Physical Invariants of Intelligence

Current research involves a quantumlike aspect of mental-to-motor feedback.

NASA's Jet Propulsion Laboratory, Pasadena, California

A program of research is dedicated to development of a mathematical formalism that could provide, among other things, means by which living systems could be distinguished from non-living ones. A major issue that arises in this research is the following question: What invariants of mathematical models of the physics of systems are (1) characteristic of the behaviors of intelligent living systems and (2) do not depend on specific features of material compositions heretofore considered to be characteristic of life?

This research at earlier stages has been reported, albeit from different perspectives, in numerous previous *NASA Tech Briefs* articles. To recapitulate: One of the main underlying ideas is to extend the application of physical first principles to the behaviors of living systems. Mathematical models of motor dynamics are used to simulate the observable physical behaviors of systems or objects of interest, and models of mental dynamics are used to represent the evolution of the corresponding knowledge bases. For a given system, the knowledge base is modeled in the form of probability distributions and the mental dynamics is represented by models of the evolution of the probability densities or, equivalently, models of flows of information.

At the time of reporting the information for this article, the focus of this research was upon the following aspects of the formalism: Intelligence is considered to be a means by which a living system preserves itself and improves its ability to survive and is further considered to manifest itself in feedback from the mental dynamics to the motor dynamics. Because of the feedback from the mental dynamics, the motor dynamics attains quantumlike properties: The trajectory of the physical aspect of the system in the space of dynamical variables splits into a family of different trajectories, and each of those trajectories can be chosen with a probability prescribed by the mental dynamics.

From a slightly different perspective, the mechanism of decision-making is feedback from the mental dynamics to the motor dynamics, and this mechanism provides a quantumlike collapse of a random motion into an appropriate deterministic state, such that entropy undergoes a pronounced decrease. The existence of this mechanism is considered to be an invariant of intelligent behavior of living systems, regardless of the origins and material compositions of the systems.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory.For more information, contact iaoffice@jpl.nasa.gov. NPO-46085

Rocket-Plume Spectroscopy Simulation for Hydrocarbon-Fueled Rocket Engines

Enhanced simulation includes code for new electronic bands in the 300-to-850-nm spectral bands.

Stennis Space Center, Mississippi

The UV-Vis spectroscopic system for plume diagnostics monitors rocket engine health by using several analytical tools developed at Stennis Space Center (SSC), including the rocket plume spectroscopy simulation code (RPSSC), to identify and quantify the alloys from the metallic elements observed in engine plumes. Because the hydrocarbon-fueled rocket engine is likely to contain C_2, CO, CH, CN, and NO in addition to OH and H_2O, the relevant electronic bands of these molecules in the spectral range of 300 to 850 nm in the RPSSC have been included.

SSC incorporated several enhancements and modifications to the original line-by-line spectral simulation computer program implemented for plume spectral data analysis and quantification in 1994. These changes made the program applicable to the Space Shuttle Main Engine (SSME) and the Diagnostic Testbed Facility Thruster (DTFT) exhaust plume spectral data. Modifications included updating the molecular and spectral parameters for OH, adding spectral parameter input files optimized for the 10 elements of interest in the spectral range from 320 to 430 nm and linking the output to graphing and analysis packages. Additionally, the ability to handle the non-uniform wavelength interval at which the spectral computations are made was added. This allowed a precise superposition of wavelengths at which the spectral measurements have been made with the wavelengths at which the spectral computations are done by using the line-by-line (LBL) code.

To account for hydrocarbon combustion products in the plume, which might interfere with detection and quantification of metallic elements in the spectral region of 300 to 850 nm, the spectroscopic code has been enhanced to include the carbon-based combustion species of C_2, CO, and CH. In addition, CN and NO have spectral bands in 300 to 850 nm and, while these molecules are not direct products of hydrocarbon-oxygen combustion systems, they can show up if nitrogen or a nitrogen compound is present as an impurity in the propellants and/or these can form in the boundary layer as a result of interaction of the hot plume with the atmosphere during the ground testing of engines. Ten additional electronic band systems of these five molecules have been included into the code. A comprehensive literature search was conducted to obtain the most accurate values for the molecular and the spectral parameters, including Franck-Cordon factors and electronic transition moments for all ten band systems.

For each elemental transition in the RPSSC, six spectral parameters — Doppler broadened line width at half-height, pressure-broadened line width at half-height, electronic multiplicity of the upper state, electronic term energy of the upper state, Einstein transition probability coefficient, and the atomic line center — are required. Input files have been created for ten elements of Ni, Fe, Cr, Co, Cu, Ca, Mn, Al, Ag, and Pd, which retain only relatively moderate to strong transitions in 300 to 430 nm spectral range for each element. The number of transitions in the input files is 68 for Ni; 148 for Fe; 6 for Cr; 87 for Co; 1 for Ca; 3 for Mn; 2 each for Cu, Al, and Ag; and 11 for Pd.

This work was done by Gopal D. Tejwani of Jacobs Technology, Inc. for Stennis Space Center.

Inquiries concerning the technology should be addressed to the Intellectual Property Manager, Stennis Space Center; (228) 688-1929. Refer to SSC-00281, volume and number of this NASA Tech Briefs *issue, and the page number.*

Research on Spoken Dialogue Systems

Human verbal interaction with complex information sources.

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Research in the field of spoken dialogue systems has been performed with the goal of making such systems more robust and easier to use in demanding situations. The term "spoken dialogue systems" signifies unified software systems containing speech-recognition, speech-synthesis, dialogue management, and ancillary components that enable human users to communicate, using natural spoken language or nearly natural prescribed spoken language, with other software systems that provide information and/or services. The research is proceeding on several fronts: recognition of speech signals, syntactic and semantic parsing, language modeling, discourse analysis, and contact modeling.

Many of the advances made thus far in this research have been incorporated into a voice-enabled procedure-browser and reader, called Clarissa, that has been tested aboard the International Space Station. [A procedure-browser and reader is essentially a software version of an instruction manual that may describe one or more possibly complex procedure(s).] Major problems that have been addressed in developing Clarissa include creating voice-navigable versions of formal procedure documents, grammar-based speech recognition, methods for accurate detection of user's speech directed toward a listener other than Clarissa based on grammar filtering or support vector machines, and robust, side-effect-free dialogue management for enabling undoing, correction, and/or confirmation of steps of a procedure.

Clarissa enables the user to navigate a complex procedure using only spoken input and output, making it unnecessary for the user to shift visual attention from the task at hand to a paper instruction manual or to an equivalent document displayed on a computer screen. Clarissa also provides a graphical user interface (GUI) for optional visual display of information. Clarissa has a vocabulary of about 260 words and supports about 75 different commands, including commands for reading steps of the procedure, scrolling forward or backward in the procedure, moving to an arbitrary new step, reviewing non-current steps, adding and removing voice notes, displaying pictures, setting and canceling alarms and timers, requiring challenges to verify critical commands, and querying the system as to status of the procedure.

Clarissa includes the following main software modules:

- Speech Processor — Performs low-level speech-recognition (input) and speech-synthesis (output) functions.
- Semantic Analyzer — Converts output from the speech processor into an abstract dialogue move.
- Response Filter — Decides whether to accept or reject the spoken input from the user.
- Dialogue Manager — Converts abstract dialogue moves into abstract dialogue actions, and maintains knowledge of both the context of the discourse and the progress through the procedure.
- Output Manager — Accepts abstract dialogue actions from the Dialogue Manager and converts them into lists of procedure calls that result in concrete system responses, which can include spoken output, requests for display of visual output on the GUI, or sending dialogue moves back to the Dialogue Manager.
- GUI Module — Mediates conventional keyboard and screen-based interaction with the user and accepts display requests from the Output Manager. This module can also convert keyboard input from the user into dialogue moves, which are sent to the Dialogue Manager.

Another accomplishment of this research has been the development of a targeted-help module that is highly portable in that it can be added to a spoken dialogue system, with minimal application-specific modifications, to make the spoken dialogue system more robust. The targeted-help module is intended, more specifically, for incorporation into a spoken dialogue system in which, as in Clarissa, there is a prescribed spoken language containing a limited number of words. The purpose served by the targeted-help module is to assist an untrained user to learn the prescribed language by providing help messages in response to out-of-coverage users' utterances (that is, users' utterances outside the prescribed language). These messages can be much more informative than "Sorry, I didn't understand" and variants thereof generated by older, less-capable spoken dialogue systems.

The targeted-help module includes two submodules that run simultaneously: a grammar-based recognizer and a statistical language model (SLM). When the grammar-based recognizer succeeds, the ordinarily-less-accurate hypothesis generated by the SLM rec-