Formal Models and Cognitive Mechanisms of the Human Sensory System

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ABSTRACT

The human sensory system is a perfect natural real-time distributed system. It transforms physical and chemical stimuli of the external environment into electronic neural signals by specialized sensory receptors. This paper presents a comprehensive framework of the human sensory system as well as its cognitive and theoretical foundations. A set of primary and perceptual sensory and neural receptors is formally modeled and analyzed. Sensory neural interfaces and interactions to the central and peripheral nervous systems of the brain and associated memories are systematically described. This work is a part of a strategic project towards the development of cognitive computers and cognitive robots.

Keywords: *Artificial Intelligence, Cognitive Informatics, Cognitive Psychology, Cognitive Systems, Computational Intelligence, Formal Models, Frequency Modulation, Human Sensory, Neural Receptors, Neuroinformatics, Perceptual Sensory, Primary Sensory, Pulse Frequency Modulation (PFM)*
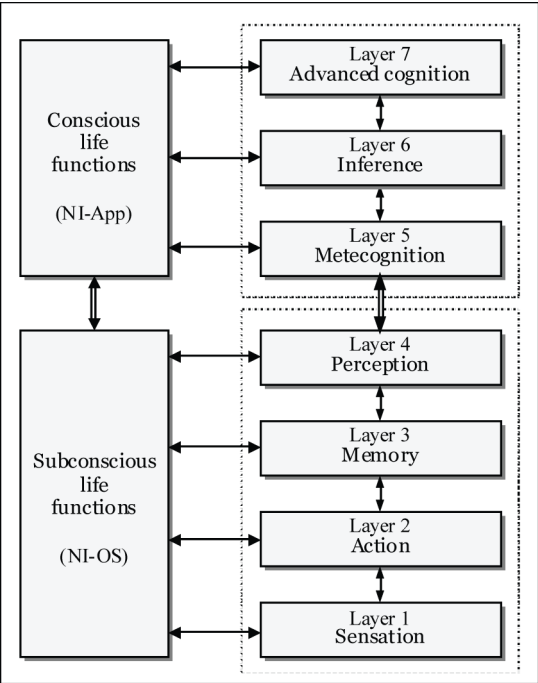
1. INTRODUCTION

It is recognized that most human behaviors are triggered by external stimuli in terms of event-, time-, and interrupt-driven mechanisms. Therefore, human sensory receptors and derived sensations play a key role in explaining human behaviors and cognitive processes. Recent advances in cognitive informatics, neuroinformatics, and computational intelligence provide rational explanations for the human sensory system as smart interfaces between the brain

and the external environment. There are five primary senses and seven perceptual senses that embody self consciousness inside the brain according to the *Layered Reference Model of the Brain* (LRMB) (Wang et al., 2006). The *primary senses*, such as those of vision, hearing, smell, taste, and touch, adopt physical or chemical receptors in order to transform real-world stimuli into uniformed electrical neurosignals in specialized neural pathways. The *perceptual senses* such as those of *spatiality, time, motion, equilibrium, posture, attention,* and *conscious-*

Figure 1. The layered reference model of the brain (LRMB)

ness (Smith, 1993; Pinel, 1997; Matlin, 1998; Westen, 1999; Reisberg, 2001; Wang, 2010b, 2012d, 2013a; Wang & Fariello, 2012; Wang et al., 2006, 2013c), generate complex and abstract sensational perceptions based on the primary senses.

Definition 1: *Sensation* is a set of cognitive processes of the brain that interfaces the brain to the external world by sensory information detection, acquisition, interpretation, and processing.

Sensation is the Layer 1 functions of the brain as modeled in LRMB as shown in Figure 1 (Wang et al., 2006). The *sensation layer* of LRMB is a subconscious layer of the brain for capturing sensory information supported by the sensory receptors. Although most of the primary senses are subconsciously processed, the main mechanisms of sensory receptors, nervous systems, pathways, and corresponding memories can be rationally analyzed and modeled based on neurological, physiological, and psychological observations.

Definition 2: The *primary senses* of the brain are physical and/or chemical stimuli of the real world directly captured by the sensory receptors such as those of *vision, hearing, smell, taste,* and *touch*.

Primary sensations are generated by the sensory neurons as sensory receptors.

Definition 3: The *perceptual senses* of the brain are composed sensory that are derived based on synthesized primary senses, as well as the current internal consciousness status, such as those of *spatiality, time, motion, posture, equilibrium, attention,* and *consciousness*.

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