Research Statement

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1 Introduction

My research primarily focuses on the broader context of leveraging multi-modal behavior sensing for smart cities, using methodologies in data-driven analytics, ubiquitous sensing and machine learning. To date, my research has a particular emphasis on **uncovering and influencing behavioral dynamics** for pervasive sensing for smart urban services, under three broader settings: (i) predictive analytics driven **city-scale sensing** for better transport modelling, (ii) **crowd/community sensing** for enhancing social cohesion, and (iii) **individualised monitoring of complex human states using wearable sensing**.

More specifically, over the past few years, my efforts are primarily driven towards the vision of "smart urban services", which requires a thorough understanding of urban mobility, context awareness, individual/collective human behaviour and potential challenges faced by city residents. The specific themes of my research interest are:

- **Wearables for Cognitive State Monitoring**
  The central goal of this project is to leverage the existing mobile and wearable devices (e.g., smartwatch and in-ear earbuds) for fine-grained and individualized monitoring of complex human states – the term "mental states" refers to both cognitive and affective states but are not part of the basic human emotions. More specifically, in this project, my aim is to understand and predict various cognitive states of humans (i.e., confused, distracted, focused etc.) while carrying out day-to-day activities (such as interacting with people, watching videos, online learning) using various cues observed using the on-body devices. To address this broader goal, I focus on the following key-points: (a) investigate novel sensors to be added to the existing wearable devices so that the smart devices can infer various cues related to cognitive states, (b) study various cues that can help us to profile various mental states. For example, (i) head gestures, such as nodding, shaking, turning, tilting etc., (ii) facial muscle movements, i.e., raising eyebrows, depressing/stretching lips, jaw drops etc., and (iii) eye gaze trend, such as blinks, saccades, gaze direction etc., and (c) devise a mental state recognition framework that relies on the cues we identified in (b) to predict individual complex cognitive states in near real-time.

- **Cognitive Test Battery for Modelling Intra-task Temporal Decay of Cognitive Skills**
  The focus of this project is on the age-sensitive core cognitive skill deficiencies faced

in the classroom by middle-aged adult learners (aged between 40 and 60) that can impede the entire learning process and academic performance. To be specific, our vision is to transform the traditional cognitive test battery process (such as Mini-Mental State Examination (MMSE) and Cambridge Neuropsychological Test Automated Battery (CANTAB)) that is predominantly designed for screening neurodegenerative diseases, such as Alzheimer's, into a continuous, convenient, and unobtrusive technology-mediated assessment of neurocognitive skills, such as memory recall, logical thinking, and focus/sustained attention, with a goal of ultimately bringing clinical sensing out of the clinic. More specifically, we propose computerised game-based neurocognitive test battery that uses wearable devices (such as smart glasses and earables) with embedded sensors to garner fine-grained insights on (a) how various biomarkers such as gaze, physiological signals, and body posture can act as foundational proxies to observe these complex cognitive skills, and (b) how such skills decay temporally while performing specific tasks (i.e., intra-task temporal decay of core cognitive functions) and how to quantify neurocognitive skill deficiencies as a function of such decay. We believe that, if successful, our research will prove that wearable devices-based cognitive tests can go beyond quantifying cognitive skill deficiencies (e.g., the standard mental state memory scores, such as MMSE) and help the learners to understand the fine-grained temporal dynamics of such skill deficiencies.

From a practical standpoint, the ability to empower such consumer-grade wearable devices (especially earables and smart glasses) to support continuous, unobtrusive monitoring of cognition would represent a breakthrough with widespread impact. In the area of remote education or online learning (a trend irreversibly accelerated by the pandemic), the ability to apply unobtrusive sensing to quantify a learner's affective and cognitive state (such as level of attentiveness, difficulty in comprehending the instructional material) can enable real-time, personalized instructional support. Likewise, in the area of elderly care and wellbeing, there is strong interest in being able to quantify the cognitive capabilities of elderly while performing everyday tasks (such as making coffee, counting coins, and sorting medicine), as such cognitive monitoring can help quantify (and even predict the onset of) conditions such as cognitive decline and dementia. Both of these application domains are of high strategic relevance to Singapore, including the Health & Human Potential (HHP) objectives of Singapore's RIE2025 research agenda.

2 Research Accomplishments

Grants:

- Ministry of Education Tier-1 AcRF, "Understanding Temporal Dynamics of Core Cognitive Functions for Individualised Learning", PI: Thivya Kandappu, May 2023 – May 2025, $123,755.09

- Ministry of Education Tier-1 AcRF, "Leveraging Mobile Sensing to Provide Early Detection of Meltdowns in Children with Autism", PI: Rajesh Balan Co-PI: Thivya Kandappu, Dong Ma, Min Lee, Andree Hartanto, Hwajin Yang, Nov 2023 – Nov 2024, $120,000
- Ministry of Education Tier-2, "BeyondTravel: A Multimodal Travel Records Analytics Framework", PI: Baihua Zheng, Co-PI: Thivya Kandappu, Nov 2020 – Oct 2023, $544,872
- A*STAR Career Development Award, "Detection and Obfuscation of Privacy Sensitive Artefacts in Visual Life-logs Used for Memory Enhancement", PI: Vigneshwaran Subbaraju, Collaborator: Thivya Kandappu, Aug 2020 – Jul 2023, $599,400
- Ministry of Education Tier-1 AcRF, "Context-aware Privacy Protection in Augmented Memory and Reality Applications", PI: Thivya Kandappu, Feb 2019 – July 2020, $91,200

Best Papers: Honorable Mention at CSCW 2016 (top-5% of the papers), Best Paper Award at COMSNETS 2014.
Recognition: Recognised as one of the 200 most qualified Young Researchers to attend Heidelberg Laureate Forum 2018.