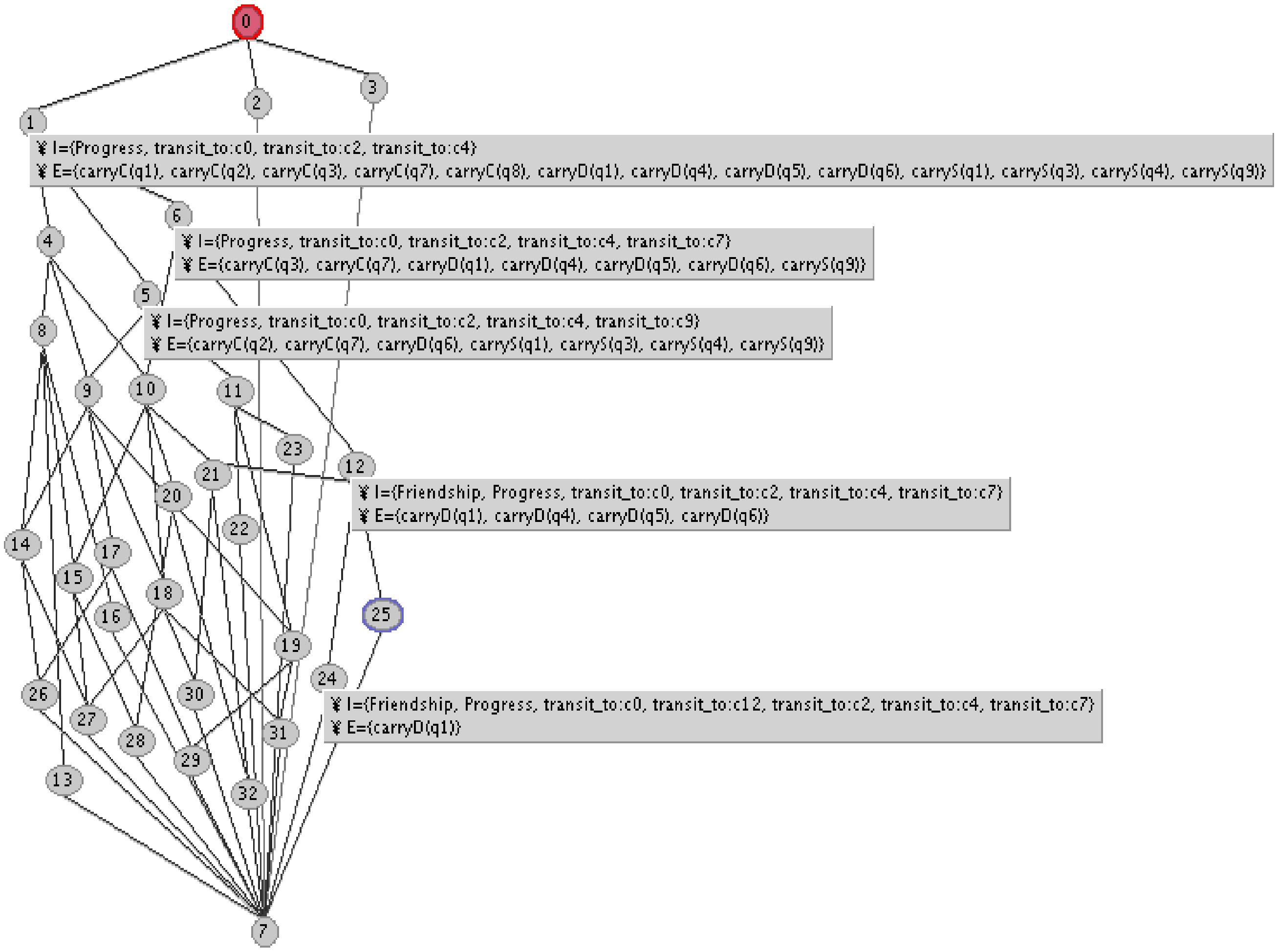

Figure 6. The lattice based representation of the relation "transit to".

problem, all the three elements must be first clearly highlighted and represented using a model that allows us to reason about the transitions from a state of affairs of the system to another. FCA can be regarded in this case as a complementing approach, providing a powerful visualization support for a complex representation of the problem, capturing in a concept based manner the states of affairs, describing the problem and the links connecting them, making easier this way the argumentation process for a complex practical decision problem.

Applied to the farmer problem, FCA provides a visualization basis for practical reasoning over the actions performed by the three agents {farmer, dog, chicken} and the transitions from a certain state to another.

In order to capture the main aspects of the value based reasoning using FCA, we will focus first on modeling the problem as a 1-step transition system. Having the initial state q1 (L(D,C,S) R(none)), the farmer must select one from his three possessions: dog, chicken, seeds to take with him to the right bank of the river, thus the possession with the highest degree of importance for him (figure 7). Based on the argumentation scheme and on the lattice representation of the 1-step transition system (figure 7), we can focus on reasoning about the transition that will lead the system from state q1 to any of the possible goal states q2, q3, q4. For example, if the goal state is selected as being q2 - L(D,C) R(S) (figure 3), the analysis process will be moved over the context with the goal state representing its extent set, in this case context #2, zooming over the Intent set. The resulted practical argument can be expressed as: from the current state q1, the system will transit to the goal state q2, described by the element (L(D,C), R(S)) of the Intent set, reached by the action representing the extent of the context #2 of the Actions lattice (figure 4), carryS, which will promote values {Progress, Seeds}. It can be observed that, although contexts #0 and #1 of the lattice Actions (figure 4) are part of the Intent set, they are not considered in the argumentation scheme, as they contain multiple elements in the Extent set, which contradicts with the notion of practical argument, defined as being directed towards a specific agent, time and choice. Similar reasoning can be applied for the situation in which states q3 or q4 are considered goal states.

However, the main characteristic of the VAF based on FCA approach, which differentiates it from the other

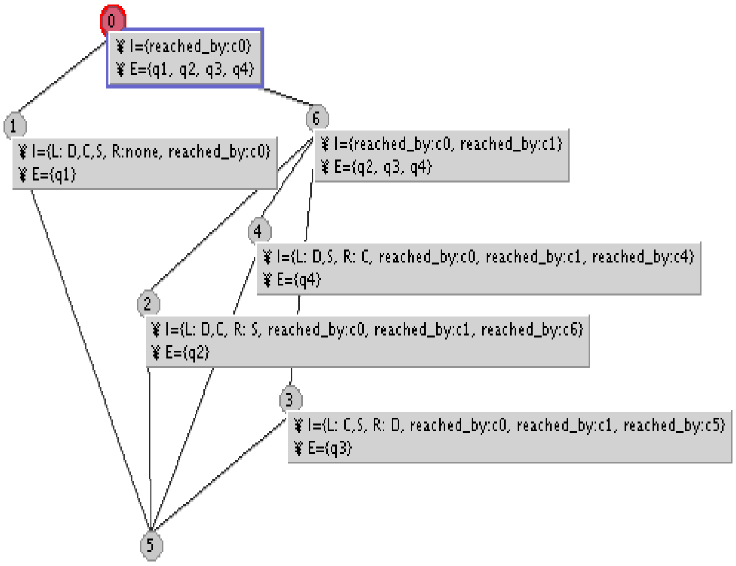

Figure 7. Zoom on the initial state of the transition.

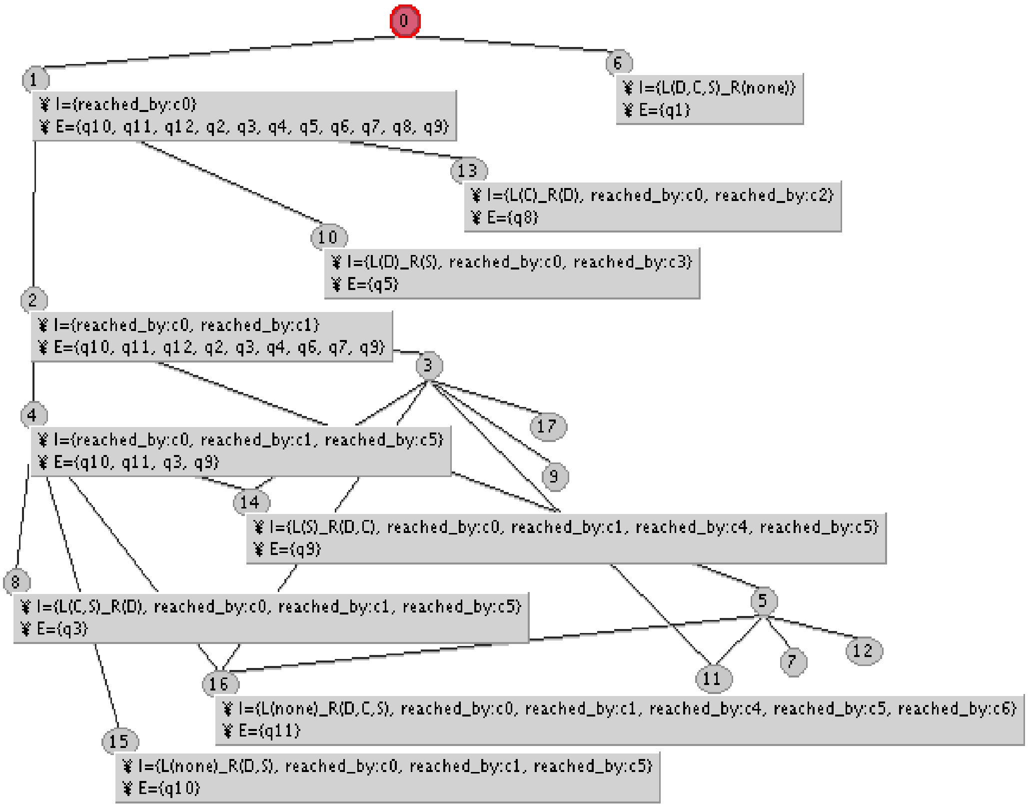

Figure 8. VAF on a selected subset of states.

argumentation methods, consists in the fact that we can reason not only about a particular state of affairs, but about a subset of related states, obtained from executing a common subset of actions and, thus promoting a common subset of values.

In order to be able to apply an argumentation scheme, we must first obtain the lattice based representation of the problem. For this, a Relational Context Family (RCF) is constructed containing the two contexts States (figure 3) and Actions (table 1), connected by a relational context based on the "reached by" relation (figure 5). The corresponding lattice representation is obtained by applying the Galois Sub-hierarchy Ceres algorithm, capturing different subsets of the set of possible states q1, q2,...,q12 (figure 8). This method allows us to select a certain part of the problem and to reason about a subset of states, which represents our focus. For example, when reasoning about the states reached by performing a certain action, the initial state q1 must not be considered as it is never reached by one of the actions:
{carryS, carryD, carryC, eatDC, eatCS}

In this case, the focus can be directed on the context #1 of the lattice representation (figure 8), allowing to extend the reasoning process over the children contexts linked to context #1.

We can go even deeper by limiting the reasoning process over a smaller subset of states. For example, we can consider context #4, having as extent the subset of states q10, q11, q3, q9, all of them having in common the fact that they can be reached by performing the action carryD (concept #5 in the Actions lattice), thus all promoting the subset of values {Friendship, Progress}. Also, it can be observed that they can represent a sequence of states that solves the farmer problem (q1 -> q3 -> q9 -> q10 or q11). From context #4, the reasoning process can be further extended to the linked contexts, such that, in the end, reasoning about a subset of states may be reduced to reasoning about each state in particular, while preserving in the same time the connections existing between them. If the states specified by contexts #8 and #15 can be reached only by carryD, the states corresponding to contexts #14 and #16 can be reached also by other actions. This observation can be easily deducted by analyzing the lattice representation, highlighting that the state q11 (context #16) depends also on context #5, thus being reached also by other actions. Similar reasoning can be applied for state q9 (context #14).

This also proves that the reasoning approach based on conceptualization allows us not only to focus on specific joint actions, but also to find new relations that connect subsets of actions.

V. CONCLUSIONS

The Value based Argumentation Framework has been proven to be a powerful reasoning tool for solving practical scenarios, in which an agent must decide what action to perform given a certain context.

Our findings include that by combining the reasoning power of VAF with the visualization support offered by

FCA, new methods may be developed for reasoning in complex situations in which an agent is required to perform a sequence of joint actions.

Further work includes the extension of the VAF based on the FCA approach for solving complex decision problems, like negotiation [5]. How the agent's practical reasoning can be captured in FCA/RCA throughout all of its phases: deliberation, means-ends reasoning, and execution, might prove to be extremely important for the development of autonomous multi-agent systems.

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