NORMATIVE APPROACH FOR SOCIO-PHYSICAL COMPUTING
An Application to Distributed Tangible Interaction

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Abstract: We present a normative multi-agent design for computer-supported collaboration in the framework of socio-physical computing. An example application (RISK game) in the context of the *TangiSense* platform supports the proposed approach. Our work is driven under four complementary views: a systemic view, according to which various designing levels, from the physical infrastructure to the social level of human coordination are integrated in a single modelling, a normative view, in which consistency and coordination of action is ensured with respect to individual as well as collective systems of norms, a trace-based view, in which traces reflecting human activity and its compliance to the norms are registered and an agent-oriented view, according to which agents are meant to process, interpret and communicate information across distant tables.

1 INTRODUCTION

This research is conducted in the framework of a project (Lepreux et al., 2011), whose objective is the management of distant interactive surfaces supporting tangible and virtual objects. The TangiSense table (Figure 1) may be seen as a magnetic retina, which is able to detect and locate tangible objects equipped with RFID tags. RFID tag events are transmitted to the host PC and processed by the infrastructure layer. The first role of this layer is to filter potentially unstable tags IDs and positions. Its second role is to proceed to the aggregation of tag events and to maintain consistent representations of tangible objects. Each RFID antenna is further equipped with 4 multicolor light emitting diodes (LEDs). When lit, they may be considered as virtual objects displayed on the table. The role of these diodes is to "react" to tangible objects positioning and moves, assessing for the user their effective detection by the table. Human activity involves the handling of tangible objects. Communication between distant tables is managed via virtual objects displaying the status of the original tangible objects. Our goal is that human collaboration be mediated rather than assisted by computerized tools. Our guiding principle is to preserve the spontaneity of human action by designing ecological working environments (Thomas and Kellogg, 1989). Our work is driven under: (i) a systemic view, integrating in a single homogeneous modelling the physical infrastructure level as well as the higher level of human coordination; (ii) a normative view, in which various systems of norms are introduced to mediate human activity; (iii) a trace-based view, to record and transcribe human activity together with its compliance to this set of norms; and (iv) an agent-oriented view, according to which agents are meant to process, interpret and communicate information. Activity traces, which are generated by the handling of tangible objects, are made to evolve according to agent-based processing, but also under the systems of norms at hand. In accordance with the principles of activity theory, norms do not act as a prerequisite, or as a way to apply a priori constraints on action. Rather, they are meant to "situate" action, by modifying trace properties that will in turn regulate agent activity, and for example influence information or communication policies. The Risk game is used as an example application.

2 STATE OF THE ART

When designing collaborative support systems, a major issue is to preserve the spontaneity and fluidity of human activity while ensuring the consistency and proper coordination of action (Pape and Graham, 2010). The COIN (Coordination, Organization, Institutions and Norms in Agent Systems) community

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(http://www.pcs.usp.br/~coin/) introduces the notion of norm in a complex agent organization as a way to cope with the conceptual antagonism between autonomy and control; it further allows approaching coordination as a social paradigm. Behaviour in such organizations is not only guided by the agents mere objectives but also regulated by norms specifying which actions are considered as "legal" or not by the group. Norms are specified in a declarative way, they may be adopted or not by the agents, and adapted to cope with the evolution of context (Boella and Torre, 2006). In multi-agent systems, a multitude of agents interact, with some intended individual or collective purposes. Such a view usually assumes structures that articulate or restrain interactions in order to make them more effective in reaching those goals, trustworthy for participants or more predictable. One major issue is then to cope with the various interaction modes of agents belonging to the same organization, according to its structural and functional specifications: the organizational model of MOISE has been extended to this end (Boissier et al., 2011). The goal of such specification is to allow the organization to check that interaction modes are used appropriately and to allow the agents to reason on these interaction modes like they do with norms. A second major issue is how to maintain consistency, especially in contexts where human actors do not know each other, are communicating from distant places, and may display opposite or conflicting goals. Activity theory articulates within

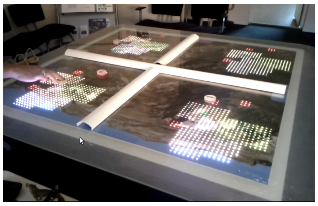

Figure 1: The TangiSense table: in this simulation, each of the four spaces is controlled by a separate PC.

a single dynamics the organizational and functional dimensions of human activity, with a further distinction between the notions of subject, object and tool. According to this theory, the tool supports and limits activity, it mediates its structure and objective, and carries the history of the relationship between the subject and the object (Bourguin et al., 2001). The object is seen and manipulated not "as such" but within the limitations set by the instrument. In turn, the tool is transformed and built along the activity and therefore keeps track of the user experience. Individual and group activity co-evolve in a context-dependent way, they are driven according to certain rules, norms and conventions; they depend on the actors roles and resources, as well as their organization. Dynamicity is core to activity theory, and any component, be it a tool, a goal, or a norm, are constantly changed, constructed, and transformed in relation to the activity outcome (Greenberg, 2001). As advocated by the proponents of situated action (Nardi, 1996), the object and motive of action reveal themselves only in the process of doing, since the involvement in action creates circumstances that could not be anticipated in advance.

A normative view is proposed to account for the specificities of socio-physical computing, that is to preserve the spontaneity and fluidity of human activity while ensuring the consistency and proper coordination of action. Human activity in the context of the proposed design involves the handling of physical, tangible objects that is performed under specific application-dependent rules. The distributed framework in which interaction takes place furthermore implies that human activity be registered and displayed for the distant human actor, in a way that is "situated" with respect to the interactive surfaces at hand. Virtual representatives of tangible objects are displayed to this end on distant tables. Tangible objects dedicated to coordination may further be introduced to ensure robust inter-table coordination. Activity traces have been proposed by several researchers as a way to represent, share and visualize human experience in the course of its interaction with numerical platforms (Djouad et al., 2010). Interaction traces have further been explored to enhance synchronous collaboration, and sharing traces at a group level has been advocated to support group awareness (Clauzel et al., 2011). In the same line, we propose to mediate human activity by tangible objects and to track this activity thanks to traces in the numerical environment. Beyond human activity, traces are further meant to reflect the activity of any computational entity in our system, be it event from the table, pattern of move from the infrastruture layer, semantic interpretation or compliance to a norm from the software layer. Any trace property may be subject to norm-dependent analysis. In line with our trace-oriented design, this analysis will result in signs deposited in the trace, enriching its content, and "situating" the activity with respect to the system of norms at hand. Compliance to a norm is processed in a way that is deeply dependent on the application domain and social organization at hand. The case of socio-physical computing suggests that norms be "carried" by tangible objects and express regulations concerning e.g. their patterns of move. Compliance to such norm would result in a feedback to the given tangible object (e.g. enlightenment of LEDs beneath its position), and therefore

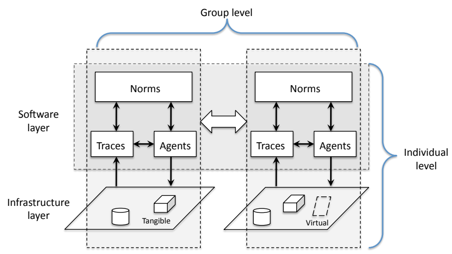

Figure 2: Functional view of the distributed architecture.

to the human actor responsible for the move. Distant collaboration across distributed interactive tables further suggests that any tangible object move be transmitted (provided it is norm compliant), for example by means of virtual displays on the distant surfaces. Privacy rules would on the contrary prohibit such display, for some objects, at some places, or at certain critical times of the collaborative work. Compliance to these norms therefore results in feedback transmitted or not to distant actors. Both local and distant feedbacks are performed by dedicated agents exploiting the tangible object traces together with their norm compliance properties.

3 PROPOSED ARCHITECTURE

We propose a layered architecture comprising two main separate layers, from the infrastructure layer to the software layer (Figure 2). The agents are designed under JADE (http://jade.tilab.com/). The software layer can be seen as integrating entities (filters, traces and agents) transparently operating over and communicating with any local or distant agent. Agents are activated via filters they have deposited in the normative space as norm instances. They operate upon traces under the mediation of these filters whose dynamics depend upon the agent social position, its compliance to the norms and its individual activity. Any trace is considered as a set of tuples $(property, value)$. We propose that each property be typed, to register its compliance to the norms. A trace is therefore expressed as $trace = \langle(p,v)\rangle$ with $p = name : consistency \in \{new, modified, valid, invalid\} : privacy \in \{private, public\}$. new and $modified$ mean that the corresponding property has been newly created or modified, which implies that compliance checking has to take place; $valid$ and $invalid$ express compliance to some application-dependent norm. $private$ means that the property is not accessible to other distant agents. Otherwise, the property is readable. Filters are in the form $(conditions, actions)$. The condition part specifies contextual patterns over trace properties. The action part may involve agent activation as well as trace modification. Three systems of norms are considered ruling privacy, consistency and coordination. Whereas the privacy policy defines the information shared between each distant player, the consistency policy checks information with respect to application rules. The coordination policy is a high-level policy regulating the activation of agents at a local or global scale. To reach this level of coordination, the trace properties of interest must be consistent and either private (local coordination) or public (global coordination). Privacy (resp. consistency) filters modify the privacy (resp. consistency) attribute of trace properties, specifying whether information is to be kept local or allowed to reach global level (resp. is valid or not). The action of filters is restricted to trace property modification. Contrarily, coordination filters do not operate any trace property modification. Rather, their role is to activate agents on a local or global scale. For this purpose, their condition parts involve the evaluation of both the consistency and privacy attributes of trace properties.

The Risk game is a turn-based strategy game for two to six players. The standard version is played on a board depicting a political map of the Earth, divided into forty-two territories. The player objective is to occupy a growing number of territories on the board, progressively eliminating other players, with results determined by dice rolls. A limited-scope scenario (identification of a new player) is used to illustrate the three proposed normative policies (Figure 3). We distinguish between 3 agents types : Gameplay Agent (*GA*) whose role is to manage the gameplay in its various phases, Interface Agent (*IA*) whose role is to display visual information on the interactive surfaces and Player Agent (*PA*) whose role is to maintain information about the player. When a player drops his identification card on the table, a low-level event is triggered which generates a tangible object trace t_{player}, in the local information space. At this time, all trace properties are initialized with extension types *new* and $private$. Since a new tangible player card has been detected, a verification process is triggered to check its compliance with the rules of the game. Two validation filters (f_{valid}, $f_{invalid}$) manage this process, under the example rule that 6 players at most may join the game ; the trace t_{game} keeps information about the current game. If successful, there is an update of t_{player} properties from *new* to $valid$. Thus, the filters f_{valid} and $f_{invalid}$ ensure that the local sub-system is consistent, by changing the value of the attribute $consistency$ for the trace properties. In our scenario, all tangible objects are equipped with tangible agents. For the player card, a player agent (*PA*) has to be initialized

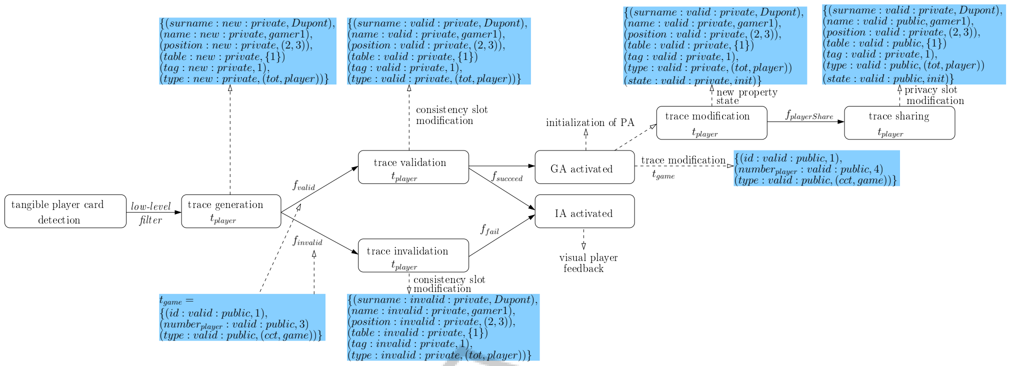

Figure 3: Evolution example of traces resulting from the flexible interleaving between agent processing and filter triggering.

if the trace is validated. After this validation process and the modification of the trace t_{player}, two filters are launched, $f_{succeed}$ and f_{fail}, whose role is to ensure local coordination, including display information. *GA* and *IA* agents are launched in case of success, with adequate parameters. *IA* provides a visual feedback to the player via the LED underneath the tangible object. The role of *GA* is to create a player agent *PA* associated to the player identifier card and to enrich the trace t_{player} by adding the property $state$ with the value *init*. The game trace t_{game} is further updated to keep track of the new number of players. In parallel to the consistency process, an information sharing process occurs. The filter $f_{player\ share}$ defines the privacy policy. Some parts of t_{player} have now to be shared, due to the basic rule that any new player must remain visible to other players. The condition to share information is that the trace is $valid$ and the agent state is *init*. When the filter is triggered, the associated action is the modification of t_{player} privacy properties. Following the specific rules of that game, distant *IA* agents are then launched by the filter $f_{player\ visual}$ in order that some virtual representative of the new player be displayed on distant interactive surfaces. New traces are generated each time a new tangible object is placed on the interactive surface. These traces evolve through the action of agents and filters, which result in new contextual pattern modifying the course of processing. Regulation of local as well as distant activities is transparently and smoothly integrated in this process.

4 CONCLUSIONS

We have proposed an original approach for normative systems in the framework of socio-physical computing. In this design, norms are meant to mediate human activity by providing signs of its compliance to the edicted rules. Norm compliance information may be processed and interpreted, possibly in different contexts, by different actors, providing a gain in flexibility and modularity. Human action in such design is mediated rather than constrained by norms which act in a productive, constructive way, by providing signs of their relationship to action, in agreement with activity theory.

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