Supporting Distant Human Collaboration under Tangible Environments
A Normative Multiagent Approach

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Abstract: The purpose of this paper is to present a new approach to support distant human collaboration under tangible environments. Our aim is not to build and transmit across the distant tables an accurate and complete description of the human activity. Rather, our choice is to restrict communication to the possibilities offered by the tangible tables (tangible object moves and virtual feedback). In this context, we propose to focus on the elicitation and sharing of the norms and conventions that frame human activity, a core issue to sustain proper collaboration. We promote in this perspective the design of a normative multiagent system, whose goal is to emulate the influence of these norms on distant cooperation, thus bringing mutual awareness to the human partners. The role of such system is (i) to represent these potentially heterogeneous and evolving systems of norms in a declarative and distributed way, (ii) to filter the interpretation and communication of human activity according to these norms, and (iii) to build an informed virtual feedback providing information about the conformity of action with respect to the conventions. An application to the RISK game is presented to exemplify the proposed approach.

1 INTRODUCTION

The purpose of this paper is to present a new approach to support distant human collaboration under a tangible environment called TangiSense (Lepreux et al., 2011). The TangiSense table may be seen as a magnetic retina that can detect and locate tangible objects equipped with RFID tags. Its spatial and temporal resolution is compatible with real-time. The table surface is further equipped with a liquid-crystal display (LCD) allowing virtual display. Each table is connected to a computer that manages tangible objects tracking and virtual feedback. Virtual display through the LCD surface may provide immersion in simulated environments but also, and more importantly, assess the effective detection of tangible object and provide feedback about their positioning and moves for distant users. Assessing the conformity of moves with respect to the rules governing the collaborative activity is a further role that is core to the present proposal. The system to be designed must support a collective and constructive approach to problem solving, as opposed to a competitive one. This implies the development of mutually consistent decision-making processes in which users share resources and knowledge. However, our aim is not to build and transmit across the distant tables an accurate and complete description of the human activity. Rather, our choice is to restrict communication to the possibilities offered by the tangible tables (tangible object moves and virtual feedback). In order that collaboration fully benefit from the specificities of tangible interaction, the design should finally preserve the spontaneous, opportunistic character of human activity. In this context, we propose to focus on the elicitation and sharing of the norms and conventions that frame human activity, a core issue to sustain proper collaboration. We promote in this perspective the design of a normative multi-agent system, whose goal is to emulate the influence of these norms on distant cooperation, thus bringing mutual awareness to the human partners. The role of such system is (i) to represent these potentially heterogeneous and evolving systems of norms in a declarative and distributed way, (ii) to filter the interpretation and communication of human activity according to these norms, and (iii) to build an informed virtual feedback providing information about the conformity of action with respect to the conventions. To exemplify the proposed approach, we describe an application to the RISK game. The RISK

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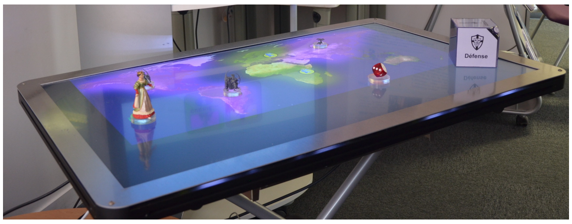

Figure 1: The TangiSense table equipped for the RISK game with tangible objects and virtual images displaying the ground map and tangible object moves.

game is a strategic board game where players fight to win territories. Upon start, each player is given an army (cannons, soldiers, cavalrymen) and a set of territories from a political map of the Earth. Each player attacks the other players in turn. To this end, he must first of all designate two territories, one from its own, supporting the attacking armies, and the other from the board, that is attacked. The attacking and attacked players then throw the dice to determine who loses and who wins the round. A sample view of the game, as played on the TangiSense table, is provided in Figure 1. This game leaves some autonomy to the players (which army to select, which territories to attack). However, they have to remember and follow the rules governing each move and proceed according to well-defined gameplay (in this case, a turn-taking protocol). Support for the follow-up of these rules will be provided by the collaborative support system that we describe in the following sections.

2 STATE OF THE ART

2.1 Collaborative Support Systems

One major challenge when designing collaborative support systems is to preserve the spontaneity and fluidity of human activity while ensuring the consistency and proper coordination of action (Pape and Graham, 2010). Informal and opportunistic working styles should indeed be promoted (Gutwin et al., 2008); at the same time, the role of the system is to support the building of a common vision or so-called ”mutual awareness” (Kraut et al., 2003). Physical co-presence provides multiple resources for awareness and conversational grounding. This has to be complemented in the case of distant communication. Tangible interaction occupies a specific niche in this respect, since tangible objects may be seen as full resources to situate action (Shaer and Hornecker, 2010). Communication is then grounded in the objects of the working space, and some of them may be designed to support action coordination and elicitation. Visual information then becomes a conversational resource that allows maintaining mutual awareness (Kraut et al., 2003). Beyond conversation, perceiving the other’s activity may be approached from the viewpoint of the other’s social embodiment, that is considering the constraints and rules that shape individual activity (Erickson and Kellogg, 2003). These issues were discussed in a previous paper (Garbay et al., 2012) into some more depth. We proposed in particular the introduction of *tangigets*, tangible objects aimed at supporting distant coordination, and ”norms”, declarative rules aimed at representing social laws and conventions, and governing the processing of tangible objects moves. Managing human activities in distributed environments requires the adoption of complex, emergent and adaptive system design, where flexibility, re-configurability and responsiveness play crucial roles (Millot and Mandiau, 1995). Various architecture models have been proposed in this respect. As quoted by (Kolski et al., 2009), these models have been largely inspired by interactive systems architectures. Among these, CoPAC, PAC* or CLOVER (Laurillau and Nigay, 2002) propose a distinction between production, communication and coordination spaces. Such distinction is of interest to our work, since there is a need to (i) ensure the follow-up of distant objects, ((ii) ensure the follow-up of the state of collaboration and (iii) provide feedback about these moves.

2.2 Normative Multiagent Systems

The goal in normative multiagent systems is to model cooperation and coordination under a social perspective. In such systems, norms drive agents toward ”proper and acceptable behavior” and define ”a principle of right action binding upon the members of a group” (Boella et al., 2007). These norms are usually represented as production rules of the form: ”whenever $\langle context \rangle$ if $\langle state \rangle$ then $\langle agent \rangle$ is $\langle deontic\ operator \rangle$ to do $\langle action \rangle$” (Boella et al., 2007). Specific to this style of programming is the fact that agents autonomously commit to obey the norms, in a way specified by the deontic operator. Any agent may however decide not to follow some norm: this may result in penalties. The implementation of normative agent architectures is very often based on the belief, desire, and intention (BDI) paradigm, with norms seen as external incentives for action (Dignum et al., 2002). Norms are triggered by a dedicated engine and result in agent notifications. Another specificity of this modeling is the fact that norms may evolve along the course of action. This may appear necessary in large, open organizations, where sub-groups often exhibit different and sometimes conflicting sets of norms. Agents in such organizations may need to join and leave the system freely, or to move from one group to another: mechanisms must be provided so that they may recognize and acquire local sets of norms (Hollander and Wu, 2011). (Boella et al., 2007) distinguishes between two complementary dynamics: the one of the social rules, and the one the environment or physical laws, which may evolve in response to changing circumstances. Such design has already been promoted in the field of CSCW. (Rong and Liu, 2006) proposes a distinction between Local agents (individual partners), Super agents (monitoring local agent actions and providing feedback so that local norms may evolve), Interactive agents (creating connections between agents based on their abilities) and Cooperation agents (monitoring agent organizations). This work is based on the EDA agent's model (Filipe, 2000) in which several types of norms with different semiotic levels are distinguished (perceptual, cognitive, behavioral and evaluative). We proposed in a previous paper (Badeig et al., 2012) an approach centered on the notion of norm awareness, with situated agents sharing a common multidimensional trace reflecting conformity to the norm.

3 PROPOSITION

3.1 Proposed View

Our approach to distant collaboration support is centered on the notion of norm awareness: core to human collaborative work is the fact that people may not share the rules and conventions their frame their activity, be it because they belong to different organization, or because they behave as individual people, and shows for example a tendency to prioritize some rules over others. We promote a multi-agent design, to cope with the distributed nature of the tangible surfaces, with the potential complexity of the task to be handled and with the potential heterogeneity of the human organizations in front. We further model collaboration as a process coupling production, communication and coordination spaces, according to the CLOVER approach for groupware design (Laurillau and Nigay, 2002). As illustrated in Figure 2, each space is populated with agents and norms of different types: events from the tangible surface are processed within the production space, virtual feedback are operated from the communication space and norms are evolved within the coordination space. The agents

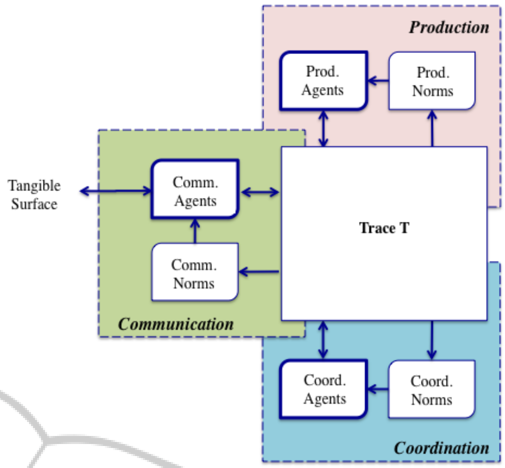

Figure 2: Functional view showing the various types of agents, filters and traces.

are situated within a multidimensional trace reflecting the evolution of human activity and its conformity to the norms under consideration. In a dual perspective, human activity is situated in the space of the tangible surface. Virtual feedback is provided to reflect distant activity as well as compliance of a tangible object move to the norm. This feedback may be considered as incentive for the co-evolution and improved coordination of actions among collaborating partners. The role of the norms, defined as condition-action rules, is to regulate the system's activity in each of the production, communication and coordination spaces, by checking the conformance of the activity and shaping agent processing in a context sensitive way. Coordination agents are provided with the abilities to update the set of norms, to account for contextual specificities (major collaboration steps or critical events detection, for example). Human and artificial agents are responsible for the activity dynamics while norms are responsible for the regulation of this dynamics. Traces evolve jointly under the asynchronous and concurrent action of human and artificial agents.

3.2 Formal Definition of the System Components

The system architecture involves four working spaces, namely the environment, the traces $space_t$, the agents $space_a$ and the norms $space_n$.

$$system = \langle environment, space_t, space_a, space_n \rangle \quad (1)$$

$$environment = \{tang_i, virt_j | \forall i, j\} \quad (2)$$

The environment is a physical space, made of tangible and virtual objects. It is open to human actors, according to certain constraints and rights. The management by the system of these objects gives rise to numerical traces, which constitute a numerical space. This space is open to artificial actors (the agents), according to other constraints and rights. These constraints and rights depends on the organizational specification of the system where each agent plays different roles, depending on its types (typically update the current normative policy for coordination agents) and belong to different groups (we typically consider that agents working on a table constitute a group). The state of the environment, at a given time, is specified by a subset of the space of traces. Core to our design is the management of the rights and constraints over physical and numerical information processing. To account for this specificity of our approach, we model a trace as a tuple of $(property, value)$ pairs with properties typed to register their compliance and handiness:

$$space_t = \{trace_i | \forall i\} \tag{3}$$

$$trace = \{(p, v)\} \text{ where}$$

$$p = \langle name : compliance \in \{valid, invalid\} \tag{4}$$

$$: handiness \in \{(type, group, role)\}\rangle$$

The compliance of a property may be typed as *valid* (or *invalid*) to express the fact that the given property is compliant (or not) with respect to the norms at hand. Various access rights may in addition be specified through the field *handiness*. The tuple $(type, group, role)$ for this field restricts the access of property p to agents of given type (*production*, *communication* or *coordination*), *group* and *role* in the system. Newly created traces are defined as not compliant with access restricted to local group $((Null, < idTable >, Null))$. We distinguish between three types of agents: *production*, *communication* and *coordination*. Communication agents ensure the communication between human and artificial actors that constitute the socio-technical system at hand: they ensure the follow-up of incoming events from the tangible surface and update the numerical trace accordingly; conversely, they exploit the numerical trace properties, depending on their compliance and handiness values, to build some virtual feedback for human actors. The role of production agents is to build an understanding of the moves at hand, accounting for the various constraints surrounding human and agent activity, and to enrich the trace properties accordingly. The coordination agents ensure the management of the norms under which human and artificial agents activity has to take place. Their role is more precisely to update the system of norms, to account for potential evolution of the state of activity and stage of collaboration. The agent space is expressed as follows:

$$space_a = \{prod_{ag_i}, comm_{ag_j}, coor_{ag_k} | \forall i, j, k\} \tag{5}$$

$$Ag = \langle id, (group, role)^+, behaviors, norms\rangle \tag{6}$$

with *id* a unique identifier, *role* the role of the agent in a specific *group* in the system, *behaviors* a list of concurrent agent abilities, *norms* the set of norms that the agent has to follow. Agents subscribe to norms, depending on their group, role, type, abilities and current context. We distinguish between three kinds of norms. Communication norms are dedicated to the formalization of human-to-human, human-to agent and agent-to-agent access rights. Production norms are dedicated to the formalization of domain- and task-dependent constraints. Coordination norms are dedicated to the formalization of the overall evolution of task requirements. The role of these norms is to launch the agents in a situated way, with respect to these constraints. The space of norms is expressed as follows:

$$space_n = \{prod_{N_i}, comm_{N_j}, coor_{N_k} | \forall i, j, k\} \tag{7}$$

$$N = \langle id, context, group, role, object\rangle \tag{8}$$

in which *context* represents an overall evaluation condition (current processing or activity stage, current system state or actors' situation), *role* represents the agent's role concerned by this norm and *object* is a complex field, typically written as $launch(conditions, actions)$ characterizing the conditional action attached to the norm (launching of agent behavior).

4 RISK APPLICATION

The purpose of this short example is to exemplify the expressiveness of the proposed approach and illustrates some of its coordination mechanisms. The system operates according to the following information flow: (1) Early detection of a tangible object move by communication norms operating at the infrastructure level: creation or update of the corresponding local trace, (2) Triggering of the coordination norms: update of the current set of norms (when necessary), (3) Triggering of the production norms: computation of further trace properties, (4) Triggering of the communication norms: providing feedback to local and distant human actors. When the game starts, a default norm policy is activated to handle the process associated with game initialization. The attacking state is reached as soon as the corresponding coordination tangiget is placed on a table. A designation tangiget may then be handled. A new norm policy must be applied to deal with this current state. A coordination norm, called $Norm_{attack}$, detects this context and

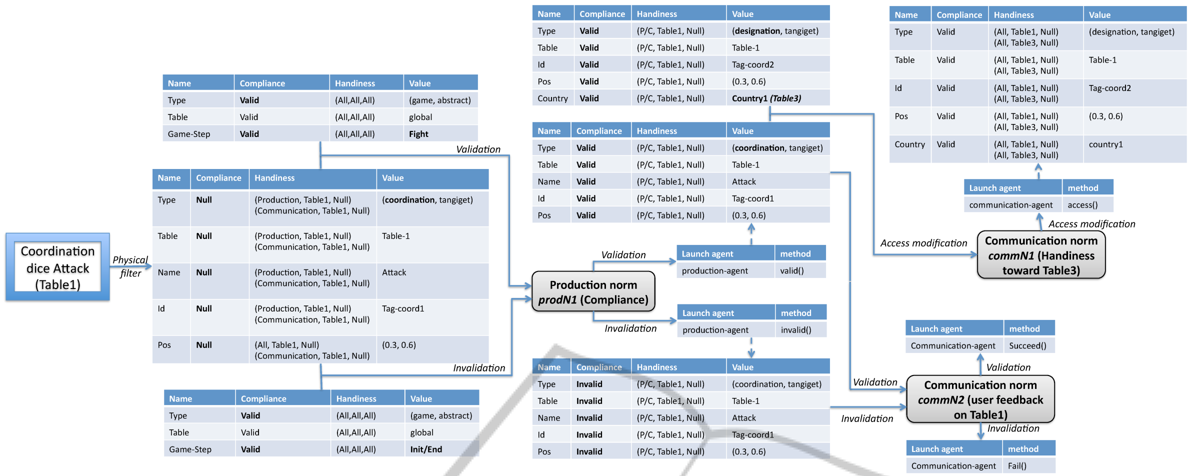

Figure 3: Compliance and Handiness process in a specific phase of the RISK game.

launches a coordination agent (role *synchro*) to update the norm policy for the attacking and attacked players:

$$Norm_{attack} =< id, [step = fight], synchro, launch(cond, manage_{normpolicy}) > \ with \tag{9}$$

$$\begin{aligned} cond = {} & [trace.type(?t1) = coordination] \\ & \wedge [trace.table(?t1) = ?tab1] \\ & \wedge [trace.name(?t1) = attack] \\ & \wedge [trace.type(?t2) = designation] \\ & \wedge [trace.table(?t2) = ?tab1] \\ & \wedge [trace.country(?t2) = ?c] \end{aligned} \tag{10}$$

At the end of an attack, each player rolls a dice to determine the winner and looser for this phase. A production norm, called $Norm_{dice\ result}$, ensures the follow-up of the dice roll results, the determination of the winner and loser and the launching of an agent (role $dice_{result}$), whose role will be to update the traces accordingly:

$$Norm_{dice\ result} =< id, [step = fight], dice_{result}, launch(cond, win) > \ with \tag{11}$$

$$\begin{aligned} cond = {} & [trace.type(?t1) = dice] \\ & \wedge [trace.value(?t1) = ?v1] \\ & \wedge [trace.table(?t1) = ?x] \\ & \wedge [trace.type(?t2) = dice] \\ & \wedge [trace.value(?t2) = ?v2] \\ & \wedge [trace.table(?t2) \neq ?x] \wedge [?v1 > ?v2] \end{aligned} \tag{12}$$

Figures 3 and 4 further depict the evolution of the trace depending on the mutual action of the agents and norms, for the attacking phase. Handling the coordination tangigets on $Table1$, and then designating an attacked territory belonging to $Table3$ modify the trace, thus triggering the successive management of its compliance and handiness properties, thanks to the production and communication norms $prodN1$ and $commN1$. This updating triggers a communication norm $commN2$, resulting in a virtual feedback to the local user operating on $Table1$. A new stage of the game must now be entered (fighting stage), which means that some norms have to be updated, for the attacking and attacked players on both $Table1$ and $Table3$. This process is divided in two steps, as illustrated by Figure 4. The first one is the modification of the global trace of the game (reachable by all agents) by a coordination agent working at the global group level. This coordination agent specifies the new norm policy in the field policy of the global trace. This agent is launched by the coordination norm $coordGlobal$. The second step is the norm modification for the attacked and attacking players, respectively on $Table1$ and $Table3$. This is performed by coordination norm $coordT1$ (resp. $coordT3$) whose role is to launch a coordination agent on the attacking and attacked tables ($Table1$ and $Table3$) to update the local norm policy as specified in the field policy of the global game trace.

5 CONCLUSIONS

In this paper, we presented a new architecture based on normative multiagent systems to support collaborative work over distant tangible surfaces. The purpose of our design, illustrated on a simple scenario from the RISK game, is to support the representation and sharing of the systems of norms that frame human collaboration. We have proposed to this end an architecture inspired from the CLOVER approach to groupware design, and involving production, com-

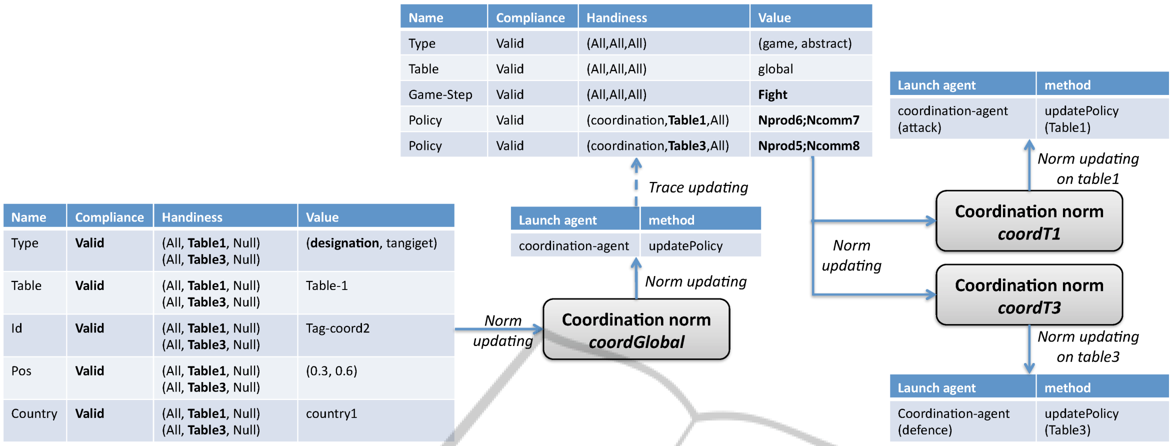

Figure 4: Norm dynamic in a specific phase of the RISK game.

munication and coordination agents. These agents are designed as sharing a common multidimensional trace reflecting human as well as artificial actors' activity. Their role, under control of dedicated norms, is to ensure the compliance, handiness and proper coordination of activity. These properties are reflected (i) in the numerical trace and (ii) over the physical surface by means of virtual display, to ensure mutual awareness between the human and artificial actors' worlds. Further work would involve considering more complex scenarios, i.e. more complex activities and human organizations styles.

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