

Augmenting $\mathcal{ALC}(\mathcal{D})$ (atemporal) roles and (aspatial) concrete domain with temporal roles and a spatial concrete domain -first results

Amar Isli

Fachbereich Informatik, Universität Hamburg
am99i@yahoo.com

WORK EXACTLY AS REJECTED AT THE MAIN ECAI¹ 2004²

Abstract. Consider an $\mathcal{ALC}(\mathcal{D})$ (tree-like) interpretation \mathcal{I} : a node of \mathcal{I} can be seen as labelled with a set of atomic concepts (atomic propositions), and pairs of the form (g, O) where g is a function representing a concrete feature and O a value from the universe of instantiation values of the concrete domain. \mathcal{I} describes thus (structured) conceptual knowledge, on the one hand, and, on the other hand, an instantiation of the variables (concrete features) with concrete values of the concrete domain. $\mathcal{ALC}(\mathcal{D})$ does not assume restrictions (specialisations) of the roles, nor of the concrete domain: the roles are considered atemporal, and the concrete domain aspatial. \mathcal{I} can be seen as a snapshot of the World at a specific moment of time, i.e., as a situation in the situation calculus terminology. Consider now an interpretation J of a modal temporal logic, assigning at each time point a truth value with each element of a set P of atomic propositions. The atomic propositions can be seen as atomic conceptual knowledge. To make such interpretations J richer, with each time point is associated an $\mathcal{ALC}(\mathcal{D})$ interpretation as described above, instead of just atomic propositions. We can go even further, by considering a (dynamic) spatial scene with, say, n objects: we can then make the J interpretation even richer: with each time point is associated, not only an $\mathcal{ALC}(\mathcal{D})$ interpretation, describing the look of the conceptual knowledge at that point (conceptual situation), but the description of the spatial scene at that point (spatial situation) as well, either by giving the positions of the different objects of the scene, or the spatial relations on tuples of objects of the scene, such as, e.g., *RCC8* relations on pairs of the objects, if the scene consists of regions of a topological space. We provide first results on a framework handling such rich structures, and obtained by augmenting $\mathcal{ALC}(\mathcal{D})$ atemporal roles and aspatial concrete domain with temporal roles and a spatial concrete domain.

Keywords: Description Logics, Temporal Reasoning, Spatial Reasoning, Reasoning about Actions and Change, Constraint Satisfaction, Knowledge Representation, Qualitative Reasoning, Situation Calculus.

1 Introduction

The well-known $\mathcal{ALC}(\mathcal{D})$ family of description logics (DLs) with a concrete domain [2] originated from a pure DL known as \mathcal{ALC} [12], with $m \geq 0$ roles all of which are general, not necessarily functional relations. It is obtained by adding to \mathcal{ALC} functional roles (better known as abstract features), a concrete domain \mathcal{D} , and concrete features (which refer to objects of the concrete domain).

Consider now the family of domain-specific spatio-temporal (henceforth s-t) languages, obtained by spatio-temporalising $\mathcal{ALC}(\mathcal{D})$ in the following way:

1. temporalisation of the roles, so that they consist of $m + n$ immediate-successor (accessibility) relations $R_1, \dots, R_m, f_1, \dots, f_n$, of which the R_i 's are general, not necessarily functional relations, and the f_i 's functional relations; and
2. spatialisation of the concrete domain \mathcal{D} : the spatialisation is \mathcal{D}_x , generated by a spatial Relation Algebra (RA) x , such as the Region-Connection Calculus *RCC8* [9].

The resulting family, together with what we will refer to as weakly cyclic TBoxes, enhances the expressiveness of modal temporal logics with qualitative spatial constraints, and consists of qualitative theories for (relational) spatial change and propositional change in general, and for motion of spatial scenes in particular. In particular, satisfiability of a concept with respect to (*wrt*) a weakly cyclic TBox is decidable.

An interpretation of a member of such a spatio-temporal family is a (labelled) tree-like structure. A snapshot of such a structure (i.e., the label of a node) describes a static situation, splitting into a propositional (sub-)situation, given by the set of atomic propositions true at that node, and a (relational) spatial (sub-)situation, given by a consistent conjunction of qualitative spatial relations on tuples of concrete features (the qualitative spatial relations are predicates of the concrete domain).³ Real applications, however, such as high-level vision, *XML* documents, or what is known as spatial aggregation (see, e.g., [3]), have a huge demand in the representation of dynamic structured data. Such structured data may consist of descriptions of complex

¹ European Conference on Artificial Intelligence.

² The *reviews* are added to the actual paper, after the references, for potential people interested in objectivity of conferences' reviewing processes.

³ We could use an instantiation of concrete values to the concrete features, but knowing that such an instantiation exists, given consistency of the conjunction of qualitative constraints, is enough.

objects, or of classes of objects, such as, e.g., a complex table setting for a meal, a tree-like description of a complex XML document, or a complex spatial aggregate.

We denote by \mathcal{ALCF} the DL \mathcal{ALC} [12] augmented with abstract features. \mathcal{ALCF} is particularly important for the representation of static structured data, thanks, among other things, to its abstract features, which allow it to access specific paths. \mathcal{ALCF} is a sublanguage of $\mathcal{ALC}(\mathcal{D})$, making the latter also suitable for the representation of static structured data. \mathcal{ALCF} , however, contrary to $\mathcal{ALC}(\mathcal{D})$, does not allow for the representation of domain-specific knowledge, which can be seen as constraints on objects of the domain of interest, and which $\mathcal{ALC}(\mathcal{D})$ is very good at, thanks to its concrete domain.

The roles in $\mathcal{ALC}(\mathcal{D})$ are interpreted in the same way as inheritance relations in semantic networks; in particular, they are given no temporal interpretation. The concrete domain is just an abstract constraint language; in particular the universe of instantiation values is given no spatial interpretation: if a constraint on X and Y is seen as a binary Boolean matrix then value 1 in entry (i, j) means that assigning the i -th value of the universe to X matches with assigning the j -th value to Y . In other words, the constraint does not say anything about how the arguments relate, say, spatially to each other, which would be different if the relations were, say, $\mathcal{RCC8}$ relations (and the universe of instantiation values, regions of a topological space). As such, $\mathcal{ALC}(\mathcal{D})$ describes structured static data, with the possibility of expressing domain specific constraints, thanks to its concrete domain.

We denote the $\mathcal{ALC}(\mathcal{D})$ spatio-temporalisation referred to above as $\mathcal{MTALC}(\mathcal{D}_x)$ (Modal Temporal \mathcal{ALC} with a concrete domain generated by spatial RA x). The roles are now given a temporal interpretation, and they consist of immediate-successor relations (functional relations in the case of abstract features, and general relations in the case of non-functional roles); they can be seen as actions in the possible-worlds semantics of the situation calculus (see, e.g., [11]).

The extension of $\mathcal{ALC}(\mathcal{D})$ we will be considering in this work is indeed a cross product of the spatio-temporalisation $\mathcal{MTALC}(\mathcal{D}_x)$, on the one hand, and $\mathcal{ALC}(\mathcal{D})$ itself, on the other hand. It will be referred to as $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$. Section 2 provides a brief background on the spatial relations to be used as predicates of the spatial concrete domain. Section 3 briefly describes an aspatial concrete domain, as the $\mathcal{ALC}(\mathcal{D})$ one. Section 4 describes the spatial concrete domains to be used in the paper. The syntax of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concepts is given in Section 5. Weakly cyclic TBoxes and the $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ semantics will be described in Sections 6 and 7, respectively. An overview of decidability of the problem of satisfiability of an $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concept w.r.t. a weakly cyclic TBox will be given in Section 8.

We first provide some background on binary relations. Given a set A , we denote by $|A|$ the cardinality of A . A binary relation, R , on a set S is any subset of the cross product $S \times S = \{(x, y) : x, y \in S\}$. Such a relation is reflexive $\iff R(x, x)$, for all $x \in S$; it is symmetric \iff , for all $x, y \in S$, $R(y, x)$, whenever $R(x, y)$; it is transitive \iff , for all $x, y, z \in S$, $R(x, z)$, whenever $R(x, y)$ and $R(y, z)$; it is irreflexive \iff , for all $x \in S$, $\neg R(x, x)$; it is antisymmetric \iff , for all $x, y \in S$, if $R(x, y)$ and $R(y, x)$ then $y = x$; and it is serial \iff , for all $x \in S$, there exists $y \in S$ such that $R(x, y)$. The transitive (resp. reflexive-transitive) closure of R is the smallest relation R^+ (resp. R^*), which includes R and is transitive (resp. reflexive and transitive). Finally, R is functional if, for all $x \in S$, $|\{y \in S : R(x, y)\}| \leq 1$; it is nonfunctional otherwise.

2 A brief background on $\mathcal{RCC8}$ and \mathcal{CYC}_t

The RA $\mathcal{RCC8}$. The $\mathcal{RCC8}$ calculus [9] consists of a set of eight JEPD (Jointly Exhaustive and Pairwise Disjoint) atoms, DC (Dis-Connected), EC (Externally Connected), TPP (Tangential Proper Part), PO (Partial Overlap), EQ (Equal), $NTPP$ (Non Tangential Proper Part), and the converses, $TPPi$ and $NTPPi$, of TPP and $NTPP$, respectively.

The RA \mathcal{CYC}_t . The set $2\mathcal{DO}$ of 2D orientations is defined in the usual way, and is isomorphic to the set of directed lines incident with a fixed point, say O . Let h be the natural isomorphism, associating with each orientation x the directed line (incident with O) of orientation x . The angle $\langle x, y \rangle$ between two orientations x and y is the anticlockwise angle $\langle h(x), h(y) \rangle$. The binary RA of 2D orientations in [7], \mathcal{CYC}_b , contains four atoms: e (equal), l (left), o (opposite) and r (right). For all $x, y \in 2\mathcal{DO}$: $e(y, x) \iff \langle x, y \rangle = 0$; $l(y, x) \iff \langle x, y \rangle \in (0, \pi)$; $o(y, x) \iff \langle x, y \rangle = \pi$; $r(y, x) \iff \langle x, y \rangle \in (\pi, 2\pi)$. Based on \mathcal{CYC}_b , a ternary RA, \mathcal{CYC}_t , for cyclic ordering of 2D orientations has been defined in [7]: \mathcal{CYC}_t has 24 atoms, thus 2^{24} relations. The atoms of \mathcal{CYC}_t are written as $b_1b_2b_3$, where b_1, b_2, b_3 are atoms of \mathcal{CYC}_b , and such an atom is interpreted as follows: $(\forall x, y, z \in 2\mathcal{DO})(b_1b_2b_3(x, y, z) \iff b_1(y, x) \wedge b_2(z, y) \wedge b_3(z, x))$. The reader is referred to [7] for more details.

3 The $\mathcal{ALC}(\mathcal{D})$ aspatial concrete domain

The role of a concrete domain in so-called DLs with a concrete domain [2], is to give the user of the DL the opportunity to represent, thanks to predicates, knowledge on objects of the application domain, as constraints on tuples of these objects.

Definition 1 (concrete domain [2]) A concrete domain \mathcal{D} consists of a pair $(\Delta_{\mathcal{D}}, \Phi_{\mathcal{D}})$, where $\Delta_{\mathcal{D}}$ is a set of (concrete) objects, and $\Phi_{\mathcal{D}}$ is a set of predicates over the objects in $\Delta_{\mathcal{D}}$. Each predicate $P \in \Phi_{\mathcal{D}}$ is associated with an arity n : $P \subseteq (\Delta_{\mathcal{D}})^n$.

Definition 2 (admissibility [2]) A concrete domain \mathcal{D} is admissible if: (1) the set of its predicates is closed under negation and contains a predicate for $\Delta_{\mathcal{D}}$; and (2) the satisfiability problem for finite conjunctions of predicates is decidable.

4 The spatial concrete domains \mathcal{D}_x , with $x \in \{\mathcal{RCC8}, \mathcal{CYC}_t\}$

The concrete domain generated by x , \mathcal{D}_x , can be written as $\mathcal{D}_x = (\Delta_{\mathcal{D}_x}, \Phi_{\mathcal{D}_x})$, with $\mathcal{D}_{\mathcal{RCC8}} = (\mathcal{RTS}, 2^{\mathcal{RCC8-at}})$ and $\mathcal{D}_{\mathcal{CYC}_t} = (2\mathcal{DO}, 2^{\mathcal{CYC}_t-at})$, where:

1. \mathcal{RTS} is the set of regions of a topological space \mathcal{TS} ; $2\mathcal{DO}$ is the set of 2D orientations; and
2. $x-at$ is the set of x atoms — 2^{x-at} is thus the set of all x relations.

Admissibility of the concrete domains \mathcal{D}_x is a direct consequence of (decidability and) tractability of the subset $\{\{r\} | r \in x-at\}$ of x atomic relations (see [10] for $x = \mathcal{RCC8}$, and [7] for $x = \mathcal{CYC}_t$).

5 Syntax of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concepts, with $x \in \{\mathcal{RCC8}, \mathcal{CYC}_t\}$

Definition 3 Let x be an RA from the set $\{\mathcal{RCC8}, \mathcal{CYC}_t\}$. Let N_C^{at} , N_C^t , N_R^{at} , N_R^t , N_{cF}^{as} and N_{cF}^s be mutually disjoint and countably infinite sets of atemporal concept names, temporal concept names,

atemporal role names, temporal role names, aspatial concrete features, and spatial concrete features, respectively; N_{aF}^{at} a countably infinite subset of N_R^{at} whose elements are atemporal abstract features; and N_{aF}^t a countably infinite subset of N_R^t whose elements are temporal abstract features. A spatial (concrete) feature chain is any finite composition $f_1^t \dots f_n^t g^s$ of $n \geq 0$ temporal abstract features f_1^t, \dots, f_n^t and one spatial concrete feature g^s . An aspatial (concrete) feature chain is any finite composition $f_1^{at} \dots f_n^{at} g^{as}$ of $n \geq 0$ atemporal abstract features $f_1^{at}, \dots, f_n^{at}$ and one aspatial concrete feature g^{as} .⁴ The set of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concepts is the union of the set of atemporal concepts and the set of temporal concepts, which are the smallest sets such that:

1. \top and \perp are atemporal concepts;
2. \top and \perp are temporal concepts;⁵
3. an atemporal concept name is an atemporal concept;
4. a temporal concept name is a temporal concept;
5. if C^{at} and D^{at} are atemporal concepts; C^t and D^t are temporal concepts; R^{at} is an atemporal role (in general, and an atemporal abstract feature in particular); R^t is a temporal role (in general, and a temporal abstract feature in particular); $u_1^{as}, \dots, u_n^{as}$ are aspatial feature chains; u_1^t, u_2^t, u_3^t are spatial feature chains; P^{as} is an aspatial n -ary predicate; and P^s is a spatial predicate (binary if $x = RCC8$, ternary if $x = C\mathcal{V}C_t$), then:
 - (a) $\neg C^{at}, C^{at} \sqcap D^{at}, C^{at} \sqcup D^{at}, \exists R^{at}.C^{at}, \forall R^{at}.C^{at}$ are atemporal concepts;
 - (b) $\exists(u_1^{as}) \dots (u_n^{as}).P^{as}$ is an atemporal concept;
 - (c) $\neg C^t, C^t \sqcap D^t, C^t \sqcup D^t, \exists R^t.C^t, \forall R^t.C^t$ are temporal concepts;
 - (d) $\exists(u_1^s)(u_2^s).P^s$, if x binary; $\exists(u_1^s)(u_2^s)(u_3^s).P^s$, if x ternary, are temporal concepts; and
 - (e) $\exists R^t.C^{at}, \forall R^t.C^{at}$ are temporal concepts.

$\mathcal{ALC}(\mathcal{D})$ is the atemporal sublanguage of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$, and is generated by Items 1, 3, 5(a) and 5(b) of Definition 3. The spatio-temporalisation $\mathcal{MTALC}(\mathcal{D}_x)$ we have already alluded to is the purely temporal part of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$, and is generated by Items 2, 4, 5(c) and 5(d) of Definition 3. We denote by \mathcal{MTALC} the sublanguage of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ given by rules 2, 4 and 5(c) in Definition 3, which is the modal temporal logic component of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$. It is worth noting that \mathcal{MTALC} does not consist of a mere temporalisation of \mathcal{ALC} [12]. Indeed, \mathcal{ALC} contains only general, not necessarily functional roles, whereas \mathcal{MTALC} contains abstract features as well. As it will become clear shortly, a mere temporalisation of \mathcal{ALC} (i.e., \mathcal{MTALC} without abstract features) cannot capture the expressiveness of a well-known modal temporal logic: Propositional Linear Temporal Logic \mathcal{PLTL} [13]. Given two integers $p \geq 0$ and $q \geq 0$, the sublanguage of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ (resp. \mathcal{MTALC}) whose concepts involve at most p general, not necessarily functional temporal roles, and q temporal abstract features will be referred to as $\mathcal{MTALC}_{p,q}(\mathcal{D}_x, \mathcal{D})$ (resp. $\mathcal{MTALC}_{p,q}$). We discuss shortly the case $(p, q) = (0, 1)$. We first define weakly cyclic TBoxes.

⁴ Throughout the rest of the paper, a feature chain $f_1 \dots f_k g$, either aspatial or spatial, is interpreted as within the Description Logics Community — i.e., as the composition $f_1 \circ \dots \circ f_k \circ g$: we remind the reader that $(f_1 \circ \dots \circ f_k \circ g)(x) = g(f_k(f_{k-1}(\dots(f_2(f_1(x))\dots)))$.

⁵ We could have used \top^{at} and \top^t for atemporal top and temporal top, respectively; and, similarly, \perp^{at} and \perp^t for atemporal bottom and temporal bottom, respectively.

6 Weakly cyclic TBoxes

An $(\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D}))$ terminological axiom is an expression of the form $A \doteq C$, such that either (1) A is an atemporal (defined) concept name and C an atemporal concept, or (2) A is a temporal (defined) concept name and C a temporal concept. A TBox is a finite set of axioms, with the condition that no concept name appears more than once as the left hand side of an axiom.

Let T be a TBox. T contains two kinds of concept names: concept names appearing as the left hand side of an axiom of T are defined concepts; the others are primitive concepts. A defined concept A “directly uses” a defined concept B if and only if $(\iff) B$ appears in the right hand side of the axiom defining A . If “uses” is the transitive closure of “directly uses” then T contains a cycle \iff there is a defined concept A that “uses” itself. T is cyclic if it contains a cycle; it is acyclic otherwise. T is weakly cyclic if it satisfies the following two conditions:

1. Whenever A uses B and B uses A , we have $B = A$ — the only possibility for a defined concept to get involved in a cycle is to appear in the right hand side of the axiom defining it.
2. All possible occurrences of a defined concept B in the right hand side of the axiom defining B itself, are within the scope of an existential or a universal quantifier; i.e., in subconcepts of C of the form $\exists R.D$ or $\forall R.D$, C being the right hand side of the axiom, $B \doteq C$, defining B .

The TBox T is temporally weakly cyclic and atemporally acyclic (or *twc-atac*, for short) if it is weakly cyclic and, whenever a defined concept A uses itself, A is a temporal defined concept. Our intuition behind the use of *twc-atac* TBoxes is to capture, on the one hand, the expressiveness of $\mathcal{ALC}(\mathcal{D})$ with acyclic TBoxes, well-suited for the representation of static structured data and known to be decidable, and, on the other hand, the expressiveness of $\mathcal{MTALC}(\mathcal{D}_x)$ with weakly cyclic TBoxes, which subsumes existing modal temporal logics while remaining decidable — $\mathcal{ALC}(\mathcal{D})$ with cyclic TBoxes is known to be undecidable. As such, *twc-atac* TBoxes are well-suited for the representation of change in dynamic structured data. We suppose that the temporal defined concepts of a TBox split into *eventuality* defined concepts and *noneventuality* defined concepts.

In the rest of the paper, unless explicitly stated otherwise, we denote concepts reducing to concept names by the letters A and B , possibly complex concepts by the letters C, D, E , general (possibly functional) roles by the letter R , abstract features by the letter f , concrete features by the letters g and h , feature chains by the letter u , predicates by the letter P . If distinguishing between “atemporal” and “temporal” (resp. “aspatial” and “spatial”) is needed, we make use, as in Definition 3, of the prefixes ‘at’ and ‘t’ (resp. ‘as’ and ‘s’).

7 Semantics of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$, with $x \in \{RCC8, C\mathcal{V}C_t\}$

$\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ is equipped with a Tarski-style, possible worlds semantics. $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ interpretations are spatio-temporal tree-like structures, together with an interpretation function associating with each temporal primitive concept A the nodes of t at which A is true, and, additionally, associating with each spatial concrete feature g and each node v of t , the value at v (seen as a time instant) of the spatial concrete object referred to by g . The interpretation function also associates with each node of t an $\mathcal{ALC}(\mathcal{D})$ interpretation, which is a tree-like structure representing structured data consisting of the situation (snapshot) of the World at the node (but excluding the

situation of the temporal primitive concepts and the relational spatial situation, which are given by the temporal primitive concepts true at the node, and the spatial concrete values associated with the spatial concrete features at the node). Formally:

Definition 4 (interpretation) Let $x \in \{\mathcal{RCC8}, \mathcal{CYC}_t\}$. An interpretation \mathcal{I} of $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ consists of a pair $\mathcal{I} = (t_{\mathcal{I}}, \cdot^{\mathcal{I}})$, where $t_{\mathcal{I}}$ is the domain of \mathcal{I} , consisting of a set of time points (or worlds, or states, or nodes), and $\cdot^{\mathcal{I}}$ is an interpretation function mapping each temporal primitive concept A to a subset $A^{\mathcal{I}}$ of $t_{\mathcal{I}}$, each temporal role R to a subset $R^{\mathcal{I}}$ of $t_{\mathcal{I}} \times t_{\mathcal{I}}$, so that $R^{\mathcal{I}}$ is functional if R is an abstract feature, and each spatial concrete feature g to a total function $g^{\mathcal{I}}$:

1. from $t_{\mathcal{I}}$ onto the set \mathcal{RTS} of regions of a topological space \mathcal{TS} , if $x = \mathcal{RCC8}$; and
2. from $t_{\mathcal{I}}$ onto the set $2\mathcal{DO}$ of orientations of the 2-dimensional space, if $x = \mathcal{CYC}_t$.

Each temporal role R should be so that the reflexive-transitive closure $(R^{\mathcal{I}})^*$ of $R^{\mathcal{I}}$ is serial and antisymmetric, making interpretation \mathcal{I} a branching tree-like temporal structure. The interpretation function $\cdot^{\mathcal{I}}$ also associates with each time point v in $t_{\mathcal{I}}$ an $\mathcal{ALC}(\mathcal{D})$ interpretation $\cdot^{\mathcal{I}}(v) = (\Delta_{\mathcal{I},v}, \cdot^{\mathcal{I},v})$, where $\Delta_{\mathcal{I},v}$ is a set consisting of the (abstract) domain of $\cdot^{\mathcal{I}}(v)$ and $\cdot^{\mathcal{I},v}$ is an interpretation function mapping each atemporal concept name C (either defined or primitive) to a subset $C^{\mathcal{I},v}$ of $\Delta_{\mathcal{I},v}$, each atemporal role R to a subset $R^{\mathcal{I},v}$ of $\Delta_{\mathcal{I},v} \times \Delta_{\mathcal{I},v}$, each aspatial concrete feature g to a partial function $g^{\mathcal{I},v}$ from $\Delta_{\mathcal{I},v}$ onto the set $\Delta_{\mathcal{D}}$ of concrete objects of the aspatial concrete domain \mathcal{D} . The interpretation function $\cdot^{\mathcal{I},v}$ is extended to arbitrary atemporal concepts as follows:

$$\begin{aligned}
(\top)^{\mathcal{I},v} &:= \Delta_{\mathcal{I},v} \\
(\perp)^{\mathcal{I},v} &:= \emptyset \\
(\neg C)^{\mathcal{I},v} &:= \Delta_{\mathcal{I},v} \setminus C^{\mathcal{I},v} \\
(C \sqcap D)^{\mathcal{I},v} &:= C^{\mathcal{I},v} \cap D^{\mathcal{I},v} \\
(C \sqcup D)^{\mathcal{I},v} &:= C^{\mathcal{I},v} \cup D^{\mathcal{I},v} \\
(\exists R.C)^{\mathcal{I},v} &:= \{a \in \Delta_{\mathcal{I},v} \mid \\
&\quad \exists b \in \Delta_{\mathcal{I},v} : (a, b) \in R^{\mathcal{I},v} \wedge b \in C^{\mathcal{I},v}\} \\
(\forall R.C)^{\mathcal{I},v} &:= \{a \in \Delta_{\mathcal{I},v} \mid \\
&\quad \forall b : (a, b) \in R^{\mathcal{I},v} \rightarrow b \in C^{\mathcal{I},v}\} \\
(\exists (u_1) \dots (u_n).P)^{\mathcal{I},v} &:= \{a \in \Delta_{\mathcal{I},v} \mid \\
&\quad \exists o_1, \dots, o_n \in \Delta_{\mathcal{D}} : u_1^{\mathcal{I},v}(a) = o_1, \dots, \\
&\quad u_n^{\mathcal{I},v}(a) = o_n, P(o_1, \dots, o_n)\}
\end{aligned}$$

where, given an aspatial feature chain $u = f_1 \dots f_n.g$, $u^{\mathcal{I},v}(a)$ stands for the value $g^{\mathcal{I},v}(b)$, where b is the $f_1^{\mathcal{I},v} \dots f_n^{\mathcal{I},v}$ -successor of a in the $\mathcal{ALC}(\mathcal{D})$ interpretation $\cdot^{\mathcal{I},v}$.

Definition 5 (satisfiability w.r.t. a TBox) Let $x \in \{\mathcal{RCC8}, \mathcal{CYC}_t\}$ be a spatial RA, C an $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concept, \mathcal{T} an $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ two-atac TBox, and $\mathcal{I} = (t_{\mathcal{I}}, \cdot^{\mathcal{I}})$ an $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ interpretation. The satisfiability, by a node s of $t_{\mathcal{I}}$, of C w.r.t. to \mathcal{T} , denoted $\mathcal{I}, s \models \langle C, \mathcal{T} \rangle$, is defined inductively as follows (Item 1. below deals with the case of an atemporal concept, the remaining 11 with a temporal concept):

1. $\mathcal{I}, s \models \langle C, \mathcal{T} \rangle \iff C^{\mathcal{I},v} \neq \emptyset$, for all atemporal concepts C
2. $\mathcal{I}, s \models \langle \top, \mathcal{T} \rangle$
3. $\mathcal{I}, s \not\models \langle \perp, \mathcal{T} \rangle$
4. $\mathcal{I}, s \models \langle A, \mathcal{T} \rangle \iff s \in A^{\mathcal{I}}$, for all primitive concepts A
5. $\mathcal{I}, s \models \langle B, \mathcal{T} \rangle \iff \mathcal{I}, s \models \langle C, \mathcal{T} \rangle$, for all defined concepts B given by the axiom $B \doteq C$ of \mathcal{T}
6. $\mathcal{I}, s \models \langle \neg C, \mathcal{T} \rangle \iff \mathcal{I}, s \not\models \langle C, \mathcal{T} \rangle$

7. $\mathcal{I}, s \models \langle C \sqcap D, \mathcal{T} \rangle \iff \mathcal{I}, s \models \langle C, \mathcal{T} \rangle$ and $\mathcal{I}, s \models \langle D, \mathcal{T} \rangle$
8. $\mathcal{I}, s \models \langle C \sqcup D, \mathcal{T} \rangle \iff \mathcal{I}, s \models \langle C, \mathcal{T} \rangle$ or $\mathcal{I}, s \models \langle D, \mathcal{T} \rangle$
9. $\mathcal{I}, s \models \langle \exists R.C, \mathcal{T} \rangle \iff \mathcal{I}, s' \models \langle C, \mathcal{T} \rangle$, for some s' such that $(s, s') \in R^{\mathcal{I}}$
10. $\mathcal{I}, s \models \langle \forall R.C, \mathcal{T} \rangle \iff \mathcal{I}, s' \models \langle C, \mathcal{T} \rangle$, for all s' such that $(s, s') \in R^{\mathcal{I}}$
11. $\mathcal{I}, s \models \langle \exists (u_1)(u_2).P, \mathcal{T} \rangle \iff P(u_1^{\mathcal{I}}(s), u_2^{\mathcal{I}}(s))$
12. $\mathcal{I}, s \models \langle \exists (u_1)(u_2)(u_3).P, \mathcal{T} \rangle \iff P(u_1^{\mathcal{I}}(s), u_2^{\mathcal{I}}(s), u_3^{\mathcal{I}}(s))$

A concept C is satisfiable w.r.t. a TBox $\mathcal{T} \iff \mathcal{I}, s \models \langle C, \mathcal{T} \rangle$, for some $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ interpretation \mathcal{I} , and some state $s \in t_{\mathcal{I}}$, in which case the pair (\mathcal{I}, s) is a model of C w.r.t. \mathcal{T} ; C is unsatisfiable (has no models) w.r.t. \mathcal{T} , otherwise. C is valid w.r.t. $\mathcal{T} \iff$ the negation, $\neg C$, of C is unsatisfiable w.r.t. \mathcal{T} . The satisfiability problem and the subsumption problem are defined as follows:

The satisfiability problem: given a concept C and a TBox \mathcal{T} , is C satisfiable w.r.t. \mathcal{T} ?

The subsumption problem: given two concepts C and D and a TBox \mathcal{T} , does C subsume D w.r.t. \mathcal{T} (notation: $D \sqsubseteq_{\mathcal{T}} C$)? In other words, are all models of D w.r.t. \mathcal{T} also models of C w.r.t. \mathcal{T} ?

The satisfiability problem and the subsumption problem are related to each other, as follows: $D \sqsubseteq_{\mathcal{T}} C \iff D \sqcap \neg C$ is unsatisfiable w.r.t. \mathcal{T} .

8 Associating a weak alternating automaton with the satisfiability of an $\mathcal{MTALC}(\mathcal{D}_x)$ concept w.r.t. a weakly cyclic TBox: an overview

It should be clear that, given decidability of the satisfiability of an $\mathcal{ALC}(\mathcal{D})$ concept w.r.t. an acyclic TBox, in order to show decidability of the satisfiability of an $\mathcal{MTALC}(\mathcal{D}_x, \mathcal{D})$ concept w.r.t. a two-atac TBox, it is sufficient to show decidability of an $\mathcal{MTALC}(\mathcal{D}_x)$ concept w.r.t. a weakly cyclic TBox. The following is an overview of a proof of such a decidability. Given an $\mathcal{MTALC}(\mathcal{D}_x)$ concept C and an $\mathcal{MTALC}(\mathcal{D}_x)$ weakly cyclic TBox \mathcal{T} , the problem we are interested in is, the satisfiability of C with respect to \mathcal{T} . The axioms in \mathcal{T} are of the form $B \doteq E$, where B is a defined concept name, and E an $\mathcal{MTALC}(\mathcal{D}_x)$ concept. Using C , we introduce a new defined concept name, B_{init} , given by the axiom $B_{init} \doteq C$. We denote by \mathcal{T}' the TBox consisting of \mathcal{T} augmented with the new axiom: $\mathcal{T}' = \mathcal{T} \cup \{B_{init} \doteq C\}$. The alternating automaton we associate with the satisfiability of C w.r.t. the TBox \mathcal{T} , so that satisfiability holds \iff the language accepted by the automaton is not empty, is now almost entirely given by the TBox \mathcal{T}' : the defined concept names represent the states of the automaton, B_{init} being the initial state; the transition function is given by the axioms themselves. However, some modification of the axioms is needed.

Given an $\mathcal{MTALC}(\mathcal{D}_x)$ axiom $B \doteq E$ in \mathcal{T}' , the method we propose decomposes E into some kind of Disjunctive Normal Form, $dnf2(E)$, which is free of occurrences of the form $\forall R.E'$. Intuitively, the concept E is satisfiable by the state consisting of the defined concept name B , \iff there exists an element S of $dnf2(E)$ that is satisfiable by B . An element S of $dnf2(E)$ is a conjunction written as a set, of the form $S_{prop} \cup S_{csp} \cup S_{\exists}$, where:

1. S_{prop} is a set of primitive concepts and negated primitive concepts —it is worth noting here that, while the defined concepts (those concept names appearing as the left hand side of an axiom) define

the states of our automaton, the primitive concepts (the other concept names) correspond to atomic propositions in, e.g., classical propositional calculus;

2. S_{csp} is a set of concepts of the form $\exists(u_1) \cdots (u_n).P$, where u_1, \dots, u_n are feature chains and P a relation (predicate) of an n -ary spatial RA; and
3. S_{\exists} is a set of concepts of the form $\exists R.E_1$, where R is a role and E_1 is a concept.

The procedure ends with a TBox \mathcal{T}' of which all axioms are so written. Once \mathcal{T}' has been so written, we denote:

1. by $af(\mathcal{T}')$, the set of abstract features appearing in \mathcal{T}' ; and
2. by $rrc(\mathcal{T}')$, the set of concepts appearing in \mathcal{T}' , of the form $\exists R.E$, with R being a general, not necessarily functional role, and E a concept.

The alternating automaton to be associated with \mathcal{T}' , will operate on (Kripke) structures which are infinite $m + p$ -ary trees, with $m = |af(\mathcal{T}')|$ and $p = |rrc(\mathcal{T}')|$. Such a structure, say t , is associated with a truth-value assignment function π , assigning to each node, the set of those primitive concepts appearing in \mathcal{T}' that are true at the node. With t are also associated the concrete features appearing in \mathcal{T}' : such a concrete feature, g , is mapped at each node of t , to a (concrete) object of the spatial domain in consideration (e.g., a region of a topological space if the concrete domain is generated by $\mathcal{RCC8}$).

The feature chains are of the form $f_1 \dots f_k g$, with $k \geq 0$, where the f_i 's are abstract features (also known, as alluded to before, as functional roles: functions from the abstract domain onto the abstract domain), whereas g is a concrete feature (a function from the abstract domain onto the set of objects of the concrete domain). The sets S are used to label the nodes of the search space. Informally, a run of the tableaux-like search space is a disjunction-free subspace, obtained by selecting at each node, labelled, say, with S , one element of $dnf2(S)$.

Let σ be a run, s_0 a node of σ , and S the label of s_0 , and suppose that S_{csp} contains $\exists(u_1)(u_2).P$ (we assume, without loss of generality, a concrete domain generated by a binary spatial RA, such as $\mathcal{RCC8}$ [9]), with $u_1 = f_1 \dots f_k g_1$ and $u_2 = f'_1 \dots f'_m g_2$. The concept $\exists(u_1)(u_2).P$ gives birth to new nodes of the run, $s_1 = f_1(s_0)$, $s_2 = f_2(s_1)$, \dots , $s_k = f_k(s_{k-1})$, $s_{k+1} = f'_1(s_0)$, $s_{k+2} = f'_2(s_{k+1})$, \dots , $s_{k+m} = f'_m(s_{k+m-1})$; to new variables of what could be called the (global) CSP, $CSP(\sigma)$, of σ ; and to a new constraint of $CSP(\sigma)$. The new variables are $\langle s_k, g_1 \rangle$ and $\langle s_{k+m}, g_2 \rangle$, which denote the values of the concrete features g_1 and g_2 at nodes s_k and s_{k+m} , respectively. The new constraint is $P(\langle s_k, g_1 \rangle, \langle s_{k+m}, g_2 \rangle)$. The set of all such variables together with the set of all such constraints, generated by node s_0 , give the CSP $CSP_{\sigma}(s_0)$ of σ at s_0 ; and the union of all CSPs $CSP_s(\sigma)$, over the nodes s of σ , gives $CSP(\sigma)$. The feature chains make it possible to refer to the values of the different concrete features at the different nodes of a run, and restrict these values using spatial predicates.

The pruning process during the tableaux method will now work as follows. The search will make use of a data structure *Queue*, which will be handled in very much the same fashion as such a data structure is handled in local consistency algorithms, such as arc- or path-consistency in standard CSPs. The data structure is initially empty. Then whenever a new node s is added to the search space, the global CSP of the run being constructed is updated, by augmenting it with (the variables and) the constraints generated, as described above, by s . Once the CSP has been updated, so that it includes the local CSP at the current node, the local consistency pruning is applied by propagating the constraints in *Queue*. Once a run has been fully constructed,

and only then, its global CSP is solved. In the case of a concrete domain generated by a binary, $\mathcal{RCC8}$ -like RA, the filtering is achieved with a path-consistency algorithm [1], and the solving of the global CSP, after a run has been fully constructed, with a solution search algorithm such as the one in [8]. In the case of a concrete domain generated by a ternary spatial RA, the filtering and the solving processes are achieved with a strong 4-consistency and a search algorithms such as the ones in [7].

9 Summary

We have provided a rich spatio-temporal framework combining a spatio-temporalisation of the well-know $\mathcal{ALC}(\mathcal{D})$ family of description logics with a concrete domain [2], with $\mathcal{ALC}(\mathcal{D})$ itself. The framework is well-suited for the representation of change in dynamic structured data, in dynamic spatial scenes, and in dynamic propositional knowledge. Contrary to most existing approaches of combining modal or description logics to get spatio-temporal languages (see, e.g., [4, 5, 6, 14]), ours leads to a decidable language. This advantage of being expressively rich while remaining decidable is the fruit of the way the combination is done, which is complex enough to make the resulting framework rich, but keeps a separation between the (decidable) combined languages large enough to bring decidability of the resulting language into decidability of the combined ones.

REFERENCES

- [1] J F Allen, 'Maintaining knowledge about temporal intervals', *Communications of the Association for Computing Machinery*, **26**(11), 832–843, (1983).
- [2] F Baader and P Hanschke, 'A scheme for integrating concrete domains into concept languages', in *Proceedings of the 12th International Joint Conference on Artificial Intelligence (IJCAI)*, pp. 452–457, Sydney, (1991). Morgan Kaufmann.
- [3] C Bailey-Kellogg and F Zhao, 'Qualitative Spatial Reasoning: Extracting and Reasoning with Spatial Aggregates', *AI Magazine*, **24**(4), 47–60, (2003).
- [4] P Balbiani and J-F Condotta, 'Computational Complexity of Propositional Linear Temporal Logics Based on Qualitative Spatial or Temporal Reasoning', in *Proceedings FroCos*, pp. 162–176, Santa Margherita Ligure, Italy, (2002). Springer.
- [5] B Bennett, A G Cohn, F Wolter, and M Zakharyashev, 'Multi-Dimensional Modal Logic as a Framework for Spatio-Temporal Reasoning', *Applied Intelligence*, **17**(3), 239–251, (2002).
- [6] B Bennett, C Dixon, M Fischer, U Hustadt, E Franconi, I Horrocks, and M Rijke, 'Combinations of Modal Logics', *AI Review*, **17**(1), 1–20, (2002).
- [7] A Isli and A G Cohn, 'A new Approach to cyclic Ordering of 2D Orientations using ternary Relation Algebras', *Artificial Intelligence*, **122**(1–2), 137–187, (2000).
- [8] P Ladkin and A Reinefeld, 'Effective Solution of qualitative Constraint Problems', *Artificial Intelligence*, **57**, 105–124, (1992).
- [9] D Randell, Z Cui, and A Cohn, 'A spatial Logic based on Regions and Connection', in *Proceedings of the International Conference on Principles of Knowledge Representation and Reasoning (KR)*, pp. 165–176, San Mateo, (1992). Morgan Kaufmann.
- [10] J Renz and B Nebel, 'On the Complexity of Qualitative Spatial Reasoning: A maximal tractable Fragment of the Region Connection Calculus', *Artificial Intelligence*, **108**, 69–123, (1999).
- [11] E Sandewall, 'Assessments of Ramification Methods that Use Static Domain Constraints', in *Proceedings of the International Conference on Principles of Knowledge Representation and Reasoning (KR)*, eds., L C Aiello, J Doyle, and S C Shapiro, p. 707, Cambridge, MA, (1996).
- [12] M Schmidt-Schauss and G Smolka, 'Attributive concept descriptions with complements', *Artificial Intelligence*, **48**(1), 1–26, (1991).
- [13] M Y Vardi and P Wolper, 'Automata-theoretic Techniques for modal Logics of Programs', *Journal of Computer and System Science*, **32**(2), 183–221, (1986).

- [14] F Wolter and M Zakharyashev, 'Spatio-temporal Representation and Reasoning based on RCC-8', in *Proceedings of Principles of Knowledge Representation and Reasoning (KR)*, eds., A G Cohn, F Giunchiglia, and B Selman, pp. 3–14, Breckenridge, Colorado, (2000). Morgan Kaufmann.

THE NOTIFICATION LETTER

(as received on 3 May 2004)

Dear Amar Isli:

We regret to inform you that your submission C0686 Augmenting ALC(D) (atemporal) roles and (aspatial) concrete domain with temporal roles and a spatial concrete domain -first results Amar Isli

cannot be accepted for inclusion in the ECAI 2004's programme. Due to the large number of submitted papers, we are aware that also otherwise worthwhile papers had to be excluded. You may then consider submitting your contribution to one of the ECAI's workshops, which are still open for submission.

In this letter you will find enclosed the referees' comments on your paper.

We would very much appreciate your participation in the meeting and especially in the discussions.

Please have a look at the ECAI 2004 website for registration details and up-to-date information on workshops and tutorials:

<http://www.dsic.upv.es/ecai2004/>

The schedule of the conference sessions will be available in May 2004.

I thanks you again for submitting to ECAI 2004 and look forward to meeting you in Valencia.

Best regards

Programme Committee Chair

REVIEW ONE

— ECAI 2004 REVIEW SHEET FOR AUTHORS —

PAPER NR: C0686

TITLE: Augmenting ALC(D) (atemporal) roles and (aspatial) concrete domain with temporal roles and a spatial concrete domain -first results

1) SUMMARY (please provide brief answers)

- What is/are the main contribution(s) of the paper?

No substantial results and contribution.

2) TYPE OF THE PAPER

The paper reports on:

☒ Preliminary research

☐ Mature research, but work still in progress

☐ Completed research

The emphasis of the paper is on:

☐ Applications

☒ Methodology

3) GENERAL RATINGS

Please rate the 6 following criteria by, each time, using only one of the five following words: BAD, WEAK, FAIR, GOOD, EXCELLENT

3a) Relevance to ECAI: FAIR

3b) Originality: WEAK

3c) Significance, Usefulness: BAD

3d) Technical soundness: FAIR

3e) References: BAD

3f) Presentation: WEAK

4) QUALITY OF RESEARCH

4a) Is the research technically sound?

☐ Yes ☒ Somewhat ☐ No

4b) Are technical limitations/difficulties adequately discussed?

☐ Yes ☐ Somewhat ☒ No

4c) Is the approach adequately evaluated?

☐ Yes ☐ Somewhat ☒ No

FOR PAPERS FOCUSING ON APPLICATIONS:

4d) Is the application domain adequately described?

☐ Yes ☐ Somewhat ☐ No

4e) Is the choice of a particular methodology discussed?

☐ Yes ☐ Somewhat ☐ No

FOR PAPERS DESCRIBING A METHODOLOGY:

4f) Is the methodology adequately described?

☐ Yes ☐ Somewhat ☒ No

4g) Is the application range of the methodology adequately described, e.g. through clear examples of its usage?

☐ Yes ☐ Somewhat ☒ No

Comments:

See below.

5) PRESENTATION

5a) Are the title and abstract appropriate?

☐ Yes ☒ Somewhat ☐ No

5b) Is the paper well-organized? ☐ Yes ☐ Somewhat ☒ No

5c) Is the paper easy to read and understand?

☐ Yes ☐ Somewhat ☒ No

5d) Are figures/tables/illustrations sufficient?

☐ Yes ☐ Somewhat ☒ No

5e) The English is ☒ very good ☐ acceptable ☐ dreadful

5f) Is the paper free of typographical/grammatical errors?

☒ Yes ☐ Somewhat ☐ No

5g) Is the references section complete?

☐ Yes ☐ Somewhat ☒ No

Comments:

See below.

6) TECHNICAL ASPECTS TO BE DISCUSSED (detailed comments)

- Suggested / required modifications:

General comments.

At the beginning of the paper, many elements are introduced at a very abstract level, with a very few explanations (and nothing is said about the supposed knowledge of the reader with respect to the subject, and the paper is far from being self-explanatory). Moreover, the reader does not understand on which basis he must rely for reading the paper, and what is the actual objective of the paper.

There is a real problem with this paper: the author(s) propose a number of definitions (not always easy to read and to understand) without giving any concrete example. There is no discussion on the framework that they have introduced, and no comparison with related papers on space and time in description logics (such as V. Haarslev, C. Lutz and R. Moeller, A Description Logic with Concrete Domains and a Role-forming Predicate Operator, *Journal of Logic and Computation*, 9(3):351-384, 1999). In these conditions, it is very difficult to have a good idea of the objectives of the paper, and the utility of the paper: this is perhaps a nice theoretical work, but what can we do with this framework? How can we really take into account in practical situations time and space for solving real-world problems? For terminating, what is the actual objective of the author(s) writing this paper? The reader is not convinced, and the paper is not acceptable under its present form.

- Other comments:

REVIEW TWO

— ECAI 2004 REVIEW SHEET FOR AUTHORS —

PAPER NR: C0686

TITLE: Augmenting ALC(D) (atemporal) roles and (aspatial) concrete domain with temporal roles and a spatial concrete domain - first results

1) SUMMARY (please provide brief answers)

- What is/are the main contribution(s) of the paper?

The paper describes the spatio-temporalisation of the ALC(D) family of description logics.

2) TYPE OF THE PAPER

The paper reports on:

☒ Preliminary research

☐ Mature research, but work still in progress

☐ Completed research

The emphasis of the paper is on:

☐ Applications

☒ Methodology

3) GENERAL RATINGS

Please rate the 6 following criteria by, each time, using only one of the five following words: BAD, WEAK, FAIR, GOOD, EXCELLENT

3a) Relevance to ECAI: FAIR

3b) Originality:

3c) Significance, Usefulness: FAIR

3d) Technical soundness: FAIR

3e) References: WEAK

3f) Presentation: BAD

4) QUALITY OF RESEARCH

4a) Is the research technically sound?

☐ Yes ☒ Somewhat ☐ No

4b) Are technical limitations/difficulties adequately discussed?

☐ Yes ☐ Somewhat ☒ No

4c) Is the approach adequately evaluated?

☐ Yes ☐ Somewhat ☒ No

FOR PAPERS FOCUSING ON APPLICATIONS:

4d) Is the application domain adequately described?

☐ Yes ☐ Somewhat ☐ No

4e) Is the choice of a particular methodology discussed?

☐ Yes ☐ Somewhat ☐ No

FOR PAPERS DESCRIBING A METHODOLOGY:

4f) Is the methodology adequately described?

☐ Yes ☒ Somewhat ☐ No

4g) Is the application range of the methodology adequately described, e.g. through clear examples of its usage?

☐ Yes ☐ Somewhat ☒ No

Comments:

The quality of presentation of the paper is not sufficient to make a reliable judgment regarding the general quality of the research, hence the largely neutral ratings of this section.

5) PRESENTATION

5a) Are the title and abstract appropriate?

☐ Yes ☐ Somewhat ☒ No

5b) Is the paper well-organized? ☐ Yes ☐ Somewhat ☒ No

5c) Is the paper easy to read and understand?

☐ Yes ☐ Somewhat ☒ No

5d) Are figures/tables/illustrations sufficient?

☐ Yes ☐ Somewhat ☒ No

5e) The English is ☐ very good ☒ acceptable ☐ dreadful

5f) Is the paper free of typographical/grammatical errors?

☐ Yes ☐ Somewhat ☒ No

5g) Is the references section complete?

☐ Yes ☒ Somewhat ☐ No

Comments:

The presentation of this work lets it down completely. It is below the standard necessary for a general international audience of AI researchers, and this virtually debars it from the possibility of a measured technical evaluation. The paper tries to cram far too much technical detail into too little space, at the expense of any high-level, informal or intuitive description of the work, or any detailed indication of its applicability. There is not a single example to aid comprehension or readability.

6) TECHNICAL ASPECTS TO BE DISCUSSED (detailed comments)

- Suggested / required modifications:

To be acceptable for publication within the given page limitation, this work needs to be described (at least partly) at a more informal and intuitive level, and with the aid of examples.

- Other comments:

REVIEW THREE

— ECAI 2004 REVIEW SHEET FOR AUTHORS —

PAPER NR: C0686

TITLE: Augmenting ALC(D) (atemporal) roles and (aspatial)...

1) SUMMARY (please provide brief answers)

- What is/are the main contribution(s) of the paper?

2) TYPE OF THE PAPER

The paper reports on:

☐ Preliminary research

☐ Mature research, but work still in progress

☐ Completed research

The emphasis of the paper is on: X

☐ Applications

☐ Methodology

3) GENERAL RATINGS

Please rate the 6 following criteria by, each time, using only one of the five following words: BAD, WEAK, FAIR, GOOD, EXCELLENT

3a) Relevance to ECAI:

3b) Originality:

3c) Significance, Usefulness:

3d) Technical soundness:

3e) References:

3f) Presentation:

4) QUALITY OF RESEARCH

4a) Is the research technically sound?

☐ Yes ☐ Somewhat ☐ No

4b) Are technical limitations/difficulties adequately discussed?

☐ Yes ☐ Somewhat ☐ No

4c) Is the approach adequately evaluated?

☐ Yes ☐ Somewhat ☐ No

FOR PAPERS FOCUSING ON APPLICATIONS:

4d) Is the application domain adequately described?

☐ Yes ☐ Somewhat ☐ No

4e) Is the choice of a particular methodology discussed?

☐ Yes ☐ Somewhat ☐ No

FOR PAPERS DESCRIBING A METHODOLOGY:

4f) Is the methodology adequately described?

☐ Yes ☐ Somewhat ☐ No

4g) Is the application range of the methodology adequately described, e.g. through clear examples of its usage?

☐ Yes ☐ Somewhat ☐ No

Comments:

5) PRESENTATION

5a) Are the title and abstract appropriate?

☐ Yes ☐ Somewhat ☐ No

5b) Is the paper well-organized? ☐ Yes ☐ Somewhat ☐ No

5c) Is the paper easy to read and understand?

☐ Yes ☐ Somewhat ☐ No

5d) Are figures/tables/illustrations sufficient?

☐ Yes ☐ Somewhat ☐ No

5e) The English is ☐ very good ☐ acceptable ☐ dreadful

5f) Is the paper free of typographical/grammatical errors?

☐ Yes ☐ Somewhat ☐ No

5g) Is the references section complete?

☐ Yes ☐ Somewhat ☐ No

Comments:

6) TECHNICAL ASPECTS TO BE DISCUSSED (detailed comments)

- Suggested / required modifications:

- Other comments: