Human-Centric Smart Service Systems for Artificial Vision, Tele-Ophthalmology, and Space Exploration

NSF defines a "smart" service system as: *"a system capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation. […] These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc. The system may exhibit a sequence of features such as detection, classification, and localization that lead to an outcome occurring within a reasonable time."* [NSF PFI:BIC 2015].

In this context, I will touch upon examples from the following complementary and synergistically connected research areas my lab engages in:

- *Biomedical Engineering & Biotronics for Healthcare, Tele-Health, and Mobile Health*
- *Autonomous Multi-agent Robotic Exploration and Synthetic Reasoning Systems*
- *Multi-dimensional Optimization and Computer-optimized Design in Support of Brain-Machine Interfaces and Reverse Engineering of Complex (Biological) Systems*

(1) Artificial Vision Implants (Neural Prostheses)

Worldwide there are numerous efforts to restore vision to the blind via visual prostheses. The majority of these efforts are based on the electric stimulation of the retina, the optic nerve, the lateral geniculate nucleus, or the visual cortex. These devices require non-trivial mapping of video inputs to appropriate electric stimulation patterns. The presentation will touch on: (1) real-time image processing systems; (2) blind subject-in-the-loop stochastic optimization of electric stimulation patterns; and (3) novel electrical stimulation strategies to improve the resolution of vision afforded by visual prostheses.

(2) "Smart Ophthalmics": An Innovation Platform for Smart Mobile- and Tele-Health

Mobile Health is an emerging field characterized by the use of portable, mobile devices capable of collecting, storing, retrieving, and transmitting data over wireless networks in real time for the purpose of improving health and quality of care. In particular, "Smart Ophthalmics" aims at extending ophthalmic healthcare to people who operate/live in austere environments, or are geographically dispersed, where time, cost, and the possibility of travel/transportation make access to even adequate medical care difficult if at all possible. The presentation will describe a framework for smartphone-based ophthalmic examination devices that, in conjunction with custom apps and smart remote server backends, perform comprehensive examinations of the eye, to greatly improve remote patient screening and triage in a timely manner to prevent permanent eye or vision damage.

(3) Autonomous Robotic Exploration Systems

Robotic agents are called for in the extreme environment of space, as well as in potentially hazardous or inaccessible operational areas on Earth. As such, future robotic missions/operations will require increasing degrees of operational autonomy, especially when following up on transient events. The presentation will discuss a patented and NASA award-winning disruptive mission paradigm, termed "Tier-scalable Reconnaissance", as the foundation for autonomous C^4ISR systems of the future. Approaches for instilling autonomy into robotic platforms will be briefly touched upon.