

Activity Theory as a Framework for MAS Coordination



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Outline

- Problem: Objective vs Subjective Coordination in MAS
 - Dualism (*the wall*) and on the need of a reconciliation (*breaking the wall*)
 - Challenges from state-of-the-art coordination systems
- An answer: Activity Theory as a Foundation Framework
 - Reconciling the approaches
 - Artifacts and Coordination Media
- Benefits
 - Engineering Impact and Coordination Scaling
- Future Works

The Wall

- Coordination
 - as a fundamental dimension for MAS engineering
 - along with *organisation*, which is strictly related
- Subjective vs. Objective Coordination
 - individual / subjective viewpoint over agent interaction
 - DAI
 - external / objective viewpoint over agent interaction
 - Coordination languages and models
- Why a wall between the two?

Need to Break the Wall

- Exploring both subjective and objective coordination main features:
 - Intelligence and skills of agents facing situated work in open (unpredictable/complex) environments
 - Fluid and automated coordination, able to scale up with respect to performance, social task complexity, agent heterogeneity, organisation size (Durfee)
- Facing the requirement from state-of-the-art coordination systems/applications (e.g.: CSCW *and* WfMS):
 - support for *different styles of coordination*, ranging from strict to loose automated coordination
 - support for *dynamically and contextually* changing/adapting the approach with respect to the needs

Looking for Foundations

- Social Theories about Organisation and Coordination in Human Societies
 - Out of CS: Interdisciplinary of Coordination
 - Interaction Space Complexity: MAS as Society
 - Theory of Coordination (Malone, MIT CCS)
 - coordination as the management of *dependencies* among autonomous activities
 - Reference theory for Objective Coordination Approaches
 - Uncoupling the glue from the parts, with focus on the glue
 - Dependency as a key element of agent society and subjective approaches (Castelfranchi)
 - Coordination as constraining interactions (Wegner)
- Bottom-up (regulatory) approach, not enough: looking for the Top-Down (constructive) counter part
- social goals/tasks as a starting point

Activity Theory Framework

- Theory about the development / dynamics of collective human work (Vygotsky '20/'30, Leont'ev '70, Engeström and Nardi '90...)
 - Social/Psychological focus on human activities
 - *objects* and *objectives*
 - *collaboration activities* and *actions*
 - Focus on *artifacts* which always mediate human activities
 - Both physical and psychological nature
 - cultural means, tools, signs mediating the relationship between human agent and objects of environment
 - Come along with any (social) human activity
 - Explicit account for environment/contexts and situated interaction
 - Stigmergy
 - Particular focus on *social artifacts*, mediating social activities

AT Hierarchical Collaborative Levels

(Engeström/Bardram)

- *Co-construction*

- (re-)conceptualising work organisation and coordination in relation to the shared objects
 - co- (collective)construction of the object and objective of work, which are not stable

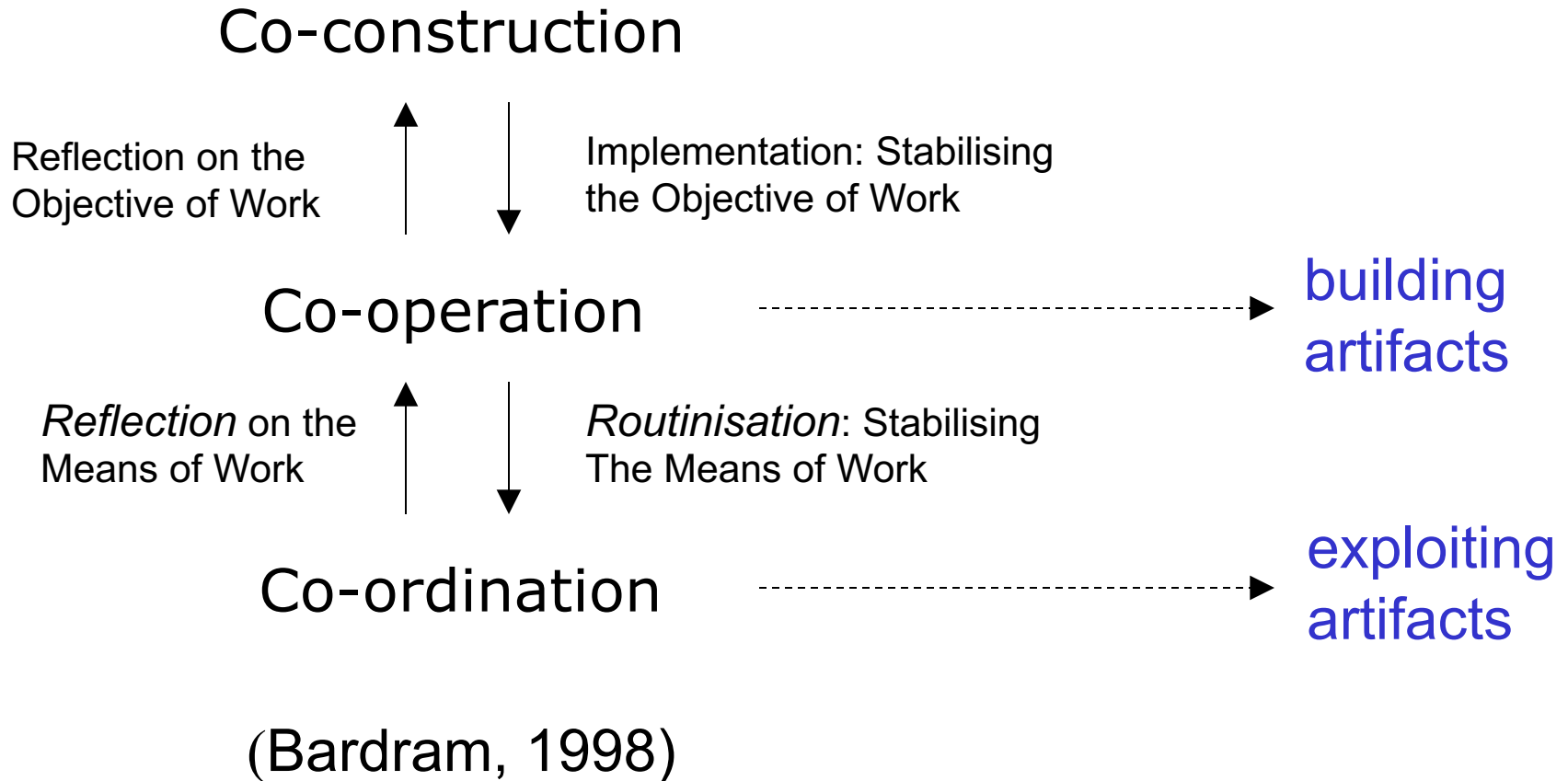
- *Co-operation*

- defining the means (artifacts) for achieving the (stable) objective of the work
 - negotiation among actors, balancing actions toward the constructions of the shared artifacts, which are not stable

- *Co-ordination*

- capture the routine flow of interaction, driven by the artifacts as stable means of work
 - participants are *wheels of the organisation machinery*
 - toward the autonomous achievement of their individual goals, pre-scripted by scripts/plans
 - no need for actors to know/fully understand/question scripts coordinating their activities

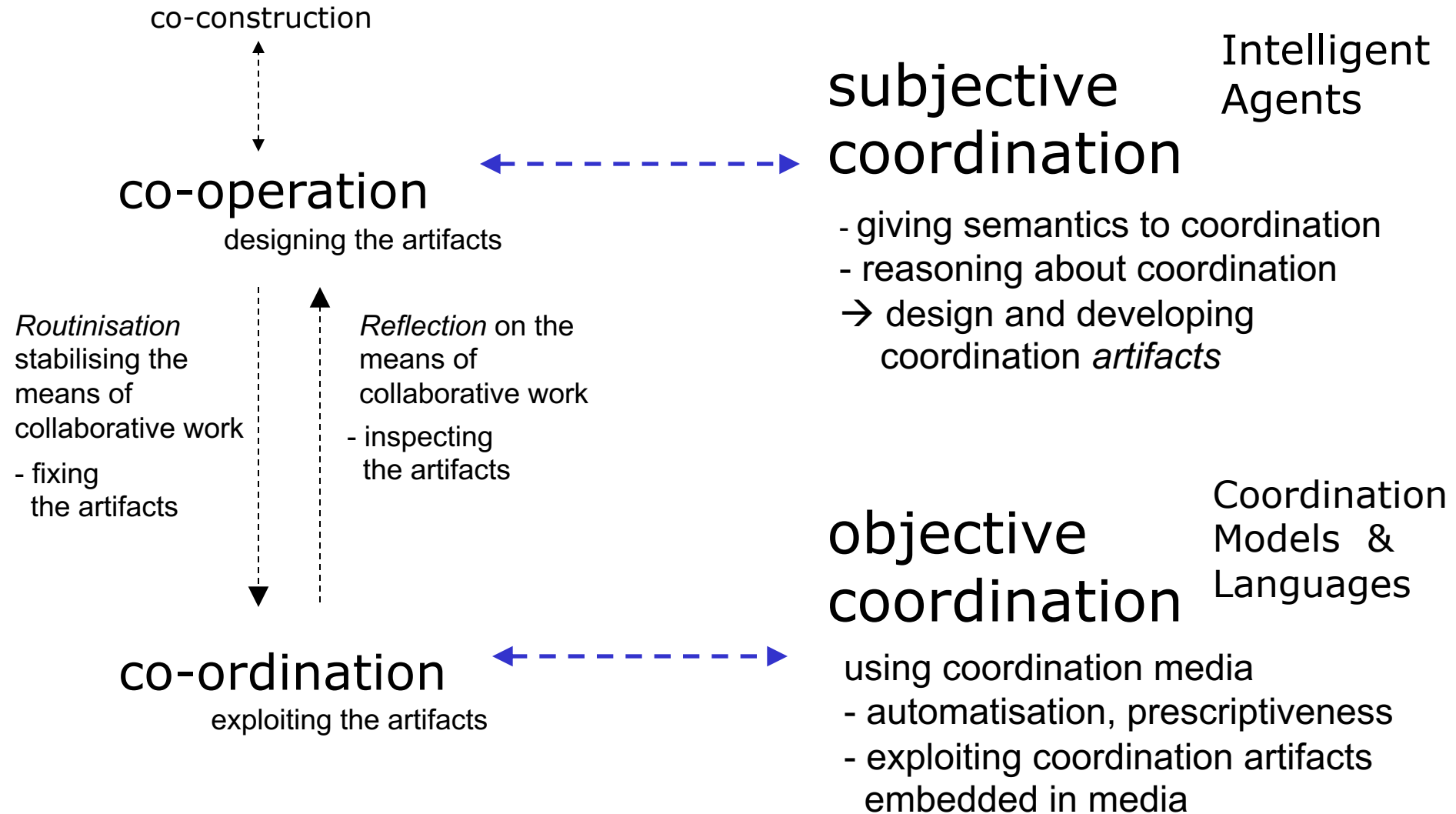
Handling Dynamics



Back to MAS: Breaking the Wall

- Subjective and Objective approaches in the same coordination context
 - conceived as different levels of the *same* collaboration activity
- Mapping the AT Concepts
 - Artifacts → coordination media
 - Social laws/norms/plans → coordination laws
 - Subjective Coordination → co-construction & co-operation
 - Cooperative design and development of the social goals, rules, norms as coordination laws
 - Building the artifacts → define coordination media behaviour
 - Objective Coordination → co-ordination
 - Automated/Prescribed coordination toward the social goals
 - Using the artifacts → interacting through the coordination media

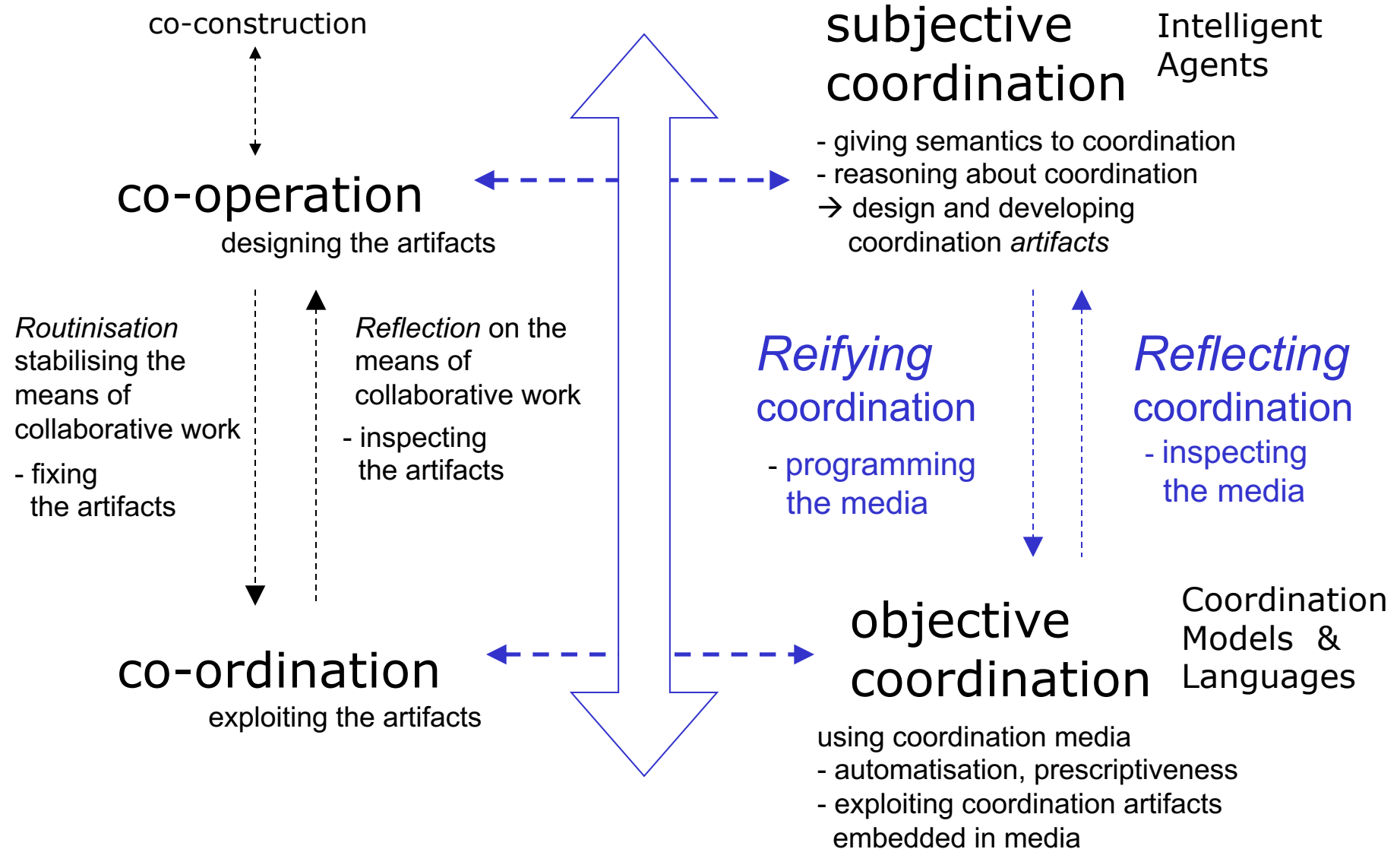
Breaking the Wall



Back to MAS: Handling Dynamics

- AT Lesson: focus on *dynamics*
 - Inspecting/adapting dynamically artifacts, by need
- Requirements for coordination media (models)
 - *dynamic* observation of artifacts → support for coordination (media) laws *inspection*
 - both from humans and intelligent agents
 - declarative specifications, formal semantics, standards
 - *dynamic* construction of artifacts → support for coordination (media) laws *programming*, *forging/adapting dynamically the media behaviour*

Breaking the Wall: Dynamics



Artifacts Facts (I)

- *Artifacts / Coordination Media are **not** Agents (!)*
 - AT Theory: artifacts do not occupy the same ontological space of actors (Nardi et al)
 - Different ontological properties wrt agents
 - (Dynamic) Inspectability & Programmability
 - Efficiency/Specificity
 - Predictability
 - Spatial/Temporal/Contextual Heterogeneity
- *Artifacts / Coordination Media **are more than barriers***
(cfr. Castelfranchi, “Engineering Social Order”, ESAW 2000)
 - means to achieve social order without sacrificing agent autonomy
 - Information / interaction *generators*, *not only enablers/constrainers*
 - drivers to social goals achievement

Artifacts Facts (II)

- Source/target of *social knowledge/intelligence*
 - dynamic/evolving repositories of social knowledge/intelligence
 - in particular about emergent collective behaviours
 - provide the context for analysis about society and interactions
- *Dissipative structures* provided by the agent organization environment
 - Artifacts/media can act as entropy drainers for the open agent organisations (cfr. Zambonelli, Parunak)
 - Keeping/constraining order in open systems
 - relationship with Social Order (Castelfranchi)?

TuCSon Example

- Coordination model/infrastructure suitable for MAS, supporting objective coordination
- The artifacts: (ReSpecT) Tuple Centres
 - *programmable* coordination media
 - coordination laws defining media (tuple centre) behaviour specified in the declarative logic based ReSpecT language
 - artifacts behaviour can be defined upon coordination laws
 - inspectability & *dynamic* inspectability
 - ReSpecT declarative specification can be dynamically inspected
 - dynamic forgeability/programmability
 - ReSpecT declarative specification can be dynamically changed/adapted

Benefits (I)

- The capability of (dynamically) inspecting / forging artifacts
 - is where objective and subjective coordination meet and provides support for
 - different MAS *coordination styles*
 - balancing the coordination intelligence/burden between media and agents, according to the need
 - *dynamic changing/adaptation* of coordination style according to environment/organisation dynamics
 - 1) choosing/changing dynamically the balance/degree between subjectiveness/objectiveness
 - 2) observing/adapting dynamically social tasks, rules and norms

Benefits (II)

- Scaling up coordination (Co-ordination stage)
 - w.r.t. performance (time)
 - artifacts focused/specialised for the social tasks
 - w.r.t. the complexity of the social activity
 - complexity embedded *and reduced* in the artifacts, by mean of *conceptual localization/centralization*
 - multi-centralization by the need
 - w.r.t. the interaction space size
 - minimising negotiation and message exchange
 - w.r.t. agent heterogeneity
 - coordination open not only to intelligent agents

Current & Future Work (I)

- Deeper understanding of Activity Theory
feedbacks on MAS organisation &
coordination (in particular wrt. methodology)
 - exploring ontological/engineering properties of
coordination artifacts
 - coordination artifacts and AOSE (SODA)
 - relationships between artifacts and contexts (Omicini)
 - artifacts expressiveness (Viroli, Omicini, Ricci)

Current & Future Work (II)

- Applying the framework in the context of TuCSoN agent coordination infrastructure
 - focus on services & tools for discovery/observation/construction/exploitation of coordination artifacts – *Tuple Centres*
 - “Coordination tools of MAS development and Deployment” (Denti, Omicini, Ricci, AAI Nov.-Dic. 2002)
 - applications: WfMS, CSCW, Pervasive Computing
- Integration of subjective coordination technologies (with FIPA-compliant BDI-like agents, why not) in the context of the TuCSoN infrastructure