CASE: A HAL 9000 for 2021
Pete Bonasso (bonasso@traclabs.com)

Abstract: This paper describes an intelligent agent, like the HAL 9000 that can plan and manage the activities for a planetary base, and can interact with users through a dialog management system.

Figure 1 The top-level CASE architectural design. The planner generates an activity plan whose actions are procedures run by the execution system, which in turn interfaces to the hardware through the control software. The planning and execution systems draw information from and update the system ontology, a smart database. A process manager spawns the main components of the system, and re-constitutes processes if their supporting computing infrastructure fails. The user interacts with the agent via a dialog manager.

I saw Stanley Kubrick’s 2001: A Space Odyssey in my senior year at West Point in 1968. West Point had only one computer— a time-shared GE 225 with a whopping 125k of memory, complete with magnetic tape loaders for programs and data. I programmed that computer to shoot pool (virtually). But when I saw 2001, I knew I had to make the computer into another being, a being like the Hal 9000. Fast forward fifty years. I’m a researcher in artificial intelligence and robotics who has specialized in engineering reasoning agents in software. Our agents are built using the 3T software architecture (Bonasso et al., 1997), to which we’ve added
a turn-based natural language dialog system (Fitzgerald and Wiseman, 1997) and software managers that maintain the state of the software components executing on several processors. When people ask me what I’m working on, the easiest thing to say is, “I’m building the HAL 9000.” Let’s discuss our most recent agent in detail.

The backbone of our agent system is composed of three levels of processing (see Figure 1). There is first the continuously running control layer that connects to hardware, such as robotic hands and eyes (HAL’s hands were the ships doors and robot arms; its eyes were the inside and outside cameras, especially that big round iconic red one). Our current agent – called a Cognitive Architecture for Space Agents, or CASE (Bonasso et al., 2018) – manages a simulation.
of a planetary base (see Figure 2), so it has control software for life support systems, power systems and planetary rovers.

The second layer executes procedures for carrying out routine activity (Izygon et al., 2008), which for Earth-based humans might be driving to work or doing a load of laundry. CASE has procedures for connecting power to batteries, starting and maintaining oxygen generation and carbon dioxide removals systems, and charging and sending a rover off to get a sample of planetary rock. These routines eventually run the controllers of the first layer, such as recognizing, grasping, lifting and navigating.

In the third layer, automatic planning software takes in the agent’s goals for the day – for example, change the air filters on the thermal control system and send two crew out on a rover to get samples of a lake bed – and figures out the procedures to use from the second layer to achieve those goals and the order in which they should be carried out. Our planner (Elsaesser and Stech, 2007) not only selects and schedules the activities around the planetary base (Bonasso et al., 2009), but can also automatically re-plan when problems arise, such as gas leaks, broken motors or planetary dust storms.

A hidden part of CASE, but one that serves as a glue for all parts of the agent, is our ontology system (Bell et al., 2013). An ontology is a rigorous, exhaustive organization of the knowledge of a domain, containing all relevant entities and their relations. It’s a database that can reason about its data. For instance, if someone moves a tool box from the equipment locker to the crew quarters, the ontology reasons that all of the tools in the box will change location as well. CASE uses an ontology server – like a Web server – to make its data available to all parts of the system, and to allow all parts of the system to update it as they carry out their actions.

CASE has many different visual displays, such as those for life support, the robot situation, and procedure execution. But we’ve also developed a turn-based dialog management system (Fitzgerald and Firby, 1998) to allow humans to ask questions, send commands and be warned about any impending problems. Carrying out conversations with an agent, human or otherwise, usually has a purpose. That is, you speak to someone to get information, or to understand a problem and to agree on a way to fix it. The combined understood problem and way to fix it is called a shared plan (Grosz and Sidner, 1990). Once our dialog manager understands the plan it shares with the user, it can direct the rest of CASE to carry it out. Our dialog manager gets all of its domain language knowledge by transforming the CASE ontology into phrase patterns the user would use. For example, the user could say, “Send the rover to the vehicle bay,” and CASE would respond, “There are two rovers. Rover1 is charging a battery. Shall I send Rover2?” Alas, if you tell CASE, “Open the pod bay doors, CASE.” (assuming there are pod bay doors in the habitat), it will respond, “Certainly, Dave.” Because we have no plans to program paranoia into the system.

CASE is a prototype. We have demonstrated it to manage a simulated base for about four hours, but much needs to be done for it to run an actual base. We are working with what NASA calls analogs (https://www.nasa.gov/analogs), places where humans get together and pretend
they are living on a distant planet or the moon. We hope to slowly, piece by piece, work CASE into one or more analogs to determine its value for future space expeditions (Schreckenghost et al., 2015). We also want to enlarge CASE’s knowledge base, particularly of actions and routines that would be carried out on a planetary surface. Since NASA will be running analogs for those in the near future, we would like to devise a way for CASE would watch the activities of the analog, memorize them and thus learn the operations of such a base. Then if CASE were deployed to the moon or Mars, it would have with it a good starting point for supporting a human crew.


