Soar & the Multi-agent Systems Paradigm

Robert Wray

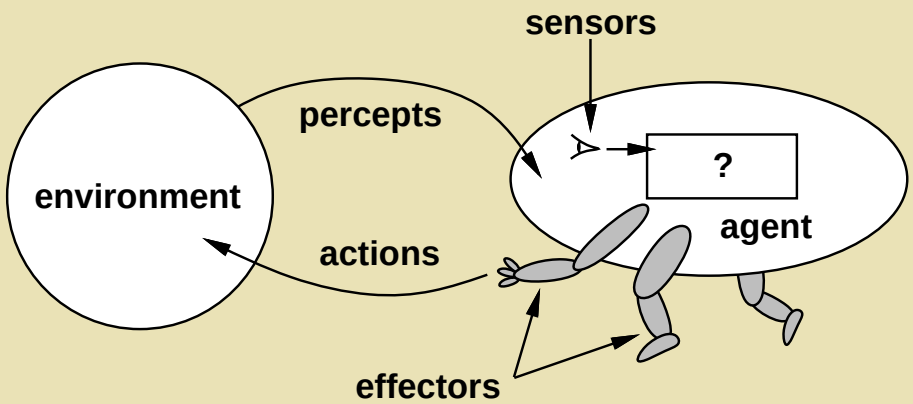
Soar 21

5 May 2001

Soar Technology

What is an agent?

- *Agents are active, persistent (software) components that perceive, reason, act and communicate*
  [Readings in Agents (RiA)]
- *Perceive, Reason, Act*
  [AIMA]



- Many Soar recent systems obviously meet this definition
  - TacAir/RWA-Soar, ISIS, STEVE, Quakebot, etc.

Given the maturity of Soar architecture (e.g., integration of reaction and deliberation), development of complex agent systems in Soar, interfaces for interacting with external systems, why isn't Soar in the mainstream of agent research and development?

Autonomous Agents & Multi-agent Systems

- Emphasis mostly on communities of agents
  - historical roots in DAI
  - one agent can not "do it all" for complex tasks
  - For some: notion of agent implies social context (no single agent systems)

MAS: Key Characteristics

- Declarative approaches
  - Assumption: "higher level declarative approaches win out“ [RiA]
- Social/Systems infrastructure
  - Common representation languages (across agent systems)
  - (Inter)Agent communication languages (ACLs)
  - Common ontologies
- Frameworks for MAS
  - Communication infrastructure:
    - P2P, multicast, broadcast; push or pull
  - Messaging protocols:
    - CORBA, DSOM, OLE, HTTP
  - Security, remittance, etc.
- Agent mobility

(List intentionally biased to exclude most Soar research)

What Soar can contribute

- Understand capabilities/properties of single agents
  - reactive/deliberate behavior in scalable framework
  - adaptable
    - error correction, instruction, experimentation, induction
  - modeling (e.g., teamwork & adversary models)
  - experience with variety of environments
    - High Level Architecture (HLA), game engines, ...
- Emulation of human behaviors
  - Intelligent user interfaces
  - Human behavior requirements ("believability")
  - Social interactions based on human interactions
    - Natural Language
    - "Social band:" teamwork, leadership, SCT, ...

Bringing Soar into the MAS Mainstream

- Problem: Soar agents do not "live" in the same social fabric as other agents in the MAS world.
- Possible solution path
  - Provide MAS-compatible social/system infrastructure for Soar
  - High payoff activities
    - Provide access/methodology for common ontologies
    - Provide general, standard agent communication language (ACL) infrastructure for Soar

    <u>These activities can be pursued in parallel!</u>

Common Ontologies

- Shared representations (usually explicit) of knowledge of some domain
  - Available to all systems/agents for communication & coordination
  - Ensure same semantics to all participants
    - "employee" payroll system: might include contractors
    - "employee" benefits coordination: might include retirees

    Common ontology provides a precise, external definition of "employee" that all agree to use in interagent communication (regardless of internal representations)
  - Access implementation neutral knowledge repositories (e.g., High Performance Knowledge Bases)
    - Pay once for knowledge representation in a domain

Why Ontologies for Soar?

- Means to represent & share declarative/factual knowledge for Soar agent design/implementation
  - Example: TacAir-Soar vehicle parameters
    - Currently: informal ontology/taxonomy of parameters
  - Provide a production-independent means to communicate parameters (e.g., validation, traceability)
    - Transparency: TAS parameters require knowledge of Soar
- Leverage knowledge developed by others
  - Example: WordNet (http://www.cogsci.princeton.edu/~wn/)
    - lexical database (organized semantically)
      - inspired by current psycholinguistic and computational theories of human lexical memory
    - large: ~50M, > 100k words, > 70k word meanings (~1990)

How can Soar use WordNet?

1. Query a standalone database?
   - limits utility of WordNet
   - not accessing associational power of Rete/knowledge
2. Transfer content directly to WM?
   - What happens to the matcher when there are > 100k WMEs? > 10^6 WMEs?
3. Transfer content to LTM?
   - How does it get there? (Learning? Translation mechanism?)
   - What happens to the matcher when there are > 100k unique conditions? > 10^6? What will be the cost of partial matches?
   - Once it's there, how do you retrieve it?
   - Once you've retrieved it, when do you "release" it?
4. New architectural processes?
   - Functional argument for activation-like memory?

Agent Communication Languages

- ACLs: "wrapper languages:"
  - knowledge-level communication protocols
  - agnostic about content language and specification of common ontology(-ies)
  - based on Speech Act Theory
- 2 Potential Standards
  - Knowledge Query & Manipulation Language(KQML)
    - DARPA knowledge sharing effort (KIF/Ontolingua)
  - Foundation of Intelligent Physical Agents ACL

FIPA/KQML

- Both KQML/FIPA provide:
  - communication level
    - Identify sender, receiver, content language, ontology, etc.
  - message level
    - *Performatives*: specify action to be performed
      - `ask-if, tell, deny`
  - content level
    - Content of the message (could be anything)
      - likely to be KIF content:
        - Knowledge Interchange Format (FOL Language)

ACL for Soar

- Approach:
  - Production level
    - create productions that tag ACL messages with required information (e.g, performatives)
      - Semantic knowledge
  - I/O subsystem
    - generate ACL messages based on output (eg, acl-output-link)
      - WME → ACL syntax transform
    - Also need a message passing infrastructure
      - SGIO probably adaptable, if not already a solution
- After this first step:
  - Still need to communicate with non-Soar agents
    - Soar2KIF and KIF2Soar? (Possible?)
  - Still need to access common ontologies

Conclusions

- Soar approaches/contributions could be of value in MAS world
  - Human interaction/Human behavior requirements
- Huge areas of application
  - Personal assistants; intelligent interfaces; information retrieval, filtering, fusion; E-commerce; enterprise integration; …
- Need to utilize existing knowledge resources and ACLs
  - Access to implementation neutral knowledge repositories
- Common Ontology/ACL interfaces: first step
  - Need a complete agent "toolbox"
    - interoperation, message passing, specifying ontologies, etc.
- What standards should we support?
  - ACLs: KQML-Lite is potentially a merge of KQML/FIPA
  - Ontologies: Ontolingua, OIL, XOL