HCC: Small: Computing Systems with Intrinsic Semantics for Enhanced Human-Computer Communication

Goal: This project will answer two scientific questions: (1) How can semantics become intrinsic to (or arise intrinsically from) computing systems, rather than such systems depending on human users to provide meaning to their internal computations and resulting outputs? (2) What impact does computing artifacts with intrinsic semantics have on human-computer interaction.

Background and Gap in Our Knowledge: With the exponential growth in the amount of information in the society and ultra-fast global networks to deliver such content, information quality (as opposed to quantity or speed of delivery) is becoming an increasing necessity. A large part of the quality issue arises due to the lack of intrinsic meaning to the information exchanged by computing systems. Semantic computing and semantic web are beginning to answer these issues, but even in these latest efforts, meaning is not intrinsic to the computing systems; meaning only resides in the brain of the observer. The problem here is that of *grounding*. According to Stevan Harnad who coined the term: "How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads?". Existing research in cognitive science addresses this problem through perception- and/or action-based (in other words, "embodied") approaches. However, in these existing works, (1) the key aspect of *intrinsicness* has been overlooked, and/or (2) an *operational recipe* for grounding has not been provided. Finally, (3) *human attitude* toward grounded and ungrounded computing systems has not been evaluated empirically.

Approach: This project draws its main inspiration from the biological brain which is the only known grounded system with intrinsic semantics. First, the problem of grounding is framed from the point of view of the brain itself, leading to a novel set of assumptions and constraints. Next, an operational recipe (in this case a reinforcement learning framework) is proposed to solve the grounding problem within the framework in the first step. Finally, the resulting system, which is expected to exhibit behavior indicative of grounding, will be used to evaluate human attitude toward grounded vs. ungrounded computing artifacts and to measure the enhancement in the efficienty of human-computer communication in systems with intrinsic semantics.

Objectives: The objectives of this project are as follows:

- Derive an operational recipe (exact framework and algorithms) for grounding of simple geometric concepts based on an internal, intrinsic perspective of the biological brain.
- Extend the operational recipe for grounding to include compositions of geometric concepts.
- Evaluate human attitude toward grounded vs. ungrounded computing artifacts.
- Measure the enhancement in efficienty of human-computer communication in systems with intrinsic semantics.

Scientific Merit: Semantic grounding based on embodied principles is not new. The main novelty of this project lies in a concrete operationalization of such principles, based on inspiration from the biological brain. Furthermore, studying the effects of grounded vs. ungrounded computing systems in human-computer interaction can generate valuable new insights on the role and importance of computing systems with intrinsic semantics.

Broader Impacts: The project will train, over three years, two graduate students through direct funding and three undergraduate students through REU supplements. Data and code resulting from this project will be disseminated with full documentation and tutorials. Computing systems with intrinsic semantics are expected to provide a more intuitive, more accessible interface to a broader, non-technical public. Such systems can also facilitate new scientific discoveries, based on semantic data mining and synthesis, not just syntactic.

Keywords: semantics; grounding; sensorimotor learning