Research Statement

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1. Background

My research lies at the intersection of mobile and ubiquitous sensing, cognitive modeling, and intelligent human-centered systems, with the long-term goal of building scalable, sensing-driven platforms that can understand and enhance human cognition and learning. Over the past decade, my work has progressed through three complementary stages: (i) large-scale behavioral sensing in naturalistic environments, (ii) fine-grained physiological modeling using eye movements, PPG, and neuromorphic vision, and (iii) adaptive AI-driven learning and creativity technologies that promote intrinsic motivation, curiosity, and self-regulated learning.

I pursue this agenda through three interrelated research threads:

- **Energy-efficient multimodal sensing for fine-grained cognitive and behavioral measurement**
  A central thrust of my work develops novel sensing pipelines, ranging from mobile wearables to neuromorphic event-based cameras, to capture subtle signatures of attention, cognitive load, visual search, motor execution, and affect. My recent projects advance energy-efficient and privacy-preserving methods for high-frequency sensing in everyday environments, enabling scalable and accessible measurement of human cognitive processes beyond laboratory settings.

- **Modeling intrinsic motivation, curiosity, and affective states**
  I build computational models that infer intrinsic motivation, curiosity, and affective states from multimodal physiological and behavioral signals. This includes work on pupil-linked curiosity markers, micro-saccadic signatures of cognitive effort, and paired sensor–behavioral representations that capture transitions in attention, engagement, and motivation. These models aim to advance the theoretical understanding of human cognition while providing practical mechanisms for real-time adaptation.

- **Designing adaptive and embodied learning technologies**
  Drawing on these sensing and modeling advances, I design intelligent learning technologies that adapt to learners' cognitive and affective states. My recent systems integrate physiological feedback with generative AI, supporting curiosity-driven exploration, embodied creative expression, and skill acquisition. These platforms use real-time human-state inference to scaffold reflection, sustain deep engagement, and ultimately foster creative and self-regulated learning.

2. Research Areas

A defining feature of my research program (illustrated in Figure 1) is a focus on problems that bridge foundational science with real-world impact, with strong alignment to both Singapore's Research, Innovation and Enterprise (RIE2025/30) priorities and current international research trends in mobile and ubiquitous computing. I choose research problems using the following guiding principles:

- National priorities with Long-Term Value: I focus on challenges that address not only immediate technical advances but also societal needs in education, health, and human capital development, directly supporting RIE2025/30 pillars such as Human Health and Potential (lifelong learning, resilient workforce). By designing systems that enhance how humans learn, engage, and adapt, my work contributes to Singapore's national vision of building a future-ready population empowered by technology.
- Cross-Disciplinary Leverage: My projects sit at the intersection of ubiquitous sensing, cognitive science, and AI, reflecting a broader research trend where mobile systems are increasingly fused with physiological and cognitive modeling. This cross-disciplinary approach enables me to open new research directions, such as curiosity-driven learning and embodied creativity, that a single field could not tackle alone, while aligning with Singapore's emphasis on interdisciplinary, translational research.

Thread 1: Energy-Efficient Sensing for Cognitive and Behavioral Understanding

This thread develops lightweight, high-precision sensing pipelines to capture the fine-grained physiological and behavioral markers that drive cognition and learning. A central focus is eye tracking as a proxy for attention allocation and information processing. We have designed neuromorphic-inspired sensing systems and event-driven pipelines that enable microsecond-level pupil detection while reducing energy consumption by 65%, making high-frequency eye tracking practical in real-world learning environments.

This thread has produced a **strong portfolio of publications** [C2-C5, J1] on physiological sensing and eye tracking, demonstrating the feasibility of **high-precision, low-power pupil tracking** in real-world settings. Our sensing pipeline achieved **state-of-the-art performance**, capturing microsecond-level pupil dynamics while significantly reducing energy consumption. These technical advances were recognized with **1st runner up place in the CVPR Eye Tracking Challenge (2025)**. The work has recently **received a competitive external grant (MOE AcRF Tier 2) of S$980k**, which will support the further development and scaling of these sensing systems.

Thread 2: Modeling Motivation, Curiosity, and Affect

While cognitive processes govern *what* we learn, motivation and affect shape *how deeply* we engage. This thread develops real-time models of intrinsic motivation, curiosity, and affective states by linking behavioral and physiological signals to learners' engagement dynamics. We study how curiosity unfolds over time by analyzing patterns such as: (a) pupil dilation and constriction during moments of uncertainty and insight, (b) skin conductance fluctuations linked to frustration or heightened engagement, and (c) motor dynamics (pressure, tilt, velocity) during expressive drawing, revealing affective modulation of motor control.

For example, our ongoing work integrates stylus-based sensing with pupillometry to predict when learners transition from focused exploration to disengagement, enabling adaptive scaffolds that sustain curiosity. This thread contributes to both theory and application: it advances foundational understanding of motivational dynamics while directly informing the design of adaptive learning systems that respond to learners' evolving states [C1 – studies the episodic memory recall failures in older adults].

Early insights from this thread demonstrated that curiosity can be effectively modeled using physiological signals, providing a foundation for real-time measurement of engagement and affect. Building on this work, a proposal we submitted on embodied creativity for the **SMU-SUTD internal grant program has been awarded S$400k**, reflecting ongoing efforts to translate affective and motivational modeling into practical learning applications.

Thread 3: Designing Adaptive, Embodied Learning Technologies

In the third thread, I translate insights from sensing and modeling into adaptive, embodied learning environments that actively partner with learners. This thread demonstrate my commitment to developing learning technologies that are not passive repositories but active collaborators, capable of scaffolding motivation, sustaining curiosity, and deepening creative capacity.

This thread has focused on translating insights from Threads 1 and 2 into adaptive, embodied learning technologies such as generative stimuli generation for learning, which integrate real-time sensing with AI-driven scaffolds to sustain engagement and curiosity. These efforts demonstrate a clear trajectory from **measurement and modeling to applied, high-impact educational systems**.

3. Grants and Funding:

3.1 External Grants:

1. "SynapSee: Multi-Light Probing for Event-Based Pupil Sensing in Neuro-Ocular Health Applications", *Principal Investigator*, Ministry of Education (MOE), AcRF Tier 2, S$ 980,696, 2026/01 – 2028/12 (**Awarded**), **PI:** Thivya KANDAPPU (SMU), **Co-PI:** Archan MISRA (SMU), Dong MA (SMU), Raymond NAJJAR (NUS)
2. "Unleashing the Potential of Photoplethysmography for Wearable Healthcare", Co-*Principal Investigator*, Ministry of Education (MOE), AcRF Tier 2, S$ 1,001,652, 2025/01 – 2028/01 (**Ongoing**), **PI:** Archan MISRA (SMU), Dong Ma (SMU) **Co-PI:** Rajesh BALAN (SMU), Thivya KANDAPPU (SMU)
3. AI-driven scaffolding of embodied creativity, *Co-PII,* Ministry of Education (MOE), Science of Learning, S$ 11,592,998 (**Under review**),
   PI: Ryutaro Uchiyama (SUTD) **Co-PI:** Thivya KANDAPPU (SMU), John KOMAR (NIE), Soh Gim Song (SUTD), Shaohui Foong (SUTD), Khoo Peng Beng (SUTD), Immanuel Koh (SUTD), David Hung (NIE), Yi Min Wan (NUHS), Wong Liang Han (MOE), Keri Tang (MOE)
4. "Improving the Selection Process for Pilots, Air Traffic Control, and Elite Athletes by Leveraging Out-of-band Sensing and Analytics", *Co-Principal Investigator*, NRF Trans 2.0, S$ 2,948,062 (**Under review**), **PI:** Rajesh BALAN, **Co-PI:** Yong Zhi LIM (RSAF), Chee Yong LOW (Sport SG), Swapna GOTTIPATI (SMU), Thivya KANDAPPU (SMU)
5. "Scalable Privacy Preserving and Accurate Monitoring of Cardiovascular and Related Ailments Amongst a General Indian Population Exposed to Elevated Air Pollution", *Co-Principal Investigator*, A*STAR & DST – Joint Grant Call, S$ 247,000 (**Under review**), **PI:** Rajesh BALAN (SMU), Rijurekha SEN (IIT, Delhi), **Co-PI:** Swapna GOTTIPATI (SMU), Thivya KANDAPPU (SMU)
6. "BeyondTravel: a Multimodal Travel Records Analytics Framework", *Co-Principal Investigator*, Ministry of Education (MOE), AcRF Tier 2, S$ 544,872 (**Completed**), **PI:** Baihua ZHENG (SMU), **Co-PI:** Thivya KANDAPPU (SMU)

3.2 Internal Grants:

1. "Modeling the effect of exploration-inducing phenotypes on age-related deficits in urban spatial cognition", *Principal Investigator*, Ministry of Education (MOE) Tier 1 (SMU-SUTD Joint Grant), S$ 400,000 (**Awarded**), **PI:** Thivya KANDAPPU (SMU), Ryutaro UCHIYAMA (SUTD)
2. "Understanding Temporal Dynamics of Core Cognitive Functions for Individualised Learning", *Principal Investigator*, Ministry of Education (MOE) Singapore Tier 1, S$ 123,755, 2023/05 – 2025/05 (**Completed**) **PI:** Thivya KANDAPPU (SMU), **Co-PI:** Archan MISRA (SMU)

3. “Context-aware Privacy Protection in Augmented Memory & Reality Applications”, *Principal Investigator*, Ministry of Education (MOE) Singapore Tier 1, S$100,000, 2019/02 – 2020/08 (**Completed**), **PI:** Thivya KANDAPPU (SMU)
4. “Leveraging Mobile Sensing to Provide Early Detection of Meltdowns in Children with Autism”, *Collaborator*, Singapore Ministry of Education Tier 1, 2024/01-2025/07, 120,000 SGD (**On-going**) **PI:** Rajesh BALAN, **Collaborator:** Thivya KANDAPPU, Dong MA, Min LEE, Hwajin YANG, Andree HARTANTO, Kyong Jin SHIM

List of Publications

Journals

[J1] EyeTrAES: Fine-grained, low-latency eye tracking via adaptive event slicing, by SEN, Argha; BANDARA, Nuwan Sriyantha; GOKARN, Ila; KANDAPPU, Thivya; MISRA, Archan. (2024). Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 8 (4), 1-32. https://doi.org/10.1145/3699745

[J2] BreathPro: Monitoring breathing mode during running with earables, by HU, Changshuo; KANDAPPU, Thivya; LIU, Yang; MASCOLO, Cecilia; MA, Dong. (2024). Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 8 (2), 1-25. https://doi.org/10.1145/3659607

[J3] A data-driven approach for scheduling bus services subject to demand constraints, by BRAHMANAGE, Janaka Chathuranga; KANDAPPU, Thivya; ZHENG, Baihua. (2023). IEEE Transactions on Knowledge and Data Engineering, 35 (7), 6534-6547. https://doi.org/10.1109/TKDE.2022.3188243

[J4] PrivacyPrimer: Towards privacy-preserving Episodic memory support for older adults, by KANDAPPU, Thivya; SUBBARAJU, Vigneshwaran; XU, Qianli. (2021). Proceedings of the ACM on Human-Computer Interaction, 5 (CSCW2), 1-32.

[J5] Obfuscation at-source: Privacy in context-aware mobile crowd-sourcing, by KANDAPPU; MISRA Archan; CHENG Shih-Fen; TANDRIANSYAH Randy; LAU Hoong Chuin (2018). Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 2(1), pp.1-24.

[J6] Scalable urban mobile crowdsourcing: Handling uncertainty in worker movement, by CHENG Shih-Fen; CHEN Cen; KANDAPPU Thivya; LAU Hoong Chuin; MISRA Archan, JAIMAN Nikita; TANDRIANSYAH Randy; KOH Desmond, Proceedings of the ACM Transactions on Intelligent Systems and Technology (TIST), 9, no. 3 (2017): 1-24.

Conferences

[C1] EmoShortcuts: Emotionally Expressive Body Augmentation for Social Mixed Reality Avatar, SEO HyunA; LEE Youngki; BALAN Rajesh; KANDAPPU Thivya, In Proceedings of ACM Symposium on User Interface Software and Technology (UIST) (2025): Busan, Korea (Accepted)

[C2] Inference-Time Gaze Refinement for Micro-Expression Recognition: Enhancing Event-Based Eye Tracking with Motion-Aware Post-Processing, BANDARA Nuwan; KANDAPPU Thivya; MISRA Archan, Proceedings of the IJCAI Workshops, 2025

[C3] Event-based eye tracking, Qinyu, Chang Gao, Min Liu, Daniele Perrone, Yan Ru Pei, Zuowen Wang, Zhuo Zou et al. In Proceedings of the Computer Vision and Pattern Recognition Conference, pp. 5164-5176. 2025.

[C4] NTIRE 2025 Challenge on Event-Based Image Deblurring: Methods and Results , Sun, Lei, Andrea Alfarano, Peiqi Duan, Shaolin Su, Kaiwei Wang, Boxin Shi, Radu Timofte et al. In Proceedings of the Computer Vision and Pattern Recognition Conference, pp. 1324-1341. 2025.

[C5] EyeGraph: Modularity-aware spatio temporal graph clustering for continuous event-based eye tracking, by BANDARA, Nuwan; KANDAPPU, Thivya; SEN, Argha; GOKARN, Ila;

MISRA, Archan. (2024). Proceedings of 38th Annual Conference on Neural Information Processing Systems (NeurIPS 2024): Vancouver, Canada, December 10-15.

[C6] Detecting foot strikes during running with earbuds, by HU, Changshuo; KANDAPPU, Thivya; STUCHBURY-WASS, Jake; LIU, Yang; TANG, Anthony; MASCOLO, Cecelia; MA, Dong. (2024). BodySYS '24: Proceedings of the 10th Workshop on Body-Centric Computing Systems, Tokyo, June 3-7, (pp. 35-40) New York: ACM. https://doi.org/10.1145/3662009.3662023

[C7] PrivObfNet: A weakly supervised semantic segmentation model for data protection, by TAY, Chiat Pin; SUBBARAJU, Vigneshwaran; KANDAPPU, Thivya. (2024). Proceedings of the 2024 IEEE/CVF Winter Conference on Applications of Computer Vision: Waikoloa, HI, January 4-8, (pp. 2410-2420) Los Alamitos, CA: IEEE. https://doi.org/10.1109/WACV57701.2024.00241

[C8] MetroWatch: A predictive system to estimate travel attributes using smart card data, by BRAHMANAGE, Janaka; KANDAPPU, Thivya; ZHENG, Baihua. (2023). Proceedings of the 39th IEEE International Conference on Data Engineering (ICDE'23), Anaheim, CA, USA, 2023 April 3-7, (pp. 3607-3610) Piscataway, NJ: IEEE. https://doi.org/10.1109/ICDE55515.2023.00279

[C9] Wearables for in-situ monitoring of cognitive states: Challenges and opportunities, by RADHAKRISHNAN, Meera; KANDAPPU, Thivya; GULATI, Manoj; MISRA, Archan . (2023). Proceedings of the 2023 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops), Atlanta, GA, March 13-17, (pp. 671-676) New Jersey, USA: IEEE. https://doi.org/10.1109/PerComWorkshops56833.2023.10150270

[C10] PrivAttNet: Predicting privacy risks in images using visual attention, by CHEN, Zhang; KANDAPPU, Thivya; SUBBARAJU, Vigneshwaran. (2021). Proceedings of the 25th International Conference on Pattern Recognition, ICPR 2020, Virtual Conference, 2021 January 10-15, Virtual Conference:

[C11] PokeME: Applying context-driven notifications to increase worker engagement in mobile crowd-sourcing, by KANDAPPU, Thivya; MEHROTRA, Abhinav; MISRA, Archan; MUSOLESI, Mirco; CHENG, Shih-fen; MEEGAHAPOLA, Lakmal Buddika. (2020). CHIIR '20: Proceedings of the 5th Conference on Human Information Interaction and Retrieval, Vancouver, March 14-18, (pp. 3-12) New York: ACM. https://doi.org/10.1145/3343413.3377965

[C12] Buscope: Fusing individual & aggregated mobility behavior for" live" smart city services, by MEEGAHAPOLA, Lakmal; KANDAPPU, Thivya; JAYARAJAH, Kasthuri; AKOGLU, Leman; XIANG, Shili; MISRA, Archan. (2019). 17th ACM International Conference on Mobile Systems, Applications, and Services, MobiSys 2019; Seoul; South Korea; Jun 17-21, 2019, (pp. 41-53) New York: ACM. https://doi.org/10.1145/3307334.3326091

[C13] A feasibility study on crowdsourcing to monitor municipal resources in smart cities, by KANDAPPU, Thivya; MISRAN, Archan; KOH, Desmond; TANDRIANSYAH, Randy Daratan; JAIMAN, Nikita. (2018). Proceedings of the 27th International World Wide Web, WWW 2018; Lyon; France; April 23-27, 2018, (pp. 919-925) New York: acm. https://doi.org/10.1145/3184558.3191519

[C14] Privacy in context-aware mobile crowdsourcing systems, by KANDAPPU, Thivya; MISRA, Archan; CHENG, Shih-Fen; LAU, Hoong Chuin. (2017). Proceedings of the IEEE International Conference on Pervasive Computing and Communications Workshops, PerCom Workshops 2017, Kona, Big Island, United States, March 13-17, (pp. 231-236) New York: IEEE.

[C15] Collaboration trumps homophily in urban mobile crowdsourcing, by KANDAPPU, Thivya; MISRA, Archan; TANDRIANSYAH, Randy. (2017). CSCW '17: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing; Portland, OR, February 25- March 1, (pp. 902-915) NewYork: ACM. https://doi.org/10.1145/2998181.2998311

[C16] A campus-scale mobile crowd-tasking platform, by JAIMAN, Nikita; MISRA, Archan; DARATAN, Randy Tandriansyah; KANDAPPU, Thivya. (2016). UbiComp '16: Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing, Heidelberg; Germany, September 12-16, (pp. 297-300) New York: ACM. https://doi.org/10.1145/2968219.2971388

[C17] TASKer: behavioral insights via campus-based experimental mobile crowd-sourcing, by KANDAPPU, Thivya; JAIMAN, Nikita; TANDRIANSYAH, Randy; MISRA, Archan; CHENG, Shih-Fen; CHEN, Cen; LAU, Hoong Chuin; CHANDER, Deepthi; DASGUPTA, Koustuv. (2016). Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing, 17; Heidelberg; Germany; September 12-16, 2016, (pp. 392-402) New York: ACM. https://doi.org/10.1145/2971648.2971690

[C18] Demo: TA$Ker: Campus-scale mobile crowd-tasking platform, by JAIMAN, Nikita; KANDAPPU, Thivya; TANDRIANSYAH, Randy; MISRA, Archan. (2016). MobiSys '16: Companion publications of the 14th Annual International Conference on Mobile Systems, Applications, and Services, Singapore, June 25-30, (pp. 105-105) New York: ACM. https://doi.org/10.1145/2938559.2938587

[C19] Campus-scale mobile crowd-tasking: deployment & behavioral insights, by Thivya Kandappu; Archan Misra; Shih-Fen Cheng; Nikita Jaiman; Randy Tandriansiyah; Cen Chen; Hoong Chuin Lau; Deepthi Chander; Koustuv Dasgupta. (2016). Proceeding of 19th ACM Conference on Computer-Supported Cooperative Work and Social Computing, CSCW; San Francisco; United States; 27 February-2 March, 2016, (pp. 800-812) New York: ACM. https://dl.acm.org/doi/10.1145/2818048.2819995

[C20] PrivacyCanary: Privacy-aware recommenders with adaptive input obfuscation, by KANDAPPU, Thivya; FRIEDMAN, Arik; BORELLI, Roksan; SIVARAMAN, Vijay. (2015). Proceeding of the 22nd Annual IEEE International Symposium on Modeling, Analysis and Simulation of Computer, and Telecommunication Systems, MASCOTS; Paris; France; September 9-11, 2014, (pp. 453-462) Washington, DC: IEEE Computer Society. https://doi.org/10.1109/MASCOTS.2014.62

[C21] Loki: A privacy-conscious platform for crowdsourced surveys, by KANDAPPU, Thivya; SIVARAMAN, Vijay, FRIEDMAN, Arik, BORELI, Roksana. (2014). 2014 6th International Conference on Communication Systems and Networks, COMSNETS; Bangalore; India; January 7-10: Proceedings, (pp. 1-8) Piscataway, NJ: IEEE. https://doi.org/10.1109/COMSNETS.2014.6734877

[C22] Exposing and mitigating privacy loss in crowdsourced survey platforms, by KANDAPPU, Thivya; SIVARAMAN, Vijay; FRIEDMAN, Arik; BORELL, Roksana. (2013). Proceedings of the ACM CoNEXT Student Workshop; Santa Barbara, CA; United States; 2013 December 9., (pp. 13-15) Santa Barbara, USA: ACM. https://doi.org/10.1145/2537148.2537150

[C23] A novel unbalanced tree structure for low-cost authentication of streaming content on mobile and sensor devices, by KANDAPPU, Thivya; SIVARAMAN, Vijay; BORELI, Roksana. (2012). Proceedings of the 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON), Seoul, South Korea, 2012 June 18-21, (pp. 488-496) Washington, DC: IEEE Computer Society. https://doi.org/10.1109/SECON.2012.6275816