ON GENERATING TILE SYSTEM FOR A SOFTWARE ARCHITECTURE CASE OF A COLLABORATIVE APPLICATION SESSION

C. Bouanaka, A. Choutri
Department of Computer Science, Mentouri University, Constantine, Algeria

F. Belala
Department of Computer Science, Mentouri University, Constantine, Algeria

Keywords: Tile Logic, Software Architecture, Architecture Description Languages, Synchronization, Dynamic connection.

Abstract: Tile logic, an extension of rewriting logic, where synchronization, coordination and interaction can be naturally expressed, is showed to be an appropriate formal semantic framework for software architecture specification. Based on this logic, we define a notion of dynamic connection between software components. Then, individual components are viewed as entirely independent elements and free from any static interconnection constraints. We also fill out the usual component description, expressed in terms of Provided/Required services, with functionalities specification of such services. Starting from State/Transition UML diagrams, representing requirements of the underlying distributed system, our objective consists of offering a common semantic framework for architectural description as well as behavioural specification of that system. Direct consequences of the proposed approach are dynamic reconfiguration and components mobility which become straightforward aspects. A simple, but comprehensive, case study, the collaborative application session, is used to illustrate all stages of our proposed approach.

1 INTRODUCTION

With computer science revolution, software applications become more complex and constantly evolving, their development requires more labour and needs increasing cost. The main difficulty in specifying distributed software systems is due either to the great number of entities composing it or to the difficulty in specifying interactions, coordination and synchronization among parts of the system. A direct consequence is that system global structure, its *software architecture*, became a central problem of conception.

The system software architecture is a form of contract showing the intended correspondence between system requirements and components of the designed system. It may be ensured all over the ongoing stages of software engineering. Consequently, a system specification may be viewed as a sequence of refinements starting from its abstract software architecture, defined as a set of communicating black boxes, until obtaining the more detailed behaviour of each component.

One challenging approach is to specify an ADL semantics allowing system architecture description as a set of black boxes related via an interconnection topology and offering necessary tools to obtain transparent boxes where internal behaviours can be specified.

In this work, we use Tile logic (Bruni, 1999), an extension of rewriting logic (Meseguer, 1992), as a common semantic framework to define abstract software architectures and their behaviours.

Our contribution consists of providing a tile logic based architecture description model for distributed application. Such architecture is defined as a set of independently executing components with a dynamic interconnection topology. Each component is defined as a set of external ports, to ensure interactions with the environment, and an internal behaviour operating on its basic structure.

Bouanaka C., Choutri A. and Belala F. (2007).
ON GENERATING TILE SYSTEM FOR A SOFTWARE ARCHITECTURE CASE OF A COLLABORATIVE APPLICATION SESSION.
In *Proceedings of the Second International Conference on Software and Data Technologies - SE*, pages 123-128

Thus, two views are considered for each component: black view defines its observable behaviour in terms of interactions, while transparent view specifies its detailed behaviour.

Based on state/ transition UML diagram, a tile system is generated for each component, transparent view, to describe both internal structure and behaviour. At higher description level, composition of all component tile systems is enriched with a set of synchronization tiles to define all possible dynamic connections while considering each component as a black box. Dynamic connection is ensured by a unique generic synchronization tile which: (1) creates a connection between the sender component and the receiver one by duplicating the output port of the former, (2) transfers port content by swapping one copy of the output port of the sender and the input port of the receiver, and (3) ends the interaction by destroying (discharging) the empty port.

The remainder of the paper is organized as follows. Section 2 compares the proposed approach to other existing ADLs. Section 3 presents the basic semantic aspects of Tile Logic. Section 4 is devoted to our proposal. It presents main ideas introduced on software architectures description, while section 5 illustrates them via a collaborative session case study. Discussion and conclusions round out the paper.

2 RELATED WORKS

A great number of ADLs have been proposed in the literature. However, most of them: Wright (Allen, 1997), Rapide (Luckham, 1995), Darwin (Magee, 1995), etc., focus on the software architecture description where component semantics is in part expressed by its interface, and system behaviour is not completely defined (Megzari, 2004). Therefore, software architecture concepts need to be associated to formal theories, clarifying these concepts or providing rules to determine whether a given architecture is well-formed.

In our proposal, a software architecture, designed to facilitate designers job, is systematically transformed to a formal theory specification, which can be prototyped or model checked. This facilitates the integration of formal specifications in the traditional life-cycle of an application development. We present an interesting combination of Tile logic, an extension of rewriting logic, and Software Architectures. Some works were already done in this direction. In (Clavel, 1999), authors specify the semantics of several typical architectural patterns in rewriting logic. In (Bragal, 2003), authors provide a mapping of Cbabel ADL concepts in rewriting logic. CommUnity (Bruni, 2004) is another ADL whose semantics was defined in Tile Logic (Bruni, 1999). Authors' objective was to show how these two models (Tile logic and CommUnity) contribute to characterize software architectures. They define a mapping of CommUnity programs into Tile Logic. Their work gives rise to some complexity particularly during the decomposition phase of a CommUnity program. Our approach is complementary to all these researches since it defines a Tile logic based model of ADLs. It considers system software architecture as a set of black boxes interconnected via a dynamic interconnection topology. It also allows defining alternative transparent boxes where internal behaviours can be formally specified.

3 TILE LOGIC

Tile logic (Bruni, 1999) is an extension of rewriting logic (in the unconditional case) taking into account rewriting with side effects and rewriting synchronization. Ordinary rewrite rules format expressing naturally state changes and concurrent calculus. However, they lack tools to express interactions with the environment; they can be freely instantiated with any term in any context. The main idea of Tile Logic is to impose dynamic restraints on terms to which a rule may be applied by decorating rewrite rules with observations ensuring synchronizations and describing interactions. The resulting rewrite rule is called a tile.

A tile α has the graphical representation in figure 1, also written $s \xrightarrow[b]{a} t$, stating that the initial configuration s can evolve to the final configuration t via α, producing the effect b, which can be observed by the environment. Such step is allowed only if the arguments (subcomponents) of s can contribute by producing a, which acts as a trigger of α. Triggers and effects are called observations; tile vertices are called interfaces (Gadducci, 1997).

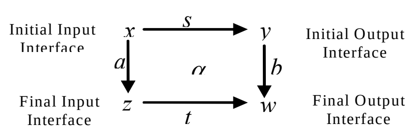


Figure 1: Graphical Representation of a Tile.

A set of tiles is defined to describe the behaviour of partially specified components (i.e., containing variables) called configurations.

A configuration is expressed only in terms of possible interactions with the inside and outside environment and system behaviour is viewed as a coordinated evolution of its local configurations.

Definition (Bruni 99): A tile system is a 4-tuple $R = (H, V, N, R)$ where H, V are monoïdal categories with the same set of objects $O_H = O_V$, N being a set of rule names and $R: N \rightarrow H \times V \times V \times H$ a function where for each α in N, if $R(\alpha) = (s,a,b,t)$, then $s: x \rightarrow y$, $a: x \rightarrow z$, $b: y \rightarrow w$ and $t: z \rightarrow w$, for suitable objects x, y, z and w, x and z are the input interfaces. While, y and w are the output interfaces.

Arrows of H and V are called configurations and observations respectively while their objects are called interfaces.

R is a set of tiles expressing all basic local changes on configurations according to the occurrence of some observations. It defines local possible evolutions of the system.

Tile logic exploits a three-dimensional view of concurrent systems: horizontal dimension (space) models coordination of components according to the structure of the system, vertical dimension (time) models state evolutions according to computation flows, while the third dimension (parallel) models distribution of activities and resources. Configurations and observations are algebraic structures equipped with parallel and sequential operators (⊗ and ; operators respectively) to allow building of larger components.

A standard set of deduction rules indicates how to build up larger steps, starting from basic tiles of the system, via horizontal, vertical and parallel compositions (see Figure 2).

Rules generating the basic tiles:

$$\frac{R(\alpha) = \langle s, a, b, t \rangle}{\alpha : s \xrightarrow[b]{a} t}$$

Rules generating the horizontal and vertical identities:

$$\frac{a : x \rightarrow z \in V}{id_V : x \xrightarrow[a]{a} z}$$

$$\frac{t : x \rightarrow y \in H}{id_H : t \xrightarrow[y]{x} t}$$

Horizontal, vertical and parallel compositions

$$\frac{\alpha : s \xrightarrow[b]{a} t \quad \beta : t \xrightarrow[d]{c} h}{\alpha \bullet \beta : s \xrightarrow[b;d]{a;c} h}$$

$$\frac{\alpha : s \xrightarrow[b]{a} t \quad \beta : h \xrightarrow[c]{b} f}{\alpha * \beta : s;h \xrightarrow[c]{a} t;f}$$

$$\frac{\alpha : s \xrightarrow[b]{a} t \quad \beta : h \xrightarrow[d]{c} f}{\alpha \otimes \beta : s \otimes h \xrightarrow[b \otimes d]{a \otimes c} t \otimes f}$$

Figure 2: Deduction Rules of Tile Logic.

If some interface rearrangements (duplications, projections, swaps) are necessary, auxiliary tiles can be added to the system and composed with the identity and basic tiles.

Tile logic offers a flexible formal framework (meta-formalism) to specify rule-based computational systems behaviour like reactive systems, open systems, coordination languages, concurrent systems, mobile calculi (Bruni, 2003), (Ferrari, 2000). In addition, tile logic benefits on all software tools (Maude environment) (Clavel, 2003) offered by rewriting logic to obtain executable specifications.

4 MAIN CONTRIBUTION

A reactive view of concurrent systems is possible in tile logic, since components can be conceived separately and then composed via their behaviours. Such a view corresponds to a software architecture view of a distributed system very loosely. Therefore, we propose a novel view of software architecture, independent from the interconnection topology. Moreover, components are viewed as floating elements since a static interconnection topology definition, like in most of existing ADLs, is completely absent. We also fill out the usual component description, expressed in terms of Provided/Required services, with functionalities specification of such services. Hence, each component will be described by a set of external ports, ensuring interactions with the environment, and an internal behaviour, specified by a tile system, to deliver system functionalities. We can obtain similar results in rewriting logic. However, rewriting logic lacks tools to express synchronization aspects. Tile logic main contribution is a formal specification of possible synchronizations between components. Traditionally, this kind of synchronization is defined by static connectors. In our work, we propose a tile based dynamic connector.

Concretely, the dynamic connection depends on the contribution of two components to execute a shared action (synchronization), expressed by a tile. When a send action (trigger of the tile) is initiated by the sender, the synchronization tile takes place and plays the role of a dynamic connection.

Synchronazation:

$$C(x) \otimes C(y) \xrightarrow[\nabla_{out(x)} \otimes id_{in(y)} ; id_{out(x)} \otimes \gamma_{in'(y), in(y)} ; id_{out(x)} \otimes !_{in(y)} \otimes id_{in'(y)}]{Send(out(x)) \otimes id_{in(y)} ; id_{C(x)} \otimes id_{C(y)}} c(x) \otimes c'(y)$$

Figure 3: Dynamic Connection Tile.

Synchronization tile is parameterized by *C(x)* and *C(y)*, which are the sender (*x*) and receiver (*y*) configurations. *out(x)* and *in(y)* are output and input ports of the sender component and receiver one respectively. Message receipt by *y* changes its configuration to *C'(y)*, since *in(x)* object value has been modified. Synchronization tile is triggered by a *send* action. It starts by preparing interaction necessary interfaces (isolates *out(x)* and *in(y)* thanks to parallel composition of horizontal identities $id_{C(x)}$ and $id_{C(y)}$). Synchronization tile effect is the following sequence: A connection Creation (∇ operator) between the sender component and the receiver one. A transfer of *out(x)* port contents by swapping (γ operator) one output port copy of the sender and the receiver input port. Then, interaction end by discharging (! operator) the empty port. We notice that, duplicator operator ∇ creates a copy of the sender output port and renames it as *in'(y)*.

5 CASE STUDY

Distributed collaborative applications are characterized by supporting groups' collaborative activities. This kind of applications is branded by physically distributed user groups, who cooperate by interactions and are gathered in work sessions (Molina, 2003). The effective result of collaboration in a session is a production of simultaneous and concurrent actions. Interactions are fundamental actions of a collaborative session and require being coordinated (synchronized) to avoid inconsistencies. We consider a simplified version of collaborative session where session management is not treated since we are more interested on synchronization aspects and their definition in tile logic.

5.1 Software Architecture of the Collaborative Application

Software architecture of a collaborative session is composed of one president and several instances of participant component (see Figure 4).

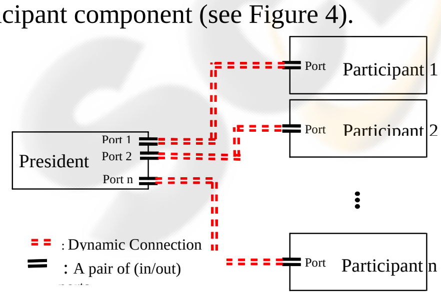
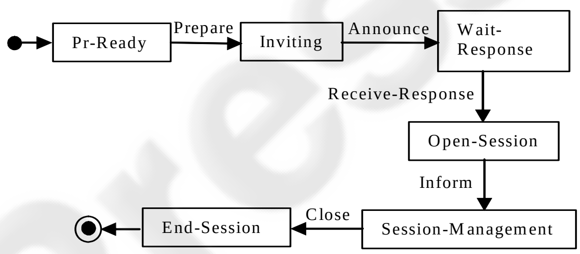


Figure 4: Software Architecture of a collaborative Session.

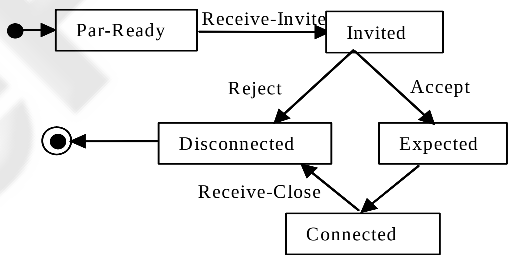
President component interact with each participant component via a pair of (in/out) ports. A connection (dashed line) between (in/out) port of the president and (out/in) port of a participant is established dynamically if needed.

5.2 Components Tile Systems

Figure 5 illustrates a president and any participant behaviour. To open a session, the president begins by announcing it. He prepares an *invite message* and broadcasts it all participants. The session is opened by the president when at least a positive response (accept to participate) is received. Participants are then informed by an *open message*. Managing session consists of realizing the collaborative task with contribution of all session members. When the collaborative task is terminated, the president closes the corresponding session by sending a *close message* to all participants.



(a) President Diagram



(b) Participant Diagram

Figure 5: State / Transition diagrams.

5.2.1 Horizontal and Vertical Categories

Objects of the two categories define component internal structure. Vertical category (observations) of a component defines its possible actions, i.e., provided services of the component. Morphismes of the vertical category specify possible actions on objects. Horizontal category (configurations) of a component defines component possible states. Gathered together via a set of tiles, horizontal and vertical categories define the expected behaviour of the underlying component. Based on diagrams presented below, one can identify configurations (states) and observations (actions) of each component. In what follows, we will present tile system associated to the president only. In a similar way, tile system associated to a participant component can be generated. Due to space limitation reasons, it is omitted.

1) Objects: Identified objects for the president are:

- *Port:* we associate a port to each participant communicating with the president,
- *Participant-List:* each entry in the list corresponds to a participant and indicates its state (*Connected/Disconnected*),
- *Buffer:* contains received messages,
- *Msg:* a message to send.

2) Configurations: Corresponds to the identified states of the president component in Figure 5(a). Each configuration is a 4-uplet *(ports, l, b, m)*, where:
Ports is a n-uplet of pairs (in/out) of ports with *n* is the number of participants, *l* is of sort *Participant-List*, *b* is a buffer and *m* is of sort *Msg*.
For simplicity reasons, we use the following notations:

-*Empty* $= \prod_{i=1}^{n}(Empty, Empty)$: to denote that all *(in/out)ports* are empty,

- *Outs* $= \prod_{i=1}^{n}(out(port(i))$: an n-uplet of all output of the president,

-*full-in(i,m)*= $\prod_{j=1}^{i-1}(in(j), out(j)), (m, out(i)), \prod_{k=i+1}^{n}(in(k), out(k))$: indicates a message deposit on the i^th^ *(in)port*,

-*empty-in(i)*= $\prod_{j=1}^{i-1}(in(j), out(j)), (0, out(i)), \prod_{k=i+1}^{n}(in(k), out(k))$: expresses that a the i^th^ *(in)port* is empty,

-*full-outs(m)*= $\prod_{i=1}^{n}(in(i), m)$: a massage deposit on all participants *(out)ports*,

- *init-list : generates an empty list.*

Basic configurations correspond to the president diagram states. Starting from the initial configuration *Pr-Ready,* which corresponds to the 4-uplet *(empty, init-list, empty, empty)*, the president can evolve to the following configurations:

- *Wait-Response = (Outs, init-list, empty, msg-invite): the president has sent an msg-invite and is waiting for a response,*
- *Open-Session = (Outs, l, empty, msg-open) : the president has sent an msg-open message to all participants (Outs term of the configuration),*
- *Session-Management = (ports, l, b, m): the president is realising the collaborative task with the* n *participants,*
- *End-Session = (Outs, l, b, msg-close): a msg-close is broadcasted to all participants.*

3) Observations: We present a subset of observations sufficient to explain our approach:

- *deposit(x:Msg) = full-outs(x)* : deposit a message on a all its (out)ports,

- *send(x:port)* : sends an *out(port)* content,

- $Send-all\ (Outs) = \bigotimes_{i=1}^{n} send(out(port(i)))$: corresponds to a broadcast action of the deposited message to all participants.

- *receive(i) (x:ports, y:Msg) = full-in(i,y)* : indicates a message receipt on the i^th^ port,

consume(i)(x:ports,y:list)=(empty-in(i),update-list(y,i)) a response withdrawal from port i and an update of participant-list.

We note that participant component manipulates: a status (Disconnected, Invited, and Connected), a pair of ports (in/out), a buffer and message. Thus its configurations are 4-uplet (st, p, b, m).

5.2.2 Tiles

The expected behaviour of the president is specified with a set of tiles. We present here tiles corresponding to session open and session close only:

***Prepare**:* $Pr-Ready \xrightarrow[deposit(msg-invite,outs)]{id} Inviting$

***Announce**:* $Inviting \xrightarrow[Send-all(Outs)]{id} Wait-Response$

***Response-Receipt**:*

$$Wait-Response \xrightarrow[consume(in(port(i)),l);deposit(msg-open,outs)]{receive(port(i),msg-Accept)} Open-session$$

***Inform**:*

$$Open-session \xrightarrow[Send-all(Outs)]{deposit(msg-Open,outs)} Session-Management$$

***Close**:*

$$Session-Management \xrightarrow[Send-all(Outs)]{deposit(msg-close,Outs)} End-Session$$

5.3 Synchronization between Components

An interaction between the president and a participant component corresponds to the dynamic connector tile execution by instantiating *C(x)* and *C(y).* As an example, the president puts an *msg-*

invite message in all output ports by executing its *Prepare* tile. Then, he sends the message by executing *Announce* tile. President state evolves to *Wait-response*. *Announce* effect is a broadcast of *msg-Invite* to all participants, which actually do nothing (*Ready* state). It triggers the synchronization tile. Instantiations are as follows:

- x = the president, y = a participant,

- $C(x) \otimes C(y)$ = *Wait-Response* $\otimes$ *Par-Ready*.

- The resulting configuration is $C(x) \otimes C(y)$ = *Wait-Response* $\otimes$ *Invited*, since the input port of the corresponding participant contains an *msg-Invite* now. We obtain the following tile: synchronization:

$$\text{Wait-Response} \otimes Par - \text{Ready} \xrightarrow[\nabla_{out(pr)} \otimes id_{in(part)}; id_{out(pr)} \otimes \gamma_{in'(part),in(part)}; id_{out(pr)} \otimes !_{in(part)} \otimes id_{in'(part)}]{Send(out(pr)) \otimes id_{in(part)}; id_{C(pr)} \otimes id_{C(part)}} \text{Wait-Response} \otimes \text{Invited}$$

where *pr* denotes the president component and *par* denotes a participant component.

6 CONCLUSION

In this paper, we showed how tile logic can be used as a common semantic framework for architectural and behavioural descriptions of distributed systems. Starting from a Place/Transition UML diagrams, describing the intended behaviour of the system, we identify basic components and possible interconnections between them via (in/out) ports. It constitutes the architectural description phase or black box view of the underlying system. Such view is then refined by opening the black boxes and glancing at their internal structure and behaviour. A tile system is associated to each component. It defines inherent objects and possible actions (observations) on them. It also defines possible state evolutions of component in terms of tiles. We have also proposed a notion of dynamic connection in software architectures. Dynamic reconfiguration and mobility of components are straightforward consequences of such component freeness from static interconnection constraints and become implicit aspects.

In our ongoing work, we plan to integrate some ADLs in tile logic to ensure that our current proposition is generic enough to cover a wide range of distributed systems. We will also focus on expressing inherent concepts of software architectures (dynamic reconfiguration, component mobility and non-functional properties of distributed systems).

REFERENCES

R., Allen, 1997. “A Formal Approach to Software Architecture.” PhD Thesis, Carnegie Mellon University, CMU Technical Report CMU-CS-97-144.

C. Braga1, A. Sztajnberg, 2003, "Towards a Rewriting Semantics for a Software Architecture Description Language", in: A. Cavalcanti and P. Machado, editors, Proceedings of WMF 2003, 6th Workshop on Formal Methods, Campina Grande, Brazil, Electronic Notes in Theoretical Computer Science 95, p.148-168.

R., Bruni, 1999. “Tile Logic for Synchronized Rewriting of Concurrent Systems”, Phd Thesis, University of Pisa, TD-1/99.

R., Bruni,, J., Meseguer, U., Montanari, 2003. **“**Tiling Transactions in Rewriting Logic”, in ENTC, Vol. 71, 20 pp. 20-35.

R., Bruni, J. L., Fiadeiro, I., Lanese, A., Lopes, U., Montanari, 2004. “New Insight into the Algebraic Properties of Architectural Connectors”, IFIP TCS, pp. 367-380.

M. Clavel, F. Duran, S. Eker, N. Martı-Oliet, P. Lincoln, J. Meseguer, and J. Quesada, 1999. Maude: Specification and Programming in Rewriting Logic. SRI International, http://maude.csl.sri.com, January 1999.

M., Clavel, F., Duran, S., Eker, N., Marti-Oliet, P., Lincoln, J., Meseguer, C. Talcott, 2003. “Maude 2”, SRI International and University of Illinois at Urbana-champaign, http://maude.cs.uiuc.edu.

G. L, Ferrari, U., Montanari, 2000. “Tile Formats for Located and Mobile Systems”, Informatica and.Computing, Vol.156, pp. 173–235.

F., Gadducci, U. Montanari, 1997. “The Tile Model”, in: G. Plotkin, C. Stirling, and M. Tofte, Eds, Proof, Language and interaction: essays in honour of Robin Milner, MIT Press, to appear.

D. C., Luckham, J. J., Kenny, L. M., Augustin, J., Vera, D., Bryan, W., Mann, 1995. “ Specification and Analysis of system Architecture Using Rapide.” IEEE Transactions on Software Engineering, vol. 21, no. 4, pp. 336-355.

J., Magee, N., Dualy, S., Eisonbach, J., Kramer, 1995. “Specifying Distributed Software Architectures.”, In Proceedings of the Fifth Symposium on the Foundations of Software Engineering (FSE4).

K., Megzari, 2004. “R EFINER: Environnement logiciel pour le raffinement d’architectures logicielles fondé sur une logique de réécriture.”, Thèse de doctorat en Informatique. Université Savoie.

J., Meseguer, 1992. “Conditional Rewriting Logic as a unified model of concurrency”, Theoretical Computer Science, pp.73-155.

J. M., Molina Espinosa, 2003. “Modèles et services pour la coordination des sessions coopératives multi-applications: application à l’ingénierie systèmes distribués”, Thèse de doctorat en Informatique et télécommunications, LAAS of CNRS, Toulouse.