Integrating Objective & Subjective Coordination in FIPA: A Roadmap to TuCSoN

Andrea Omicini Alessandro Ricci
Giovanni Rimassa Mirko Viroli

***Abstract*— Subjective and Objective coordination can be integrated and exploited fruitfully in the same context. In this paper we investigate such integration in the context of FIPA agents, aiming at exploiting the coordination services provided by TuCSoN coordination infrastructure.**

I. THE BABEL'S TOWER OF COORDINATION

Research on coordination possibly represents the most un-coordinated activity in the history of computer science. Roughly speaking, coordination research has developed along two basically separated lines in the DAI and SE field, respectively. In the former, coordination was interpreted as an individual, psychological activity, performed by a component (typically, an agent of a multi-agent system – MAS henceforth) trying to achieve its own subjective goals in the context of a multi-component system. In the latter, coordination was basically regarded as normative activity performed by some part of a multi-component system on behalf of the system's designer – typically, by a coordination medium provided by an infrastructure. With respect to components, two different views were adopted on coordination: the first, where components are the *coordinating* entities, the second where components are the *coordinated* entities.

Not surprisingly, the first approach seems to better suit systems whose components exhibit a high degree of autonomy (intelligent agents being the most obvious example), whereas the second fits well application scenarios involving a finer component granularity (as typical in the case of mobile agents). Dually, scientific confusion was not the only problem produced by these divergent efforts. The SE approach (see for instance MANIFOLD [2]) often disregarded any capability of the components in terms of autonomy or deliberation – not to speak of component intelligence. On the other hand, the DAI approach has struggled with intra-agent issues for several years – so that inter-agent issues, like infrastructural ones, which are mandatory for applicability to real-world scenarios, are still far from a satisfactory solution (see current efforts in FIPA [7], [9], [10]).

Seemingly, the two approaches provide two complimentary views over coordination: strangely enough, this apparently obvious statement took its time to be shared by the different communities working on coordination. The first successful attempt to put the two things altogether was made by Schumacher: in [24], the notions of *subjective* and *objective* coordination were introduced, and used to classify the research on coordination. In the context of MAS, subjective and objective coordination were defined as coordination *inside* and *outside* the agents, respectively – thus accounting for the psychological vs. normative acceptations of coordination recalled above. A step beyond was then the recognition that any non-trivial multi-component system cannot but rely on the fruitful exploitation of both approaches. Along this line, in [22] Activity Theory was proposed as a unitary and coherent conceptual framework for both coordination approaches, whereas [19] advocated that both play a fundamental role in the engineering of MAS, and that any methodology for the design and development of MAS should necessarily exploit both objective and subjective coordination models and technologies.

The distinction between the two approaches was finally recognised essentially as a *methodological* one: the key point is then not which approach is the best one, but rather when they have to be used in the modelling and engineering of complex systems (say MAS), and how they could be used altogether effectively. It does not come by surprise, then, that the frameworks that better reconcile the two lines are organisational ones – like Activity Theory. In fact, a main concern for organisations is typically how to make individual (psychological) and social (normative) aspects fruitfully coexist. A social norm, there, can be either imposed or accepted, and also interiorised by agents of the organisation – that can then perform their activity (either intelligent or not) according to their nature and goals.

However, to reconcile the two models is not enough. The conceptual divergence has led to a technology / infrastructure legacy that should be now somehow re-composed. For instance, the TuCSoN agent (objective) coordination infrastructure [21] and the JADE FIPA-compliant framework [11] are in some sense effective and powerful solutions to complimentary class of problems – however, it is not easy at all to devise out how to make them live and work together in an effective way. As a result, any attempt to put objective and subjective coordination altogether should not only aim at providing a uniform conceptual framework, but also at suitably integrating technologies and infrastructures. While some steps in the right direction have already been done (as in the case of the notion of agent coordination context, implemented in TuCSoN [20], or conversations in FIPA [7]), in this paper we try to devise out a possible roadmap towards a possible convergence, by taking TuCSoN and FIPA as our references.

So, in this paper we first frame objective and subjective co-

A. Omicini, A. Ricci, and M. Viroli are affiliated with DEIS, Università degli Studi di Bologna, via Rasi e Spinelli 176, 47023 Cesena (FC), Italy – email: aomicini@deis.unibo.it, aricci@deis.unibo.it,mviroli@deis.unibo.it. G. Rimassa is affiliated with AOT Lab, DII, Università degli Studi di Parma, Parco Area delle Scienze, 181A, 43100 Parma, Italy, and with FRAMeTech s.r.l, Via S. Leonardo, 1 – 43100 Parma, Italy – email: rimassa@ce.unipr.it

ordination in the same conceptual framework supported by Activity Theory, then we apply the framework in the context of FIPA. We outline an integration between coordination artifacts and the FIPA standard, and define a roadmap for achieving agent semantic interoperability through coordination artifacts and the BDI model, extending current applications of FIPA ACL [4]. Finally we investigate a possible roadmap for integrating FIPA agent model and TuCSoN (objective) coordination model/infrastructure.

II. Framing Coordination within Activity Theory

Activity Theory (AT henceforth) can be used as a suitable conceptual framework to conceive subjective and objective approaches and their relationships in the same context [22]. AT is a social psychological theory about the developmental transformation and dynamics in collective human work activity [27], [13], [3]; recently, it has been introduced in some fields of computer science – in particular in CSCW [12] and computer system design [15].

AT focuses on human *activities*, distinguished by their respective (physical and ideal) *objects*, that give them their specific directions, i.e. the *objectives* of the activities. Cooperation is understood as a *collaborative activity*, with one objective, but distributed onto several actors, each performing *actions* accordingly to the shared objective. Explicit norms and rules regulate the relationships among individual participants' work. Central to AT is the notion of *mediated interaction*: any complex social activity is found to be always mediated by *artifacts*, both physical and psychological, such as operating procedures, heuristics, scripts, individual and collective experiences, and languages. When artifacts are meant to be shared and exploited by a collectivity (society) of actors – in order to, for instance, fulfill some social task, or to access some contexts with social norms – we refer to them as *coordination artifacts*. This is the typical case of collaboration activities.

Following AT and the framework provided in [22] three hierarchical levels for analysing every collaborative activity in MAS can be identified, working with coordination artifacts: *co-ordination*, *co-operation* and *co-construction* (see Fig. 1):

- *co-ordinated* aspect of work captures the normal and routine flow of interaction. Participants follow their roles, each focusing on the successful performance of their actions, implicitly or explicitly assigned to them; they share and act upon a common object, but their individual actions are only externally related to each other. Artifacts coordinating participants' actions are not questioned or discussed, neither known/understood in all their complexity: in this stage actors act as "wheels in the organisational machinery" [12], and co-ordination artifacts ensure that an activity is working in harmony with surrounding activities.
- *co-operative* aspect of work concerns the mode of interactions in which actors focus on a common object and thus share the objective of the activity; unlike previous case, actors do not have actions or roles explicitly assigned to them: with regard to the common object, each actor has to balance his/her own actions with other agent actions, possibly influencing them to achieve the common task.

  So, at the co-operative level, agents – once established the objectives of the social task – define cooperatively, typically by means of negotiation, the structure and behaviour of the coordination artifacts to be shared and exploited at the co-ordination level;
- *co-constructive* aspect of work concerns interactions in which actors focus on re-conceptualising their own organisation and interaction in relation to their shared objects. Neither the object of work, nor the coordination artifacts are stable, and must be collectively constructed, i.e. *co-constructed*. So, basically at the co-construction level, agents establish the shared objective characterising the social task.

In the analysis of collaborative activities, AT emphasises that an activity cannot be said to exist at one level only: co-ordination, co-operation, and co-construction are *analytical* distinctions of the same collaborative activity, and concur in different times and modes to its development. Consequently, the notion of dynamic transformation between the hierarchical levels is crucial: transformation from co-ordination to co-operation / co-construction happen when the coordinated flow of work relying on coordination artifacts needs to be cooperatively re-established and the behaviour of the artifact inspected for possible changes; the reasons can be either co-ordination breakdown, or a deliberate re-conceptualisation of the way the work is achieved currently. Transformation from co-operation to co-ordination works in the opposite direction: once re-established the co-ordinated work, artifact behaviour is changed accordingly and provided again to participants in order to be exploited for the co-ordination stage.

Given this framework, it is easy to understand that objective and subjective approaches can be exploited in the same coordination context, but at different conceptual and operational levels: in particular subjective approaches can be used for co-construction and co-operation level, and objective at the co-ordination level. In the first case, agents exploit their high level capability (reasoning and communication) to reason about what kind of coordination is required, what kind of coordination laws must be developed to manage interactions identified in co-construction stage. Instead objective approaches can be used in co-ordination stage, where the coordination laws and organisational rules must be enacted in the most automated, fluid, optimised manner through the exploitation of the coordination artifacts.

The FIPA approach – which is fundamentally subjective – basically adopts disembodied coordination artifacts, such as the ACL itself and the shared ontologies. However, also in the FIPA context – and, more generally, in the ACL community – the need of stronger infrastructure support to coordination has emerged recently [7]: interaction protocols, conversations [7], social contracts [9] are examples of more involved coordination artifacts which are currently studied for the purpose.

It's worth noting that, as remarked in the context of CSCW, the embodied and disembodied characterisation of an artifact has a deep impact on the complexity and quality of the coordination activities which can be supported [1], [23]: experiences in the context of coordination in complex societies revealed that disembodied artifacts – typically based on language pro-

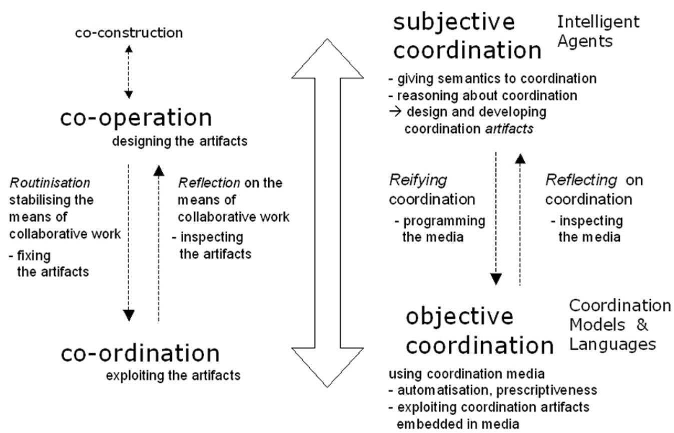

Fig. 1. Dynamics between Objective and Subjective Coordination

tocols – becomes inadequate as a means of coordination in high complexity cooperative work, since they generate a very high coordination workload; conversely, these studies highlight the benefits coming from using suitably engineered embodied artifacts (even if the transformation of coordination work from the medium of disembodied artifacts to embodied ones in neither trivial, nor well understood [1]).

III. Artifacts in FIPA

Our aim is to explore the integration of objective and subjective coordination in the context of the FIPA model, both at a conceptual and a technological level. This means modelling and engineering the coordination services typically provided by objective approaches in a world of agents using FIPA ACL and related ontologies to interact and coordinate subjectively, and BDI as a logic framework to represent the environment and the society. Our target scenario consists then in FIPA agents that can dynamically find and use coordination artifacts provided by the infrastructure as a service to capture / automate / make fluid the coordination with other agents – which could be also non FIPA agents – involved in the same social activities, in the same organisational context.

The main difficulty that arises in this integration is that FIPA standard currently does not conceive communications between agents and other abstractions, provided that the latter are not wrapped by agents – that is, are agentified themselves. More generally, current FIPA model does not properly take into account the relationships and interaction between agents and the (physical and logical) environment, and investigations and proposals are under development in order to overcome this limitation [16]. As claimed e.g. in [22], engineering methodologies may fall short to be effective when handling coordination artifacts as if they were agents. Rather, we find more useful and conceptually clean to realise this integration by modelling coordination artifacts as resources that FIPA agents can access and use by means of *physical acts*. As conceived by the FIPA model, in this case the coordination artifact is not thought of as a medium enabling and ruling agent communication acts – as usually happens for coordination media in objective coordination approaches –, but as a medium enabling and ruling physical acts executed by the agents that share it. We are at the root of the concept of mediated interaction, which does not necessarily involve communication, but the *structural coupling* of an entities and an interaction medium [14].

Following the AT framework, it is possible to identify immediately two types of relationships linking agents and artifacts:

- agents as users of the artifacts; this includes the physical acts that can be used by agents to access and exploit the coordination service, according to protocols established for their role inside the society and the organisational rules;
- agents as creators / administrators of the artifacts: this includes the physical acts that can be used by agents to inspect / change / adapt dynamically, at runtime, the coordination laws and social norms which define the behaviour of the coordination artifacts. Typically the coordination laws and norms are expressed in some specific language, which depends on the coordination model adopted, which must be suitably modelled in the FIPA context.

The first relationship typically concerns agents involved in the co-ordination stage of the collaborative activity, while the last typically concerns agents involved in the co-operation stage.

A key role for this integration is played by the notion of *agent coordination context* (ACC henceforth), studied in its general setting in [17] and applied in the extension of the TuCSoN infrastructure in [20]. An ACC is an abstraction *(i)* meant to be provided to agents by the supporting infrastructure, *(ii)* to be negotiated by agents when entering a given society of resources, and *(iii)* ruling all the interactions between the agent and its environment. In the context analysed in this paper, an ACC defines and constraints the space of (physical) acts that a FIPA agents can execute on coordination artifacts, according to its role inside the society. So, a third aspect to explicitly model in the integration is the description of an ACC and the actions and ontology available to a FIPA agent in order to *(i)* inspect and know the ACCs available for agents within an organisation, and *(ii)* negotiate the entrance of the agent in an agent coordination context with a specific configuration.

IV. Semantic Interoperability: A Roadmap

The FIPA ACL is equipped with a formal semantics by which agents can exchange messages mutually understanding each other, sharing meaningful knowledge and cooperating for the achievement of social goals – supporting the so-called *semantic interoperability* [4]. This not only involves understanding the content of messages exchanged, which is typically tackled by domain ontologies, but also knowing the expected cause and effect of utterances, so that automatic reasoning can enable agents to achieve their goals in cooperation. This ACL semantics considers agents assuming the so-called *intentional stance* [8]: an agent is interpreted as an entity with beliefs, desires, and intentions (and in general, any other meaningful mentalistic property), and acting rationally with respect to its goals.[1] In particular, according to the *speech-act theory*, a performative is attached to each message – such as *inform*, *request*,

[1] It worth noting that conceptually this interpretation is independent of the actual agent architecture. However, it is reasonable to argue against the usefulness and pragmatics of this stance for those agents that do not have any actual inter-

not-understood – that characterises the intended meaning of the message content. So, in order to avoid ambiguity and effectively support interoperability, these performatives are given a formal semantics in terms of feasibility preconditions (FP) and rational effects (RE) expressed as mentalistic properties (beliefs and intentions): FP must hold in the sender and can be assumed by the receiver, RE must be intended by the sender and the receiver should believe such intentions. As discussed in [4], [5] this mechanism can be exploited by agents built over the BDI model to subjectively coordinate their behaviour, e.g. to decide to participate in those conversations that the agents believe could help bringing about their goals.

A. An example

It worth here considering a simple example of ACL semantics resembling the FIPA (and KQML) approach. In the following, $\phi \in \Phi$ stands for any predicative formula, a for an actions, s for the identifier of an agent sending a message, r for the receiver, $B_j\phi$ for "entity j believes ϕ", $I_j\phi$ for "entity j intends ϕ", and $done(a)$ for "action a has just happened". The message $inform(s,r,\phi)$ – sender s informs receiver r that he believes ϕ – has the precondition $B_s\phi$, namely, the sender must believe ϕ in order to send message ($B_s\phi$), and when the receiver gets the message he can believe that the sender believes ϕ ($B_rB_s\phi$). Dually, the message $request(s,r,a)$ – sender s requests r to execute action a – has the rational effect $done(a)$, that is, the sender should intend a to be executed $I_s done(a)$ and the receiver may believe such an intention $B_rI_s done(a)$. This kind of formal approach enables semantic interoperability. In particular, we consider the case that the agent i receives from another agent j a message a of the kind $\textit{request}(j,i,b)$ where $b = \textit{inform}(i,j,\phi)$ – j requests i to send a message declaring that he believes ϕ. When i reaches the message a, he will believe $I_j done(b)$, hence its mental state will include the formula $B_iI_j done(b)$. If i is programmed so as to be willing to cooperate with j, then from $B_iI_j done(b)$ i's mental state will be updated so as to include $I_i done(b)$ – e.g., by a so-called *interaction law* [4]. If i actually believes ϕ, then such an intention will make i actually inform j that he believes ϕ.

B. An Extension Towards ACCs

It is of no surprise that a main goal of our research in this field is to extend this model considering the new framework where agents coordinate one to another by means of coordination artifacts and under the control of an ACC, thus integrating the objective and subjective viewpoints over coordination. The notion of ACC can be exploited as a means to decouple these two viewpoints. The ACC notion has been introduced to regulate the actions (and perceptions) allowed by an agent. As a feature, the ACC can also be inspected by an agent [20], which may be interested in information such as the actions currently allowed, or how an ACC rule is affected by the execution of an allowed action. Indeed, inspectability is a very crucial aspect, because it allows agents of an open environment to dynamically get information on their environment and reason about them. This characterization can be naturally extended to the case of semantic interoperability: an agent may inspect an ACC not only to know the allowed actions, but also to get information about their semantics – most likely represented by FP and RE expressed in terms of the agent mentalistic properties as described above. It worth noting that information on such semantics should not necessarily reside within the ACC, rather, the ACC may be in charge of retrieving them from other abstractions provided by the infrastructure. Most notably, the ACC may query the coordination artifacts about the semantics of the services they provide. Notice that this schema does not prevent an agent from already possessing information on the semantics of actions – either because they are hard coded in its program or because they are specified by the domain ontology. So, in general, querying the ACC can be considered as a further mechanism to deal with opennes and to support dynamic adaptability. In this framework, the subjective viewpoint of coordination naturally amounts to *(i)* the agent negotiating an ACC with the supporting infrastructures, and *(ii)* the agent inspecting the ACC in order to know the semantics of allowed actions. Then, as for the FIPA ACL approach, such semantics can be exploited by the agent to schedule the sequence of actions that may better allow the agent to achieve its goals. On the other hand, the objective viewpoint of coordination, instead, concerns *(i)* the policy by which an infrastructure handles the negotiation of ACCs with agents – including handling higher-order concepts such as authentication, resource control, and roles – and *(ii)* the definition of the actions (along with their semantics) that an ACC should allow based on the coordination artifacts that the agent needs to access. This basic organisation has an impact also on the methodology we intend to follow in order to reach the integration: key subjective and objective coordination aspects can be studied, analysed and developed in isolation, with the ACC being the conceptual locus where they come together and realise semantic interoperability. In particular, issues about subjective coordination – such as representation of preconditions and effects, and their integration with domain ontologies – can be studied considering very simple, trivial coordination artifacts (e.g.: simple communication channels), thus directly extending the standard FIPA ACL approach. Conversely, issues about objective coordination – namely, representing actions and their semantics given the rules implemented by the coordination artifacts – can be studied separately as a problem of devising an ACC behaviour given the coordination artifacts and their access policy.

V. Toward TuCSoN Coordination Services in FIPA

Most notably, this approach can be applied to investigate the use of TuCSoN [20] coordination services – which support the ACC notion and feature ReSpecT tuple centres as coordination artifacts [18] – within a FIPA-compliant context.

TuCSoN is an infrastructure providing services for the specification and enactment of coordination in multiagent systems (MAS) [21], according to the *coordination as a service* approach [26]. Coordination services are embodied in *tuple centres*, that are design / runtime coordination abstractions provided to agents by the infrastructure in order to enable and gov-

nal representation of mentalistic properties [25], e.g. when they do no adhere to the standard BDI model [6] or some variation of it.

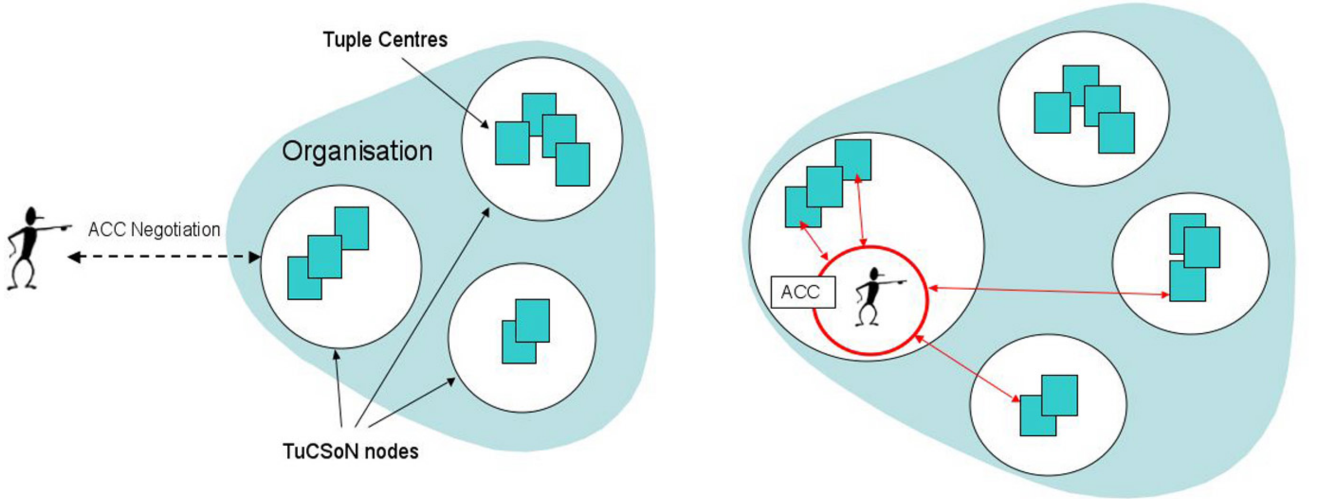

Fig. 2. ACC negotiation (left) and entrance / use (right) in TuCSoN

ern their interaction [18]. More precisely, tuple centres are *programmable* tuple spaces [18], that is, sort of reactive logic based blackboards; agents interact by writing, reading, and consuming *tuples* – ordered collections of heterogeneous information chunks – to/from tuple centres via simple communication operations (*out*, *rd*, *in*) which access tuples associatively. While the behaviour a tuple space in response to communication events is fixed and pre-defined by the model, the behaviour of a tuple centre can be tailored to the application needs by defining a suitable set of *specification tuples*, which define how a tuple centre should react to incoming/outgoing communication events. Then, tuple centres can be seen as general-purpose customisable coordination artifacts, whose behaviour can be dynamically specified, forged and adapted so as to automate the co-ordination stage among agents using such artifacts [22].

From the topology point of view, tuple centres are collected in TuCSoN nodes, spread over the network and belonging to soecific organisations. Here we come to the use in TuCSoN of the agent coordination context abstraction: in order to access and use tuple centres of an organisation context, an agent must negotiate and enter an ACC, which is used to define its presence / position inside the organisation in terms of allowed actions on the available artifacts. Fig. 2 shows these basic stages: first an agent negotiate the configuration of the ACC with proper service provided by the TuCSoN infrastructure (here called welcome service), specifying the society and the role which it aims at playing[2]; then, if the agent request is satisfiable according to the organisation rules defined by the specific organisation context, an ACC with the specific configuration is created and entered logically by the agent.

How all this can be conceived in a FIPA context? In the following we sketch the same stages in the case in which a FIPA agent joins a TuCSoN organisation and participates to its coordination activities through tuple centres.

[2]society, role, organisation are abstractions defined by the TuCSoN organisation model

A. Negotiating an ACC

The first step to consider is the ACC negotiation. For the purpose, one or more FIPA agents can can play the role of TuCSoN welcome service, with the responsibility to receive agent requests to enter in a specific TuCSoN organisation context and negotiate the ACCs (see Fig. 3, left picture). For simplicity, here we can think to model the agents request by means of the FIPA communicative act `request` of performing an action, that is create a properly configured ACC according to the specified role and then to let the requesting agent enter and exploit it. A proper FIPA ontology – called here `TuCSoN-ACC-Management` – can be used to store the definition and sematics of basic protocol(s) that characterise ACC negotiation. PCL (Prolog Content Language) can be chosen as the content language, perfectly suiting the logic nature of TuCSoN communication language and of the ReSpecT specification.

As an example, let's call the FIPA welcome agent `tucson_welcome_service`, and let's say that the agent `sensorXYZ` wants to join the society `health_monitoring` actually defined in the organisation context the TuCSoN node `deis.unibo.it`, in the role of `temperature_sensor`[3]. Then, a possible sketch of the request could be:

```
(request
    :sender (agent-identifier :name sensorXYZ)
    :receiver (set (agent-identifier
            :name tucson_welcome_service))
    :ontology tucson-ontology
    :language PCL
        :protocol ACC-Negotiation
        :content
            (action
                'agent-identifier' (name: 'sensorXYZ'),
                enterACC(society(health_monitoring),
                            role(temperature_sensor)))))
```

If the negotiation is successful, the FIPA agent enters its new ACC properly configured, and can then interact with other agents by means of the tuple centres provided by the organisation.

[3]Here we follow the convention established for the Prolog Content Language for specifying actions

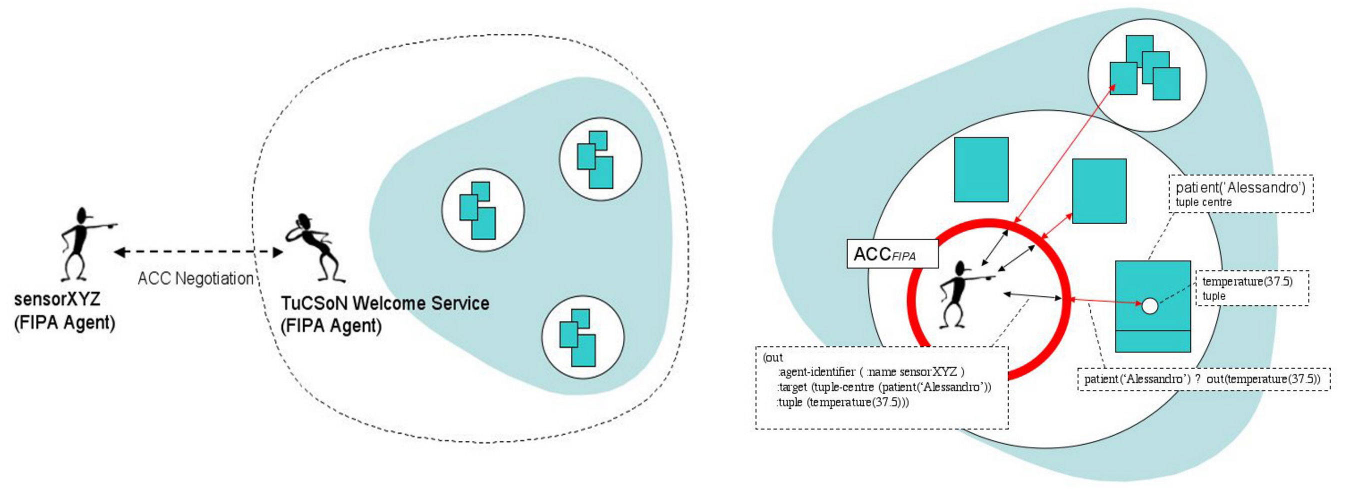

Fig. 3. FIPA Agent negotiating an ACC (left) and FIPA Agent using a tuple centre (right) in TuCSoN

B. Exploiting tuple centres

Once entered in its ACC, the agent can execute the coordination primitives to (inter)act (with)on tuple centres. In the case of a FIPA Agent, the ACC would provide these actions as physical acts (see Fig. 3, right picture). As previously, a proper specific ontology – called here `TuCSoN-ACC-Use` – could be used to define the syntax and semantics of the physical acts.

As an example, let's suppose that the agent `sensorXYZ` – in the role of temperature sensor of the agent society involved in the health care of a patient – wants to insert a tuple containing current temperature value in the tuple centre `patient('Alessandro')`. Then, a possible way to conceive this coordination primitive invocation as physical act could be:

```
(out
    :agent (agent-identifier :name sensorXYZ)
    :target (tuple-centre( patient('Alessandro') ))
    :ontology TuCSoN-ACC-Use
    :language PCL
    :content (temperature(37.5)))
```

So, analogously to speech acts we aim at specifying directly the physical act representing the coordination primitive, and the related information concerning target tuple centre, the agent issuing the action and the tuple content of the action, in the Prolog language. The action could fail, in the case that it does not belong to the set of the actions allowed by the agent ACC. At the semantic level, the constraints on allowed actions can be used to specify the feasibility precondition of the acts, that is the feasible precondition of a specific coordination primitive invocation is that the action is allowed by the ACC. The rational effects of the act obviously depend on the specific coordination primitive executed: in the example the rational effect is the creation of a new belief for the agent `sensorXYZ` about the existence of the tuple `temperature(37.5)` in the tuple centre `patient('Alessandro')` sometime in the past, between agent act performance and the current time.

For coordination primitives that retrieve tuples from a tuple centre (such as the `in` and `rd`), the structural coupling model applies: the related physical acts structurally modify in one shot both the coordination medium enabling / target of the act and the agent itself, in particular its believes. For instance, let's considering an agent in the role of doctor assistant – let's call it `healthControllerXYZ` –, aiming at retrieving last temperature measurement of a patient:

```
(in
    :agent (agent-identifier :name healthControllerXYZ )
    :target (tuple-centre( patient('Alessandro') ))
    :ontology TuCSoN-ACC-Use
    :content (temperature(X)))
```

The rational effect of this act is the new belief for the agent `healthControllerXYZ` about the past existence of tuple `temperature(X)` with `X` possibly bound to some value in the tuple centre `patient('Alessandro')`, sometime before agent's act.

C. Inspecting and programming tuple centres

As discussed in Section III, the second class of actions enabled by an ACC concerns the (dynamic) inspection and modification / adaptation of coordination artifacts. Accordingly, in TuCSoN the coordination primitives `get_spec` and `set_spec` can be used respectively to get and set the behaviour specification of a tuple centre, as multiset of logic tuples expressed in the ReSpecT language. As the previous case, these coordination primitives can be modelled as specific physical acts, and the PCL can be used to represent the ReSpecT specification. For instance:

```
(set_spec
    :agent (agent identifier :name healthController)
    :target (tuple-centre(patient('Alessandro') ))
    :ontology TuCSoN-ACC-Use
    :language PCL
    :content (
        reaction(out(temperature(T)),(
             rd_r(pressure(P)),
             in_r(product(Old)), out_r(product(P*T)))),
        reaction(out(pressure(P)),(
             rd_r(temperature(T)),
             in_r(product(Old)),out_r(product(P*T))))).
```

In this case, tuple centre `patient('Alessandro')` is programmed (or rather the coordination artifact is forged) to keep track *consistently* of the product of the temperature and the pressure, as their value is manifested by the insertion of the proper tuples. The purpose of this coordination law could be, for instance, the need to monitor the occurrence of the composite logic event concerning the overflow of the product of the temperature and pressure of some threadsold[4].

In a similar way, a physical act could be used to inspect tuple centre behaviour:

```
(get_spec
    :agent (agent identifier :name healthController)
    :target (tuple-centre(patient('Alessandro') ))
    :ontology TuCSoN-ACC-Use
    :language PCL
    :content (Spec))
```

The rational effect of this act is the new belief for the agent `healthControllerXYZ` about the behaviour specification of the tuple centre `patient('Alessandro')` – represented by the logic tuples referred by `Spec` variable, at the moment of the act execution.

VI. Conclusions and Future Work

In this work we recalled the basic motivations for exploiting subjective and objective coordination in the same engineering context, and then we presented the basic intuitions for conceiving such integration in the case of FIPA agent model (as subjective approach) and TuCSoN coordination model/infrastructure (as objective approach).

Lots of exiting work still remains to do. The following lines seems of particular interest, and will be subject of further research:

- extending the mechanism by which ACCs can be inspected in TuCSoN as to incorporate the notion of semantics to an action
- defining the FIPA ontology for ACC negotiation and coordination artifacts use/manipulation. In particular, defining formally the model / language for expressing the TuCSoN coordination primitives as physical actions – classified in the two basic categories – and the formal semantics, in terms of FP and RE of each physical act. We can use the Prolog Content Language, already available in the FIPA context, as content language for expressing logic tuples involved in coordination primitives execution, both for expressing tuple inserted and retrieved in tuple centre and the ReSpecT behaviour specification
- experimenting in practice the integration with the available technology, i.e. the JADE FIPA compliant platform and TuCSoN technology.

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