Perceiving and interpreting human activity: a normative multi-agent system

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ABSTRACT
Introduction: We present an approach for the follow-up of human activity in the complementary settings of health monitoring and collaborative work. **Method**: Rather than aimed at providing an accurate and complete description of this activity, our system is aimed at framing the perception or interpretation processes according to various universes of discourse and evolving requirements: the one of the application domain, the one of the human acting or observing this activity, the one of the technical system at hand. We further promote a unified designing approach grounded in normative multi-agent systems theory. **Results and discussion:** We discuss the approach potential with respect to (i) human activity monitoring, (ii) support to tangible collaborative activity.

KEYWORDS
Human activity follow-up; normative multi-agent systems; monitoring; remote collaboration.

PROBLEMS AND ISSUES

We consider the follow-up of human activity, in two complementary contexts: monitoring and remote collaboration. Grounding on activity theory (Engestrom, 1991), we propose a *situated* approach that accounts for various perspectives and universes of discourse. Our goal is not to provide a single "most-likely" interpretation result, but rather to collaboratively maintain an interpretation path within the bounds of varied and evolving frames. This is implemented by means of normative agents constructing and framing interpretation under various constraints (Vettier, Amate & Garbay, 2012; Garbay, Badeig & Caelen, 2012). As regards monitoring, the purpose is to track the activity of a person equipped with ambulatory sensors and to check whether it conforms to existing scenarios and personalized models (Vettier et al., 2012). Context sensitivity, personalization and pro-activeness are core properties for monitoring systems, together with their compliance to social conventions (Aarts & de Ruyter, 2009). The analysis process must imply several levels of abstraction, involving the global level of norms, functional requirements and goals (Weber & Glynn, 2006). For (Greenberg, 2001), context must be seen as a dynamic construct evolving with time, episodes of use, internal goals, or social interaction. Following (Klein, Phillips, Rall & Peluso, 2006), we approach interpretation as "a process of fitting data into a frame that is continuously replaced and adapted to fit the data". Therefore, we model the understanding process as interleaving focus, perception, interpretation, context modeling and anticipation activities. These activities are framed by mutually evolving norms, which represent requirements of three categories: application, actor- and system-dependent. A major breakthrough in the field of CSCW is to preserve the spontaneity and fluidity of human action while ensuring its consistency and proper coordination (Pape & Graham, 2010). Mutual awareness is central in this respect. We consider the case of actors working around remote interactive surfaces with no communication means except the moves of tangible objects on these surfaces. In this context, we approach collaboration as a conversational process involving several signs of dialog and threads of activity (Kraut, Fussell & Siegel, 2003). We further consider coordination as a compromise between the handling of implicit communication norms and affordant objects (Sire & Chatty, 1998). Dedicated tangible objects, called *tangigets*, are introduced to produce additional signs and traces to sustain conversational activity. Beyond information sharing, perceiving the other's activity must further be approached through the constraints and rules that ground social organization (Erickson & Kellogg, 2003). Informed virtual feedbacks are provided so that mutual awareness be approached as the sharing of norms that frame human activity (Garbay et al., 2012).

PROPOSED DESIGNING APPROACH

We propose an original designing approach for human activity follow-up, that we characterize as distributed (agent-based), situated (trace-oriented) and normative. Distribution is motivated by the heterogeneity and simultaneity of information threads to be managed at various levels of abstraction. Normative MAS are a class of Multi-Agent Systems in which agent behaviour is not only guided by their mere individual objectives but also regulated by norms specifying in a declarative way which actions are considered as legal or not by the group

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(Castelfranchi, 2006). Agents acting in such system may be seen as “socially autonomous”. These norms are designed as condition-action rules; they are triggered by a dedicated engine and result in agent notifications (Boissier, Balbo & Badeig, 2010). Such design supports the separate modeling and exploitation of a variety of functional and non-functional requirements, from the application domain, singular actor/organization, or system at hand. The role of the norms is to express these requirements and frame agent’s processing accordingly. A norm has the following simplified expression: *N := <id, context, role, object>* in which *context* represents an overall evaluation condition, *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. The trace is a multidimensional component reflecting human/system activity and its conformance to the requirements at hand. We distinguish between production, communication and coordination agents; depending on their types, they are provided with autonomous decision-making abilities as regards the enrichment of the trace (production), the feedback to the actors (communication) and the modification of the set of norms which frame interpretation (coordination), thus providing the system with pro-active behavior.

HUMAN ACTIVITY MONITORING

The goal is to provide a personalized follow-up of human activity, based on physiology and actimetry data (heart and breath rate, movement…) acquired by ambulatory sensors. Production agents are designed to manage concurrent and uncertain hypotheses at various abstraction levels: their role is to enrich a dynamic hypothesis population keeping track of human activity, both by verifying current hypotheses and by producing new hypotheses (prediction), to cope with the evolving input data (Vettier et al., 2012). The verification process results in the computation of hypothesis confidence degree (*low*, *medium* or *high*), depending on thresholds that may be dynamically adjusted by dedicated norms. Prediction may be performed by generalization (from a low to a higher level hypothesis), or by anticipation (transition between hypotheses at the same abstraction level), based on semantic networks expressing the relationships between hypotheses. The interpretation process is framed by a set of high-level requirements of three types: Application-Dependent (assessing the “normality” of features or situations…), Actor-Dependent (accounting for personnal profiles, expectations of the monitoring institution as regards what is alarming or not…) and System-Dependent (assessing the effectiveness, efficiency and informativity of monitoring). In the example below, the *Anticipation* rule activates agents whose hypotheses appear less than likely, so that successor agents, predicting new hypotheses, are generated. Some parameters such as confidence thresholds and minimum durations are necessary; they can be subjected to adaptation from the coordination agents.

Norm-anticipation:= <id, always, All, launch(cond1+cond2, create-successors) >
  cond1 := [agent-confidence = medium/low]
  cond2 := [agent-timer(medium/low) > minimum-duration-anticipation]
Norm-termination:= <id, always, All, launch(cond3+cond4, delete) >
  cond3 := [agent-confidence = low]
  cond4 := [agent-timer(low) > minimum-duration-termination]

These requirements are prone to evolve, in case of activites with varying constraints, modifications of surveillance priorities, or to ensure increased sensitivity and accuracy when faced with critical situations. In this design, *alarms* (situations which do not fit the *frame*) are considered as incentives to adapt the interpretation process' *frame*. Such adaption is managed by the coordination agents, which are launched by norms in charge of detecting such patterns of evolution. Two coordination norm examples are provided below. The *Parsimony* norm is only evaluated in a non-alarming context : its goal is to remove the least relevant agents when there are too many unlikely hypotheses, thus improving efficiency. The *reduce-openness* function will change the *medium/low* and *minimum-duration* thresholds (thus impacting the termination norm). The *Informativeness* norm is triggered when there are no likely hypotheses (an alarming situation from a non-functional viewpoint) : the *force-anticipation* function will result in *framing* the Production rules so that all current agents *anticipate*.

Norm-Parsimony:= <id, [no-alarms], Probe, launch(number-of-agents > N, reduce-openness) >
Norm-Informativeness:= <id, [always], Probe, launch(n-HighConfidence = 0, force-anticipation) >

Figure 1 shows an example coordination behaviour implying various kinds of norms and agents. A coordination agent (Probe Agent) is also running to check for the presence of any disorder (some requirements are violated) and frame the system activity accordingly. The green, yellow and red lines in this figure represent the likelihood of the agent's hypotheses (high, medium, low). The vertical arrows show the triggering of norms. The *A* arrows represent regular *Anticipation* notifications (when the input data changes, the agents reflect it by generating new hypotheses). The *P* arrows mark that the Probe Agent is activated to analyse more closely the situation, which eventually results in its forcing a Framing change (*F* arrow) so that all agents *Anticipate*. The Input Norms regularly notify the agents to feed them input data (no arrows shown for the sake of clarity).

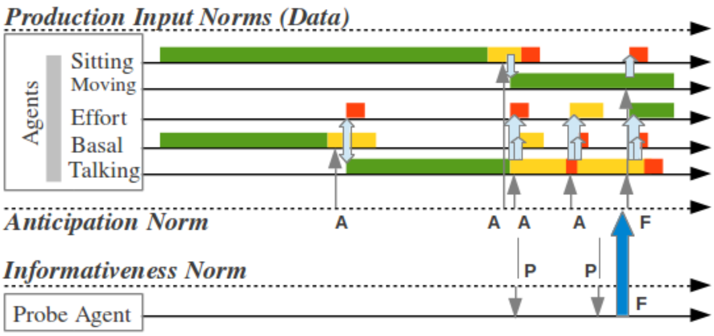

Figure 1. An example view of coordination behaviour for human activity monitoring.

COLLABORATIVE SUPPORT SYSTEM

The goal is to design a system ensuring smooth coordination between people working over remote interactive surfaces. The infrastructure, called *TangiSense* (Lepreux, Kubicki, Kolski & Caelen, 2011), makes use of RFID technology to locate/identify tagged tangible objects. Multicolor leds on top of each RFID antenna provide virtual feedback to local/remote users (assessing detection or conformity of tangible objects moves). No communication means is provided except the table and its tangible and virtual equipment. We discuss here an application to the RISK game, a strategic board game where players compete towards domination of the Earth. At start, each player is allocated an army and territories that his army occupies. An attack involves the designation of attacking and attacked territories and dice rolls to determine who is losing or winning this round. The proposed system involves production, communication and coordination agents communicating via multidimensional traces. Production agents ensure the follow-up of tangible object moves and perform application-dependent computations. Their activity is framed by norms of various kinds: application-dependent norms trigger production agents upon the detection of incoming moves; actor-dependent norms triggers higher-level production agents to follow events occuring over remote surfaces. We provide below an example of a norm ensuring the follow-up of two remote dice roll results, which results in the determination of a winner and loser and the launch of an agent whose role will be to update the traces accordingly.

Norm-dice-result:= <id, [step = fight], dice-result, launch(cond, win)>
cond := [trace.type(?t1) = dice] & [trace.value(?t1) = ?v1] & [trace.onTable(?t1) = ?x] & [trace.type(?t2) = dice] & [trace.value(?t2) = ?v2] & [trace.onTable(?t2) ≠ ?x] & [?v1 > ?v2]

The role of communication agents is to ensure the processing of events from the infrastructure layer and to provide informed virtual feedback (led display) to local/remote user. Their activity is framed by System-, Application- and Actor-dependent norms to regulate (i) the creation of traces (to keep track of events generated by object moves) and (ii) the launching of local/remote feedback agents (to provide informed follow-up of object moves, depending on conformity and privacy criteria). The role of coordination agents is to ensure the consistency of trace components (and therefore of overall activity) in a context where concurrent actions are performed by remote human and artificial actors. Updating the conformity and privacy fields of trace properties is of particular importance in this respect, since it results in modifying the trace local visibility and accessibility to remote actors. Application-dependent norms are used to this aim: they update the trace conformity and privacy, depending on the compliance of activity, to the task at hand, and to potential privacy tangiget moves. Coordination agents further ensure the adequacy of the set of norms in front of system-dependent, application-dependent or actor-dependent evolutions. Handling coordination tangigets is a way to indicate such evolutions. In the RISK game, a *stage* tangiget allows to follow gameplay evolution (e.g. from intialization to fight) and a *designation* tangiget to indicate the opponent area that the player wants to attack. We provide below an example of a coordination norm handling these coordination tangigets and launching a coordination agent whose role will be to modify the policy at hand by depositing the corresponding set of norms.

Norm-attack-policy:= <id, [step = fight], coordination, launch(cond, manage-norm-policy)>
cond:= := [trace.type(?t1) = coordination] & [trace.onTable(?t1) = ?tab1] & [trace.value(?t1) = "attack"] & [trace.type(?t2) = designation] & [trace.onTable(?t2) = ?tab1] & & [trace.value(?t2) = ?jd]

Inter-player coordination is finally ensured (i) by actor-dependent tangiget handling, (ii) by system-driven policies of action and (iii) by user-oriented visual feedback. This process (figure 2) is decomposed as follows: handling the coordination and designation tangigets modify the corresponding traces, which triggers the tangiget norm f1; this norm will launch AT1 on the attacking player local environment together with AT2 on the attacked player remote environment; it is then the role of AT1 and AT2 to deposit the policy they plan to follow for this new phase of the game, in the form respectively of communication norms f2 and f3 (these norms differ, depending on the table and player's role); the role of f2 is to launch AI2, so that information about the attack under preparation be provided to the remote player; upon reception of this feedback, player 2 reacts by handling his own coordination tangiget, thus acknowledging reception of this action; the role of f3 is now to launch AI1, to transmit player 2's acknowledgement of reception.

CONCLUSION

We have proposed in this paper an original architecture for advanced ambient intelligence system design. Our proposal allows for a clear separation between two universes of discourse, that of the data, and that of the requirements (be it application-dependent, actor-dependent or system-dependent). It further ensures the proper coupling of these evolving universes, by means of situation-dependent evolving frames that act in turn to frame the perception and interpretation processes. We have considered two complementary applications, highlighting the unfolding of interpretation/collaboration processes. Following activity theory, framing processes do not act as a prerequisite to action. Rather, they allow to situate activity within a variety of socio-technical stances and operate as incentives to the process unfolding.

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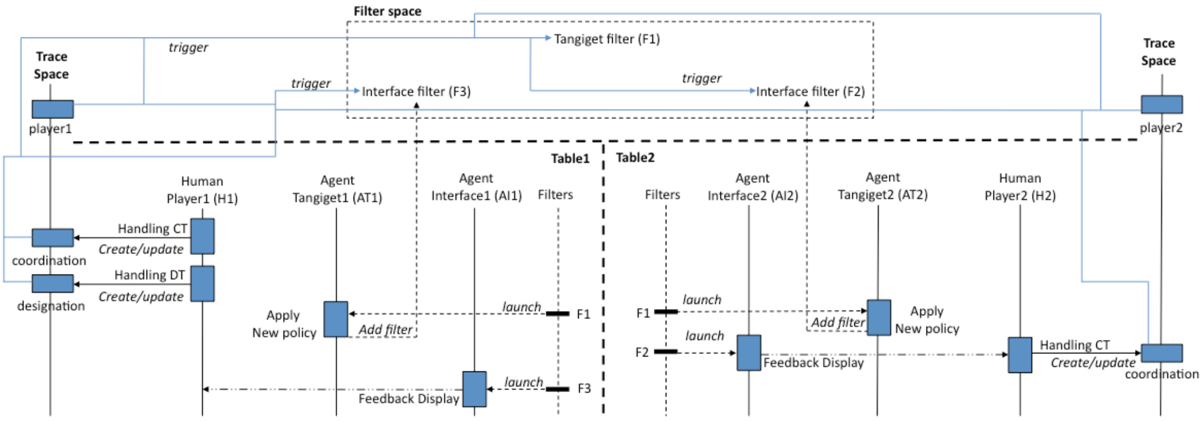

Figure 2. Inter-player coordination in the RISK game: the interleaving between tangiget, norms and agent handling may be observed in this short example.

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