Constraints on the Design of a High Level Model of Cognition

Randolph M. Jones and John E. Laird

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university of michigan
artificial intelligence laboratory

Is TacAir-Soar a Model of Cognition?

From one perspective, TacAir-Soar has an arguably very loose and ill-defined design constraint:

> *Generate human-like behavior in the tactical air combat domain.*

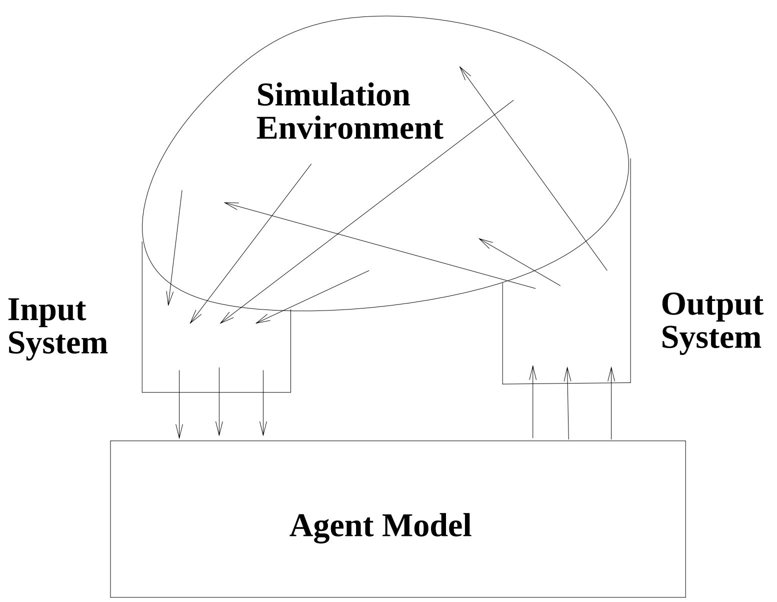
In principle, it seems possible to build a system that meets this constraint, but behaves nothing like a human at the symbol level.

Intelligent Forces

However, there are actually a number of goals for intelligent synthetic forces (IFOR), which constrain how the agent model must be developed.

- IFORs should model the behaviors of individual entities.
- Observable behavior should be believable and human-like.
- The intelligent agent must interact with a realistic environment.
- Intelligent agents should interact with humans as naturally as possible.
- The agent model should be computationally efficient, to allow for large populations of IFORs.

The Simulation Architecture



Claim: If the simulation environment and the input and output interfaces are as realistic as possible, the combined constraints lead to a symbol-level model of human behavior.

The Simulation Environment

The simulation environment is represented by distributed computation over the Defense Simulation Internet (DSI).

The program our agents use to interface with the environment is called ModSAF.

- ModSAF provides realistic simulation of vehicle, weapons, and sensor dynamics.
- Weaknesses in ModSAF's realism directly translate into weaknesses in the cognitive model.

The Input Interface

The input interface attempts to provide TacAir-Soar with similar types of information available to a human pilot, at an appropriate level of representation.

- Radar blips, visual contacts, cockpit gauges and screens, verbal input over radio
- The agent senses only an appropriate portion of the simulation environment.
- Sensory input is represented symbolically.
  - Assume that lower levels of sensory representation are not significant for the simulation goals.

The Output Interface

As with the input interface, the output interface design provides TacAir-Soar with influence on the simulation environment similar to a human in a cockpit.

- Aircraft maneuver commands, various buttons to control weapons and sensors, simulated verbalization over the radio
- The agent can only make a change in the simulation environment through the output interface.
- Assume low-level motor routines are well rehearsed, so we only need to reason to the level of intention.
- Symbolic intentions translate into ModSAF function calls.

The TacAir-Soar Agent

The task of the agent model is to map symbols from the input system to command symbols accepted by the output system, while also conforming to the task constraints of believability and efficiency.

These constraints require the integration of a number of intelligent capabilities.

- Reasoning about and achieving the complex web of goals involved in various missions.
- Maintaining realistic situational awareness.
  - In particular, mapping many sensory inputs to many external agent representations.
- Coordinating and communicating with other agents (and possibly humans).
- Efficiently generating appropriate behavior even when the environment is changing rapidly.
- Do everything as efficiently as possible.
  - Does this conflict with believability constraints?

Constraints on Knowledge Representation

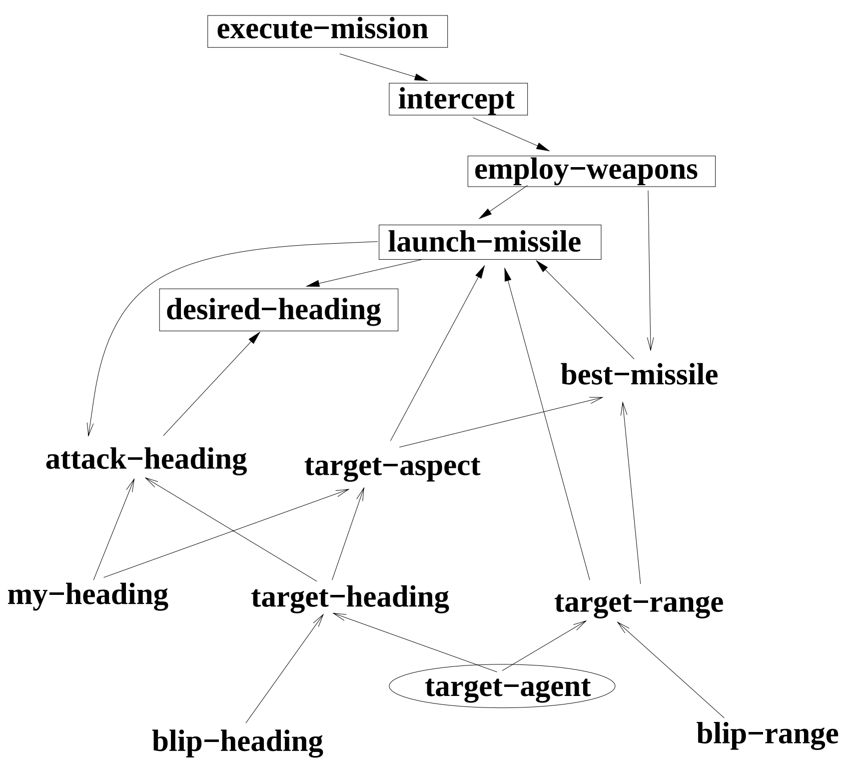
Soar allows a fairly wide choice of knowledge representations, but it encourages hierarchical representations.

The military also tends to use hierarchical representations for tactics and command structure.

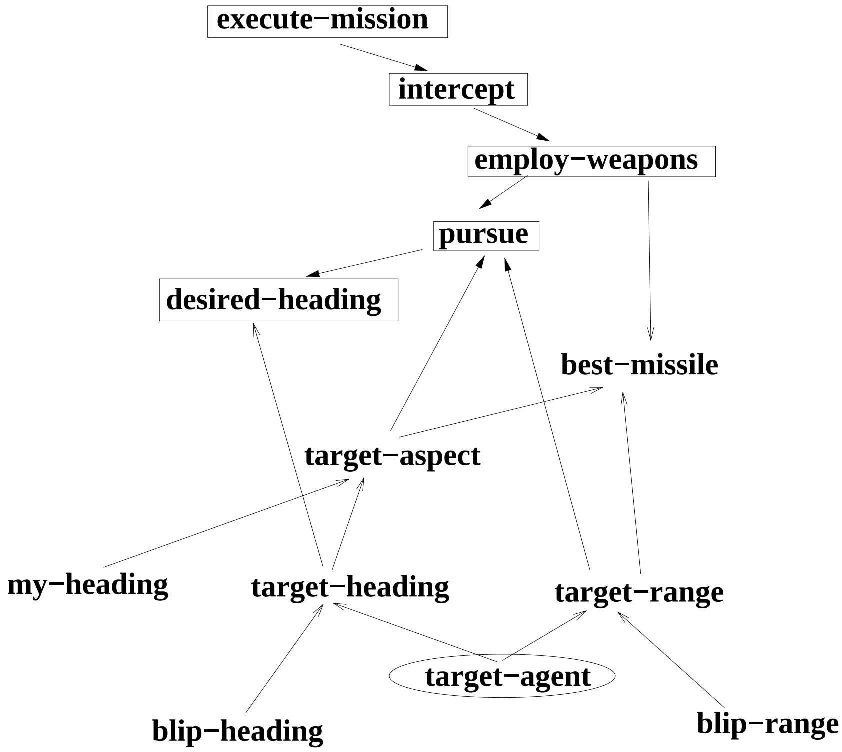
Thus, within TacAir-Soar, most long-term knowledge is organized into two hierarchies.

- Bottom-up hierarchy of interrupt-driven situation interpretations
  - Allows efficient, rapid reaction to new situations at appropriate levels of operationality.
- Top-down hierarchy of goals
  - Focuses the context of interrupt processing and new goal creation.
- The mixture of hierarchies can be viewed as “reactive, completable planning”.

A Simplified Example, Part 1



A Simplified Example, Part 2



Learning From The Agent Model

Since the earliest "mature" versions of TacAir-Soar, we have made a number of improvements in efficiency and quality of behavior. Some of these have taught us interesting things about the model and the task domain.

- Automated spatial perception
  - Move low-level geometric interpretations from the agent model into the input interface.
  - Suggests similar enhancements to real radar interfaces (some of which already exist)
- Focus of attention
  - Allow agent to choose different levels of information (low, medium, or high) to be computed for different types of contacts.
  - Required changes to agent model, input system, and output system
  - Purely functional concerns appear to improve the psychological plausibility of the model

Learning From The Agent Model

- Expanded aircraft control
  - Initial output system allowed control via high-level "auto-pilot".
  - This suffices for most maneuvers, but not all.
  - Mixture of control levels are common in commercial aircraft. Should they be used more in combat aircraft?
- Automated memory aids
  - Automated spatial perception reduces cognitive load for existing contacts, but not when contacts disappear (from radar or visual field).
  - Moving "projected memories" from agent model to input system results in similar reduction of cognitive load.
  - Suggests automated memory aids in real cockpits.
- Development of the agent model guides knowledge acquisition
  - E.g., using Computer Controlled Impact Point (CCIP) for aiming bombs

Conclusions

Claim:

- The combination of constraints imposed on the TacAir-Soar agent have led to (*require?*) the creation of an accurate, symbol-level model of a "generic" expert combat pilot.

Evidence:

- The quality of the current model is limited mostly by imperfections in the simulation environment and input and output interfaces.
- We have begun to learn things about pilots and air combat *from the model* rather than from the subject-matter experts.

Conclusions

Surprising Result:

- Improvements in efficiency have generally led to improvements in the quality of the cognitive model (so far).

Remaining Question:

- Would it be possible to build a system that meets all of TacAir-Soar's constraints, but is *not* an accurate symbol-level model of cognition?

The Future:

- TacAir-Soar is intriguing enough to other cognitive scientists that it is being used as the basis for a study on the effects of fatigue on pilot behavior, and is being considered for a project to build a detailed model of weapon-firing behavior.