Achieving Global Coherence in Multi-Agent Caregiver Systems: Centralized Versus Distributed Response Coordination in I.L.S.A.

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What is Coordination?

- Coordination is the process of achieving global coherence when control and processing is distributed and autonomous.
- Conceptual example:
  - Easiest to cast in a physical space ñ weíll return to I.L.S.A. in a moment.
  - Consider two robots, Shakey-A and Shakey-B, each of whom is planning to go through the same door at the same moment in time. They can charge ahead and let obstacle avoidance resolve the situation or they can coordinate via communicate to decide who should go through the door and when.

Shakey Aís Plan

- Move through door 12A at time 13:05.
- Deliver package to main office.
  - Traverse hall 113 for 20 meters going South.
  - ..
  - ..

Shakey Bís Plan

- Move through door 12A at time 13:05.
- Test shin bumping arm on students.
  - Traverse hall 113 for 5 meters going North.
  - ..
  - ..

Harmful temporal & resource interaction between tasks.

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Types of Coordination and Formalisms

ï Many types of coordination in agent-based systems.
  ñ Over shared resources, e.g., network bandwidth, sensors for component construction (manufacturing application).
  ñ Over task interactions, e.g., Bill needing a specification from Mary before he can perform his task.
  ñ Many classes ñ positive, negative, hard, soft, fixed temporally, etc.

ï In general, if there is an interaction between the activities of different agents coordination is required to make sure the collection of agents (called a multi-agent system) does the right thing.

ï Coordination generally entails determining which tasks to perform, when, in what sequence, etc., and generally involves a communication-based dialog between interested parties.

ï Many formalisms involving joint goals and shared plans, e.g., Grosz et al, Tambe et al, Cohen et al, Jennings et al, etc.

ï Many implementations and techniques, e.g., Lesser, Decker, Tambe, Durfee, Jennings, Wagner, etc.

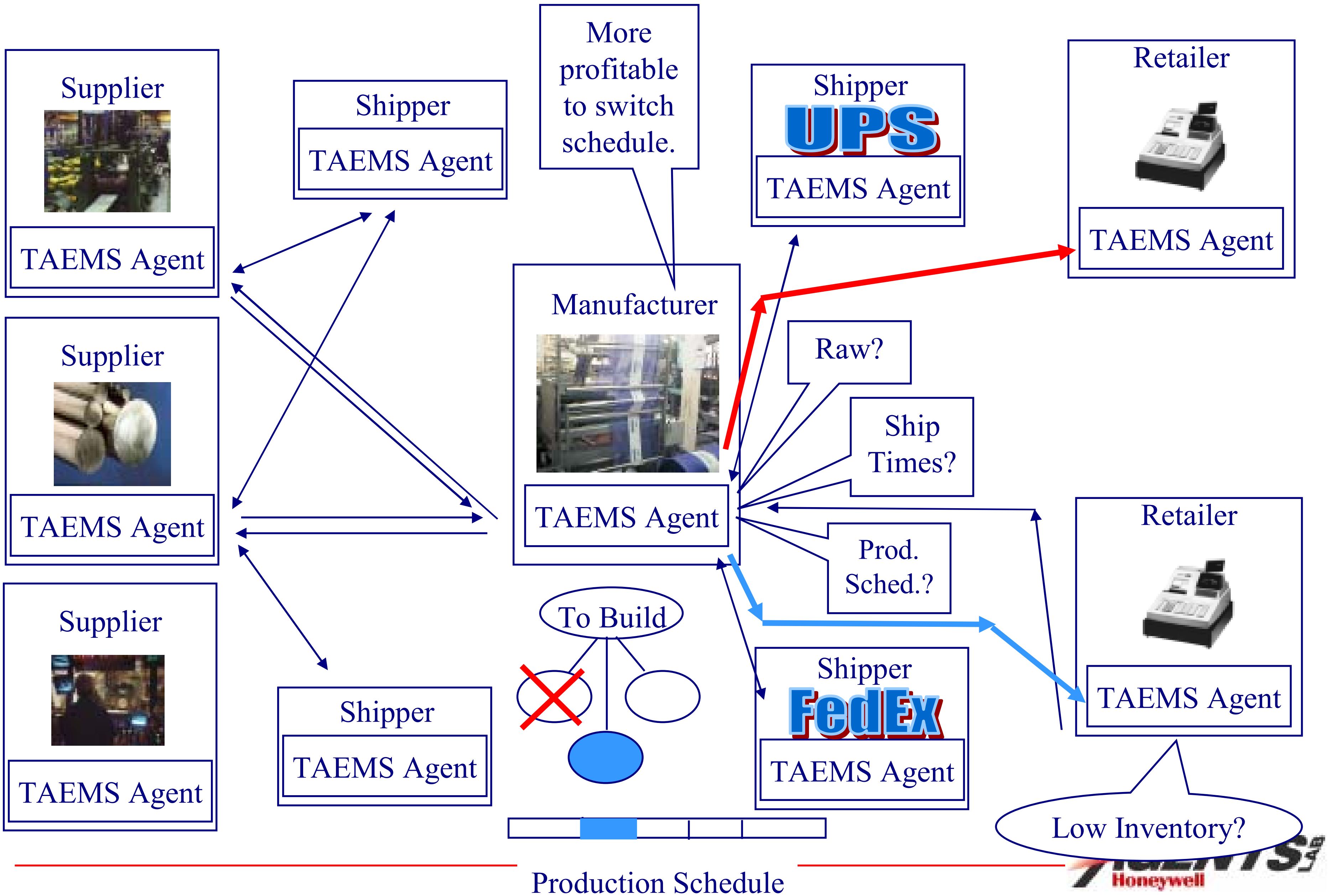
Understanding MAS Problem Spaces

- Coordination is generally a distributed process. Partial rationale:
  - The involved agents are locally autonomous (asynchronous, local authority and local decision making).
  - Not all agents will interact all of the time.

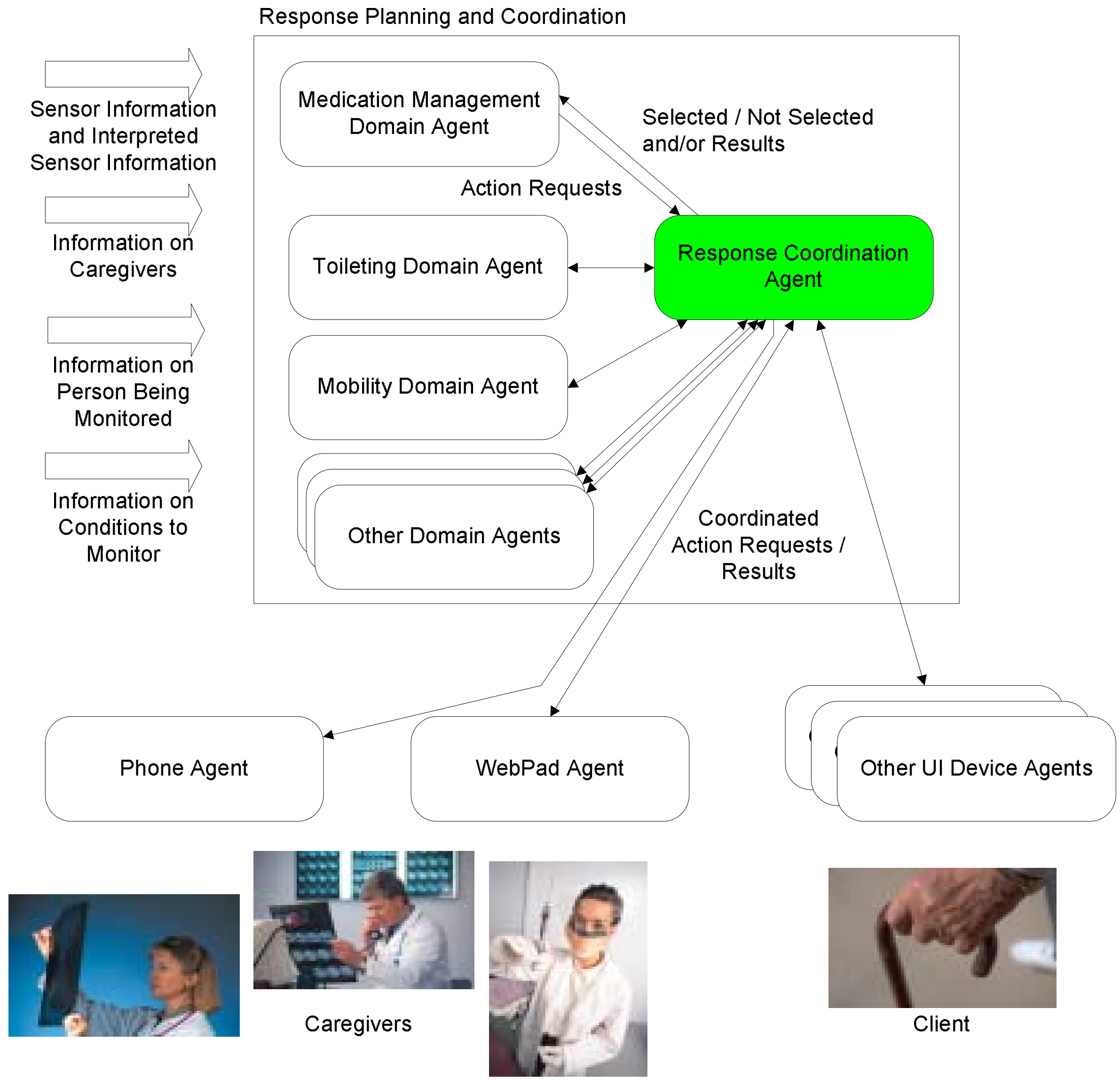
- This characterization is *application dependent.*
  - The community is working toward a science of which techniques to use, and when, based on the features of the problem space (Wagner & Durfee et al, in progress í02).
  - Most agent-based application spaces require distributed techniques.
  - Multi-agent caregiver systems may represent a different/new class of problems.

- Example of a more classic multi-agent application -- dynamic supply chain management (Wagner et al í02).

Dynamic Supply Chains



The I.L.S.A. Coordination Problem Is Different – Yours Is Probably Different Too



- Interactions in the MAS are between the domain agents through their shared need to access/interact with human caregivers and the client (Lois).
- The caregivers and Lois can be seen as shared resources.

Major Coordination Requirements & Key Domain Characteristics

- Flexibility - individual tasks are not fixed temporally ñ they do not have hard deadlines but instead must be performed according to some overall policy, e.g., alerts must be issued as fast as possible.
- Global constraints that must be enforced:
  - There exist *global* system-wide *policies* that must be enforced, e.g., when the system is in alarm state reminders are not issued.
  - There exist *global contact protocols* for a given response type, e.g., for alerts contact authorized contactees on their devices sequentially in order of priority, stopping when one contactee accepts the alert.
- Some degree of computational predictability -- the ratio of responses to computational processing power will be small in general because all responses must eventually involve a human caregiver or client. (The ìdistribution to avoid a bottleneckî view doesnít apply here.)
- Potential nuisance factor -- because the agents interact over a human shared resource, there is an added issue of minimizing the nuisance factor. Without coordination, for instance, it is possible for different domain agents to ring Loisí phone every two minutes to issue different reminders.

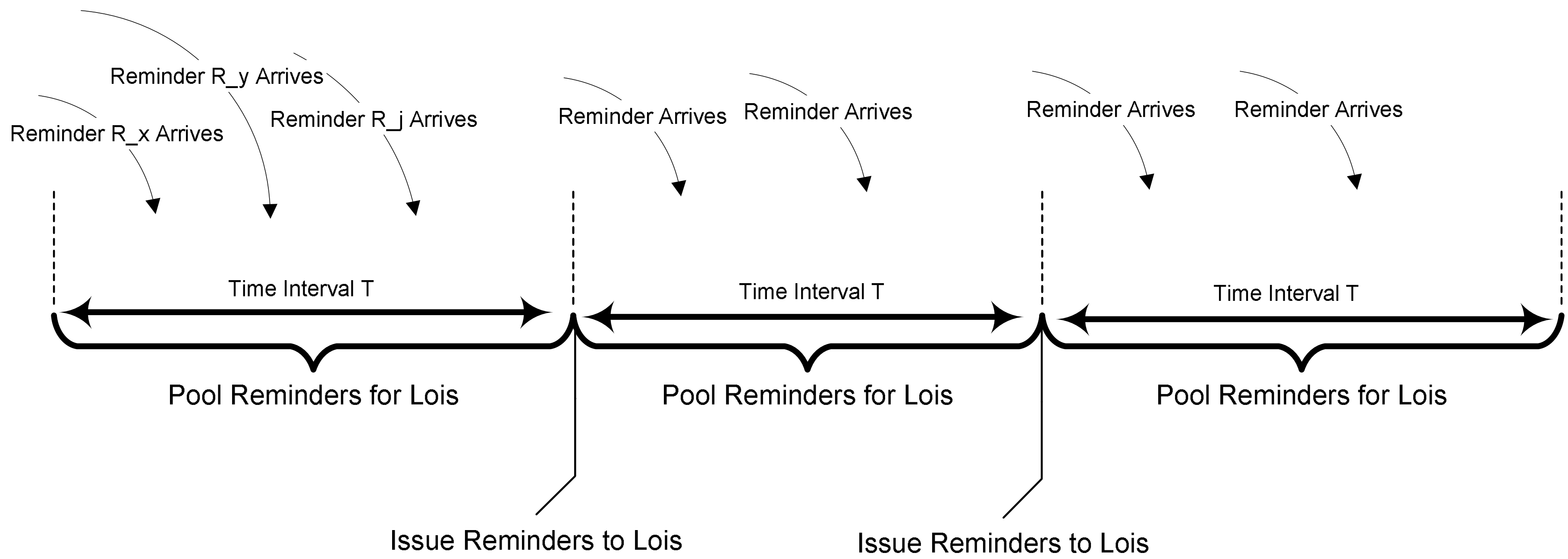
Implications

- Distributed coordination will work fine but is overkill and unnecessarily expensive.
  - Higher cost in technology development.
  - Higher computational cost in agent control problem solving overhead and network bandwidth / message passing.
  - Much harder to debug algorithms, prove properties, etc.
  - Can achieve a partial global view over the interaction space (no privacy concerns or conflicting objectives issues), i.e., can actually have access to all responses, etc.

- Solution is centralization in a different agent called the response coordinator whose job is to coordinate the interactions between the domain agents and the caregivers/client.

The Response Coordinator (RC)

- All requests / actions sent from domain agents to RC.
- RC enforces states, e.g., if the system is in alarm state, suppress reminders.
- RC and device layer implement global contact policies, e.g., for alerts contact in sequence.
- RC multiplexes reminders and notifications to control the nuisance factor.
- Centralization also provides a measure of control over 3rd party agents ñ the Honeywell ìcertifiedî RC can enforce the global system-wide policies.



Multiplexing reminders for Lois to lower the nuisance factor.

Take Home

- If you are constructing a multi-agent caregiver system, you probably donít need and donít want distributed agent-to-agent coordination. Centralizing simplifies policy enforcement and multiplexing of related messages.

- Multiple caregiver systems interacting, e.g., multiple I.L.S.A.ís installed in a nursing facility, may be a different problem instance and may require decentralized techniques.

- The process of evaluating an application and determining which coordination technique to use is currently an experience-based art, though, the agent community is moving toward a science of application.

- Wagner et al are open to interaction / advisory roles on other projects.
- Note also that Honeywell has some IP in this area.