Ananta Narayanan Balaji

Personal Information

UNIVERSITY:	National University of Singapore
MAJOR:	Electrical and Computer Engineering
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ADDRESS:	Systems and Networking Lab 6, School of Computing, NUS
PERSONAL WEBPAGE:	https://anantabalaji.github.io
LINKEDIN PAGE:	https://www.linkedin.com/in/anantabalaji/

Research Interests

Low-power Mobile/Wearable Computing and sensing, On-device ASIC/FPGA-based AI architectures for future resource-constrained wearables, and Efficient Deep Learning solutions for sensor data-driven AI applications.

Education

2018-2023	Ph.D. Candidate in Electrical and Computer Engineering Specialization: Signal Processing and Machine Intelligence National University of Singapore Thesis title: Design of Wearable Applications and Platforms for Next Generation Personalized Sensing Advisor : Prof. Peh Li-Shiuan CAP: 4.6/5
2015-2016	M.Sc. in Computer Engineering National University of Singapore Thesis title: Segmentation of femoral head in 3D ultrasound images of infants Advisor : Prof. Ashraf Kassim CAP : 4.45/5
2011-2015	B.E. in Electronics and Computer Engineering Thiagarajar College of Engineering, India CGPA: **9.9/10 (1st of 150)**

Work Experience

Jan 2024 -	**Research Scientist** @ Nokia Bell Labs, Singapore Novel Low-power sensing and compute solutions for earable devices.
Oct 2023 - Jan 2024	**Research Scientist** @ Respiree Singapore Signal Processing and ML solutions for robust clinical-grade respiration sensing and pulmonary disease progression.
May 2022 - Aug 2022	**Research Scientist Intern** @ Meta Reality labs, Redmond **Advisors :** Dr. Morteza Khaleghimeybodi, Dr. Jennifer Monti, Dr. Anurag Kumar, Dr. Thomas Lunner Singe PPG only in-ear earable hardware prototype development and accompanying calibration-free (wrist/in-ear) motion-resilient blood pressure sensing technique based on signal processing and deep transfer learning
Sep 2021 - Nov 2021	**Research Intern** @ Nokia Bell labs, Cambridge **Advisors :** Dr. Alessandro Montanari, Senior Research Scientist

	[Dr. Fahim Kawsar](#), Founding Director of Pervasive Systems research
	Stereo in-ear PPG-based blood pressure sensing and Systematic characterization of facial motion artifacts observed in-ear PPG signals.
Mar 2020 - Jun 2020	**Research Intern** @ Google, San Francisco
	Advisors : [Dr.David Kim](#), Research Scientist and Software Manager
	[Dr. Ruofei Du](#), Research Scientist
	Low-power, Low-compute, and User-friendly 3D input tracking for future Augmented reality devices.
	ACM IMWUT (ACM Ubicomp 2023) Distinguished Paper Award Vol. 6
Jan 2019 - Jun 2019	**Software Engineer** @ Portcast, Singapore
	Developed an optimal route prediction algorithm for marine logistics
Oct 2016 - Dec 2017	**AI engineer** @ Works Applications, Singapore
	Worked on NLP/Deep learning-based automatic form filling from PDFs for payment invoices
Apr 2016 - Jul 2016	**Research Intern** @ Temasek Labs, NUS
	Advisor: [Dr. Garrick Orchard (Now Sr. Research Scientist @ Intel)](#)
	Noise filtering and UAV tracking with Neuromorphic cameras.
Dec 2015 - Mar 2016	**R&D Intern** @ Panasonic R&D Center, Singapore
	Mentor: Mr. WEI Zheng (Now R&D Director @ Deep North Inc.)
	Developed deep learning based Sentence Classification for Chatbots.

PUBLICATIONS

1. pH Watch - Leveraging Pulse Oximeters in Existing Wearables for Reusable, Real-time Monitoring of pH in Sweat
   Ananta Narayanan Balaji*, *Chen Yuan*, Bo Wang, Li-Shiuan Peh, Shao Huilin*
   ACM International Conference on Mobile Systems, Applications, and Services (MobiSys) 2019
   Media Coverage : [Straitstimes](#), [NUS News](#), [Healthtech Insider](#), [ACM news](#) etc.

   - pH Watch proposes a passive sweat pH (an indicator of dehydration risk) sensing approach using PPG sensors found in today's smartwatches.

2. AI-on-skin: Enabling On-body AI Inference for Wearable Artificial Skin Interfaces
   Ananta Narayanan Balaji, *Li-Shiuan Peh*
   CHI'21: 2021 CHI Conference on Human Factors in Computing Systems, May 2021
   Media Coverage : [Hackster.io](#)
   Project webpage : https://aionskin.github.io/

   - AI-on-skin integrates wearable artificial skin interfaces with an on-body neural network hardware accelerator that can be reconfigured across diverse neural network models and applications.

3. AI-on-skin: Towards enabling On-body AI Inference for Wearable Artificial Skin Interfaces
   Ananta Narayanan Balaji, *and Li-Shiuan Peh*
   Proceedings of the ACM on Human-Computer Interaction, EICS 2023
   Project webpage : https://aionskin.github.io/

   - In this work, we proposed a distributed AI-on-skin compute architecture comprising tiny, low-power, accelerators distributed across the body. Through real-time demonstrations, AI-on-skin motivates the need for an efficient on-body AI compute for future smart textiles.

4. RetroSphere: Self-Contained Passive 3D Controller Tracking for Augmented Reality
   Ananta Narayanan Balaji, *David Li, Clayton Kimber, Shenghzhi wu, Ruofei Du and David Kim*
   Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 2022
   (IMWUT/ACM Ubicomp'23)
   Project webpage : https://retrospherev1.github.io/

     - RetroSphere is a low-cost, low-power, and low-compute self-contained 6DoF tracker
       that can provide 3D input on almost any device.

5. EarSet: A Multi-Modal Dataset for Studying the Impact of Head and Facial Movements on
   In-Ear PPG Signals
   Andrea Ferlini*, Alessandro Montanari*, **Ananta Narayanan Balaji**, *Cecilia Mascolo and Fahim Kawsar*
   Nature Scientific Data 2023 (To Appear)

     - *EarSet* is a novel, multi-modal, dataset that allows studying of the impact of body and
       head/face movements on both the morphology of the PPG signal captured at the ear,
       as well as on the vital signs estimation.

6. Stereo-BP: Non-invasive Blood pressure sensing with earables
   Ananta Narayanan Balaji, *Andrea Ferlini, Alessandro Montanari and Fahim Kawsar* 24th ACM
   International Workshop on Mobile Computing Systems and Applications (HotMobile 2023)
   Project webpage : https://anantabalaji.github.io/stereoBP.html

     - Stereo-BP leverages the pulse time differences between left and right ears for non-
       invasive blood pressure sensing with earables.

7. SeRaNDiP - Leveraging Inherent Sensor Random Noise for Differential Privacy Preservation
   in Wearable Community Sensing Applications
   Ayanga Kalupahana, **Ananta Narayanan Balaji**, *Xiaokui kui and Li-shiuan Peh* Proceedings of
   the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 2023 (IMWUT/ACM
   Ubicomp 2023)

     - SeRaNDiP is a differential privacy framework that utilizes the inherent random noise
       existing in wearable sensors for community sensing applications that rely on wearable
       sensor data.

8. 1.7pJ/SOP, 0.5V Scalable Neuromorphic Processor with Integrated Partial Sum Router for In-
   Network Computing
   B. Wang, M. M. Wong, D. Li, Y.S. Chong, J. Zhou, W. F. Wong, **Li-shiuan Peh**, *A. Mani, M. Upadhyay,*
   Ananta Narayanan Balaji, *and A. T. Do* 2023 IEEE International Symposium on Circuits and
   Systems, ISCAS 2023.

Manuscripts to be submitted

1. StressScope: Real-time, non-invasive and reusable cortisol sensing from sweat
   Ananta Narayanan Balaji*, *Chen Yuan*, Li-Shiuan Peh, Shao Huilin*

     - Off-the-shelf sensing solution for real-time and reusable cortisol sensing from
       sweat with existing wearables.

Patents

1. Wearable sweat sensor
   Ananta Narayanan Balaji*, *Chen Yuan*, Bo Wang, Li-Shiuan Peh, Shao Huilin*
   WO2021107871A1 2019

2. Infrared camera-based 3D tracking using one or more reflective markers
   Ananta Narayanan Balaji, *Clayton Kimber, Ruofei Du, David Kim* **(Google)**
   US Patent Application 18/495,483 2024

3. In-ear blood pressure sensing device
   Ananta Narayanan Balaji, *Morteza Khaleghimeybodi, Jennifer Monti, Thomas Lunner*

(Meta Reality Labs)
US Patent Application 2022 (Pending)

4. Multimodal silent speech interfaces with future AR/VR devices
Ananta Narayanan Balaji, *Morteza Khaleghimeybodi, Melinda Anderson, Thomas Lunner* **(Meta Reality Labs)**
US Patent Application 2022 (Pending)

DEMO

1. pH Watch - Leveraging Pulse Oximeters in Existing Wearables for Reusable, Real-time Monitoring of pH in Sweat
Ananta Narayanan Balaji*, *Chen Yuan*, Bo Wang, Li-Shiuan Peh, Shao Huilin*
ACM International Conference on Mobile Systems, Applications, and Services (MobiSys) 2019

REVIEWER

2020	IMWUT, CHI
2021	IMWUT, CHI, TEI, DIS, Ubicomp/ISWC, EICS
2022	IMWUT, CHI, TEI, Transaction on Computers(TC), Ubicomp/ISWC
2023	Reviewer : ACM IMWUT, CHI, CSCW, IEEE TBME
	PC Member: Mobisys Artifacts Evaluation, EICS Late Breaking Work
2024	Reviewer: CHI, UIST, IMWUT,DIS, EuroHaptics
	PC Member: Mobicom Artifacts Evaluation, Ubicomp/ISWC, Mobisys Artifacts Evaluation, Earcomp

INVITED TALKS

1. "Making Smartwatches to sense dehydration" – CS Research Week, NUS School of Computing - August 2020.

2. "Making Smartwatches to sense dehydration" – Systems and Networking Seminar Series – NUS School of Computing - January 2021.

3. Next generation Low power Wearable applications - Biosensors seminar series, Meta Reality Labs - Oct 2022.

4. Next generation Wearables - Pervasive Systems group, Nokia Bell Labs - Sep 2023.

AWARDS AND SCHOLARSHIPS

2024	Only PhD Student to be Nominated for ACM SIGMOBILE Doctoral Dissertation Award from School of Computing at National University of Singapore.
2023	ACM IMWUT (Ubicomp 2023) Distinguished Paper Award for Retrosphere
2018-2022	NUS Research Scholarship Award
2015	Best outgoing student - Medal of Excellence, Thiagarajar College of Engineering
2011-2015	Academic Proficiency Award, Thiagarajar College of Engineering
2014	Top 10 Finalists in Honeywell Young Innovators Challenge

Programming Skills

Proficient:	C/C++ (Embedded software development), Python, Java, JavaScript, SystemVerilog
ML/DL libraries and Tools:	PyTorch, TensorFlow, Tf-lite, AWS SageMaker, Microsoft Azure ML, IBM Watson, CMSIS (Arm neural network library), Mxnet etc.
Basic Knowledge:	VHDL, Matlab, Synopsis, SQL, Cassandra
Development Boards:	Raspberry Pi, Pynq FPGA, Ultra96 FPGA etc.
Sensors:	PPG, EMG, EEG, ECG, Temperature sensors, Cameras, Depth cameras, GSR and microphones

References

1. Prof. Li-Shiuan Peh
   Provost's chair professor, School of Computing, National University of Singapore.

2. Prof. Chan Mun Choon
   Professor, School of Computing, National University of Singapore.

3. Dr. David Kim
   AR Prototyping Lead, Google.

4. Dr. Alessandro Montanari
   Principal Research Scientist and Technical Lead, Nokia Bell Labs, Cambridge.

5. Dr. Morteza Khaleghimeybodi
   Principal Research Scientist, Meta Reality Labs, Redmond.