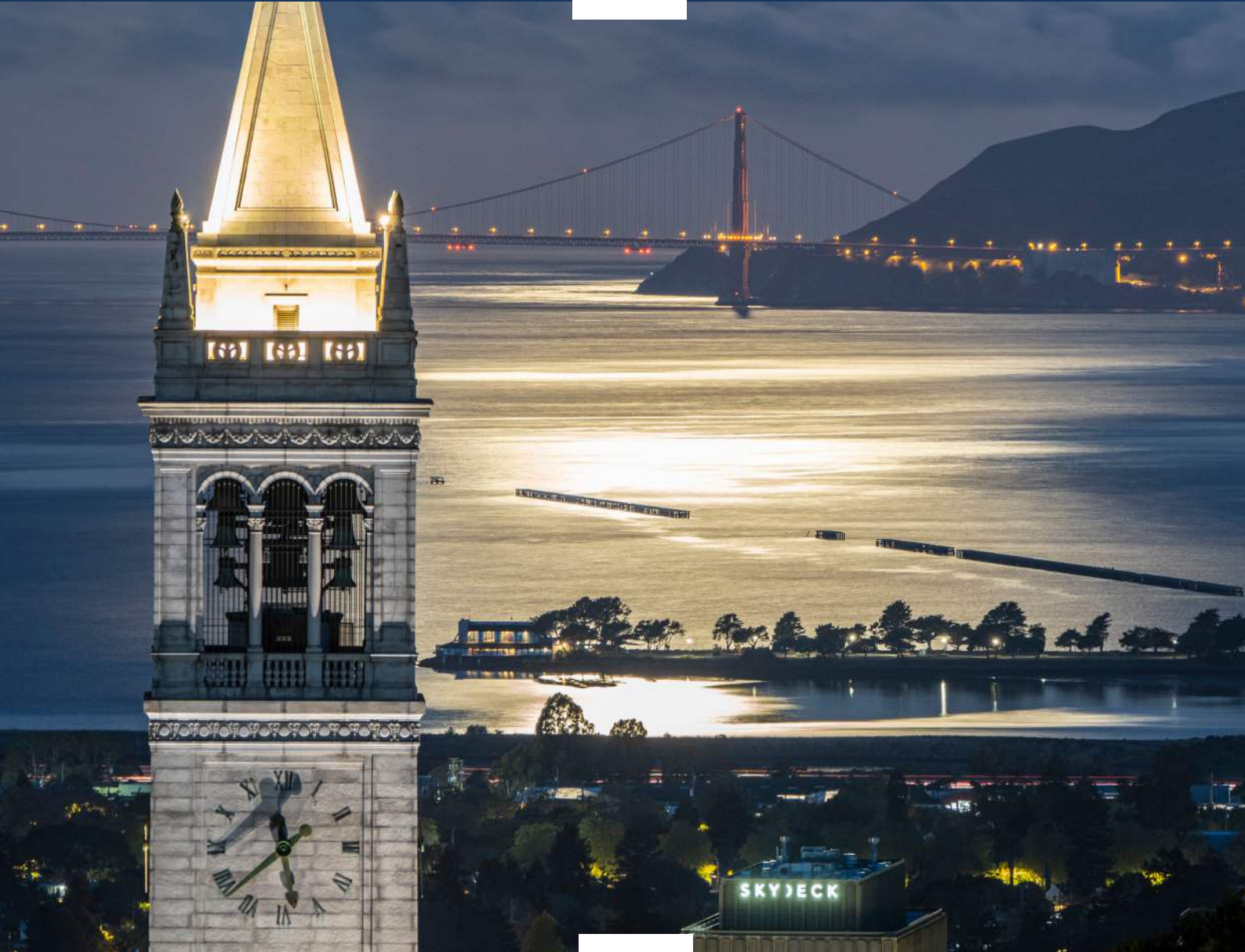




FHL VIVE CENTER

FOR ENHANCED REALITY



ANNUAL REPORT

2022



3rd Place





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MESSAGE FROM ALLEN YANG

One of the hottest topics in 2022 is clearly the advancement of AI technologies and new product demos that they underpin. In Natural Language Processing (NLP), new deep learning-based models not only can demonstrate Turing Test passing results, but also have stirred debates about whether AI has started competing with human users for jobs. In the automotive industry, we continue to see innovation of autonomous driving solutions in the forms of autopilots, robotaxis, and service robots.

With great excitement, a group of MEng students from EECS and ME departments joined me, and we established the Berkeley ROAR Racing team to participate in the Indy Autonomous Challenge as part of the AI Racing Tech together with Hawaii, UCSD, and CMU. As a new team in AI racing and some may say an underdog, our students put their hard work and passion into the project, and achieved surprising winning results in head-to-head competitions at speed up to 150 mph: winning 2nd place at 2022 Indy Dallas Race and 3rd place at 2023 Indy CES Race. I also must acknowledge that several of our graduated alumni currently working at Tesla, Intel, Google, etc. donated their valuable time and engineering expertise to be part of our exciting journey in pushing AI innovation in motorsports.

In the area of AR/VR and immersive computing, our faculty has started working on expanding our teaching curriculum to answer the calls from many undergraduate students to have a mezzanine-level course on the topic. One of our student teams participated in the MIT Reality Hackathon and received the dolby.io mixed reality award. We expect to see more innovations and consumer hardware products to be introduced in the market in the coming year.

Finally, our faculty and students are excited about exploring new applications in the domain of metaverse. One special research area that we have been looking into is decentralized identity, interoperability across metaverse applications, and user privacy. We call for more collaboration with our industry partners to truly democratize the power of computing and information technologies to the masses.

Sincerely,
Allen Yang
Executive Director, FHL Vive Center for Enhanced Reality





MESSAGE FROM SHANKAR SASTRY

Watching the growth of the FHL Vive Center since its launch in 2019 has been an exciting ride. From the most difficult years of the pandemic, in 2022 we gathered in-person – most notably, last November, to celebrate placing silver in the Indy Autonomous Challenge at Texas Motor Speedway outside of Fort Worth.

As this report is being prepared, we are also celebrating an early 2023 third-place award at the Las Vegas Motor Speedway on January 7, as part of the annual Consumer Electronics Show. We continue to advance the science, pushing the boundaries of autonomous vehicles and contributing to increased safety and performance.

Another critical part of our mission is to develop the next generation of engineers and computer scientists who will design the autonomous vehicles of tomorrow. Now in its third year, the ROAR Academy is expanding its K-12 outreach into more regions and countries to ensure we're providing STEM opportunities to diverse audiences. Similarly, our Ambassador Program has doubled in size, from 2 to 4 students, bringing the ROAR experience into their high schools in and around the Bay Area.

The open-source, low-cost, autonomous driving ROAR racing platform is now in use by several graduate-level research courses here at UC Berkeley, in Robotics, Deep Reinforcement Learning, Computer Vision, and AR/VR.

Meanwhile, our space over at the Richmond Field Station is enabling us to begin building out our awaited Go-Kart Racing Series.

Beyond our now well-established – and award-winning – partnership with the University of Hawaii and fellow universities on the Indy Challenge team, we are also now partnering with the University of Southern California's Team Aegis, on the 2023 NASA S.U.I.T.S. Challenge.

I am very excited to see where 2023 will take this exciting, young, growing organization. We invite you to join our efforts, follow our news, and of course, we welcome your donations.

Sincerely,
Shankar Sastry
Founding Director, FHL Vive Center for Enhanced Reality

Highlights



AI Racing Tech (UCSD - Hawaii - Berkeley) Team wins 2nd place at 2022 IAC Dallas

AI Racing Tech Wins Silver Medal at Indy Autonomous Challenge Dallas Race

It can only be described as an understatement that winning a Top 3 ranking in 2022 season Indy Autonomous Racing has never been a topic discussed among our team members when we arrived at Dallas. We ARE a clear underdog, starting competing in AI racing events just in 2021 and going against a slew of battle-tested European racing teams. So we are beyond thrilled to cap out our 2022 experience with a Runner-Up Silver Medal win for the Indy Autonomous Challenge at Dallas on November 11, 2022.

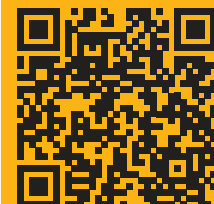
First, we have to give credits to all graduate and undergraduate students of the Berkeley ROAR Racing team:

Project Manager: CK Wolfe, Aman Saraf.

Racing Perception: Aman Saraf (lead), Tianlun Zhang (lead), Junjie Chen, Xuan Liu, Franco Leonardo Huang, Cyrus Hung, Carl Gan, and Yunhao Cao.

Vehicle Dynamics: Jad Yahya (lead).

Vehicle Simulation: Jazzy Rao (lead), Aman Saraf, Tianlun Zhang, Xiushi Shen, and Aaron Xie (a highschool ROAR Ambassador).



View the full broadcast of the 2022 Indy Autonomous Challenge.



Berkeley ROAR team celebrates their success at Vive Center Gala (2022)

Second, Our students are trained to develop cutting-edge AI racing solutions from two Berkeley programs:

First, we have been running ROAR Racing graduate study program with the Coleman Fung Institute for Engineering Leadership . Most of our graduate students have been recruited from their strong pool of candidates. Thanks to the interdisciplinary organization, the program allows the best experienced students from both ME and EECS Departments to team up, leading to a diverse skill set that is necessary to develop on a full-scale 200-mph capable racing vehicle.

Second, many of our undergraduate students, including some high schoolers accepted through our ROAR Ambassadors Fellowship, have been trained via our STEM educational program called Robot Open Autonomous Racing (ROAR) Academy.

Third, At UC Berkeley, the ROAR Racing platform has been made available for several graduate-level research courses, including Robotics (EE 106/206), Deep Reinforcement Learning (CS 285), Computer Vision (CS 280), and AR/VR (CS 294-137). We are proud to see our ROAR ecosystem continues to support advanced research projects at the highest academy level.

Where do we go from here? We always believe the future is brighter and there are more good things in store for us as innovators and developers. Our immediate goal for 2023 is to continue our endeavor to democratize AI education and research through expanding high-quality, accessible, open-source competitions. Together with our other UC campuses and their faculty collaborators, we plan to launch an intercollegiate AI Go Kart Competition. We are calling interested industry partners and other universities to join forces to create a high-caliber, best-in-class research and education platform for the next generation innovators.

ROAR Ambassador Program 2023 Class



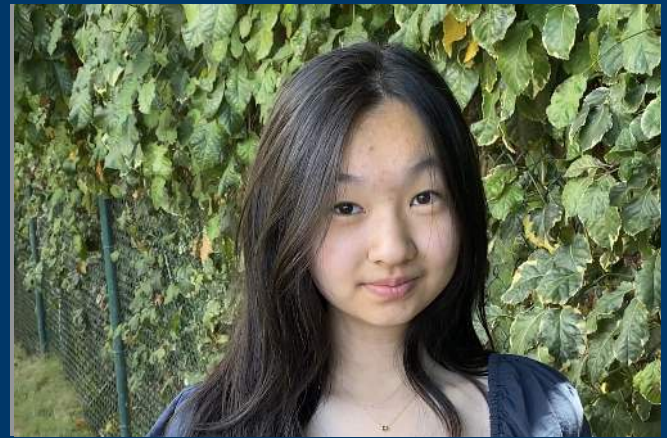
Aaron Xie, Campolindo High School



Harris Song, Walnut High School



Benny Liu, Valley Christian High School



Vivian Zhu, Vista Del Lago High School



The Berkeley ROAR Ambassador program was launched in 2022 to recognize the outstanding efforts and dedication of selective high school students who have been veterans of our ROAR platform, who have successfully completed ROAR AI Racing, and would like to contribute more by becoming an advocate and leader at their own school communities. The program sponsors activities at ambassador schools including organizing AI and Autonomous Driving seminars, participating in ROAR AI Racing, providing program feedback to us, and potentially becoming an active researcher to help grow the Berkeley ROAR program. Each ROAR ambassador are teamed up with one ROAR faculty member and one graduate student at Berkeley.

A year later, we want to thank our 2022 Ambassador Cameron Shaw for all his contributions to the ROAR platform at Athenian High School. Furthermore, we are thrilled to announce our new class of 2023 ROAR Ambassadors, Harris Song, Zeyu (Benny) Liu, and Vivian Zhu. Furthermore, Aaron Xie's ambassadorship has been extended for another year.

Aaron Xie has currently participated in four ROAR simulation racing competitions. Going into this second year as a ROAR ambassador, he plans to continue entering future competitions and learning more about artificial intelligence. In addition to autonomous driving, Aaron is interested in other computer science applications, such as game design, networking, and mixed reality.

Harris Song is a junior at Walnut High School in Walnut, California. He has participated in the 2022 Summer ROAR Academy and competed in the fall 2022 ROAR series. He enjoys hiking through the local Los Angeles mountains with friends and trying new drinks at local cafés.

Benny Liu is currently a junior at Valley Christian High School in California. Benny was first introduced to the ROAR program during the summer of 2022, attending the ROAR academy and taking part in the competition. He is now taking many stem-related classes, such as Multi-Variable Calculus and AP Physics C. He is immensely interested in programming, working on many Python and Java related projects during his free time. He also enjoys pondering and solving logical problems and wants to improve his coding abilities.

Vivian Zhu is currently a junior at Vista Del Lago High School in Folsom, California. She is interested in technology and machine learning related activities like the UC Berkeley ROAR Academy summer camp and S1/S2 competitions. She has founded her high school's first machine learning club "Computer Machine Learning Club" to share and promote machine learning knowledge in the neighboring schools and communities. In her spare time, Vivian likes to play cello solo and in orchestras like the Sacramento Youth Symphony premier orchestra and the California All-state Symphony Orchestra.

NetFlowCoin and UC Berkeley Establish a Partnership for Blockchain and Web 3.0 Infrastructure Research

On April 6, NetFlowCoin and Berkeley Defi Research Initiative announced an industrial partnership to jointly develop new blockchain technologies and Web 3.0 applications solutions, leveraging on the strong blockchain community and deep expertise of its faculty and students at UC Berkeley.

UC Berkeley has been a leading institution at the forefront of innovation in blockchain and Web 3.0 applications. Through this new partnership, NetFlowCoin will donate its network validators and engineering resources to establish a NetFlowCoin witness node at Berkeley. Berkeley Defi Research Initiative will sponsor forward-looking research topics based on the NetFlowCoin network and also Berkeley students to utilize NetFlowCoin’s capabilities in their research projects.

Aiming to become an integral part of rapid growing Web 3.0 infrastructure, NetFlowCoin has created a platform that allows users to share, store, and stream data in a completely decentralized environment, while rewarding contributors in the process. The NetFlowCoin ecosystem is a combination of blockchain, SDVN, and DAPPS. Each area provides value to the space.

NetFlowCoin has expressed its commitment to further strengthen its academic outreach program at Berkeley as the initial phase of the partnership is taking place.



USC and UC Berkeley Team Aegis Selected for 2023 NASA SUITS Challenge

Congratulations to USC and Berkeley Team Aegis for being selected into 2023 NASA SUITS Challenge, where students will be designing the next generation space suit user interface and technologies.

Team Aegis is a collaborative team of UC Berkeley and USC students selected by NASA to develop a holographic heads-up-display for the NASA SUITS challenge. Our team is developing AR software on the HoloLens 2, a sophisticated headset that projects “Iron Man-esque” holograms into the user’s field of view.

Berkeley Major Map released for Simulation Racing Series



Berkeley ROAR team created a customized CARLA map to facilitate the research and competition using the ROAR software in a simulated mixed urban/suburban environment.

The Berkeley Major Map was created using CARLA and Unreal Engine, and was based on a 3D LIDAR scan of the Berkeley campus and its surrounding hill roads. The map includes a closed circuit that can be driven from both directions. The 3D model of the map accurately represents the altitude variation of the real streets where the model is based on in the real world.

In addition to the provided CARLA server build that is pre-loaded with the Berkeley Major Map model, an official waypoint list file and an orthographic occupancy map file are also provided for reference. ROAR users may freely modify these reference files for the purpose of improving the performance of the autonomous driving agent.

The team continues to work on upgrading the map for the ROAR Simulation Racing Series.



Simulation Racing Series Updates

The S1/S2 Series Competition began in 2019 to tackle several remaining pain points in our community's effort to bring such AI systems to be fully autonomous and be more safe than human drivers. We have been able to use this competition as a research platform to expand into other competitions including winning a silver medal at the Indy Autonomous Challenge in 2022.

With new challenges and objectives in the space, our future going forward for the ROAR Racing Series will be a focus on:

- Simulation Racing Series
- Go Kart Racing Series
- Indy Autonomous Challenge

We are calling interested industry partners and other universities to join forces to create a high-caliber, best-in-class research and education platform for the next generation innovators.

2022 Simulation Racing Series Winners

For 2022, we have been using the new Berkeley Major Map. We have researchers continuing to work on upgrading the virtual maps to simulate UC Berkeley's campus.

Spring Series

Grand Prize: Aaron Xie (Record: 559 s)

Second Place: Cameron Shaw, Kaveer Gera, Dorian Kolis, and Phillip McClure (669 s)

Third Place: Ryan Chen (832.3 s)

Special Awards:

Prime Directive (Fastest system that had zero crashes during competition): Aaron Xie

Summer Series

Grand Prize: Team Scissors (Daniel Chuang Yuxuan (Lucy) Zhang, Chris Zhang)

Second Place: Team Sharpinclude (Daniel Chuang)

Third Place: Team Vista (Vivian Zhu)

Special Awards:

Prime Directive (Fastest solution that successfully follows safe on-road traffic rules): N/A

Fall Series

Grand Prize: Cougar – Aaron Xie (Record: 546.85 s)

Second Place: Crashy McCrashface – Aaron Chen (607.05 s)

Special Awards:

Prime Directive (Fastest solution that successfully follows safe on-road traffic rules): N/A

XRLAB UPDATES

Virtual Studio: Social VR Collaborative Platform based on UC Berkeley Digital Twin

Luisa Caldas, Elnaz Bailey, Oscar Dorado, Daniel He, Extended Reality Student Club members

Digital twin of selected buildings at UC Berkeley campus, including the Architecture building, with its studios and exhibitions spaces. Virtual Studio is composed of: 1) a cloud-based 3D publishing platform for design work in virtual reality, allowing others to instantly navigate and experience architecture projects three-dimensionally; 2) a custom-made 3D authoring tool, where students without specific training can create and share their designs in the form of virtual models; 3) a multiuser collaborative platform for shared design experiences, synchronous and asynchronous communication, and hosting of curated events.

This year we received the support of Central Campus at UC Berkeley, through the Research, Teaching and Learning services, to continue developing Virtual Studio to serve the campus community at large.

1. Development of universal VR Headset Viewer for Virtual Studio

Description: Create a VR Viewer for the Virtual Studio app. Using UnityXR we are developing a VR interface for 6DOF headsets. Both tethered and untethered versions will be explored.

2. Azure Cognitive Services API

Description: Azure is an API from Microsoft that has a library of accessibility features/technologies related to vision/speech. This collection of cloud-based services offers, among other things, real-time speech and language services, e.g., speech-to-text, text-to-speech, language translation. We are researching what accessibility features are adequate for implementing on Virtual Studio that can help with accessibility in a VR or desktop application setting. We are providing Life Captioning in Virtual Studio by default, changing the paradigm from accessibility by request to accessibility by default, a current trend. Furthermore, we are researching if this new feature could also be leveraged to provide voice activation to VBW for some user interaction commands that do not relate to locomotion, but to content interaction. Voice controls are a welcome addition to the user experience.

3. Virtual Studio Web Browser Version

Description: Create browser version of Virtual Studio app. Currently the application runs only on a computer. Having a web browser version would drastically increase Virtual Studio accessibility and democratize it, as users would no longer run into issues of space (downloading files from cloud), OS compatibility (Win/Mac), necessary computer hardware for graphic intense scenes, and app installation.



InsightXR: Re-Imagining the Future of Design Learning in Virtual and Augmented Reality

Elnaz Bailey, PhD student in Architecture
Advisor: Luisa Caldas

InsightXR enables multiple users to collaborate from different locations using AR technology, and helps provide users, in this case design students and faculty, information about feedback and areas of high concentration of focus and interest that are ultimately used to inform the generation of new design ideas. This platform provides user's interactions with the 3D content to the designers, and helps them improve their projects using generative design tools in Grasshopper in Rhinoceros.

New additions and features in 2022: New additions include an NSGA-II algorithm that applies design operations on massing for 3D design optimization. PhD student Elnaz Bailey developed a multi-objective optimization algorithm using a non-dominated sorting genetic algorithm (NSGA II) by customizing Pymoo's NSGA-II framework where 3D geometries are optimized using objectives such as passive zone, floor area ratio, and shape coefficient objectives. These algorithms are a part of my PhD research project, InsightXR. InsightXR enables experts and non-experts to visualize 3D designs and provide feedback on designs within augmented reality (AR). Elnaz also designed a case study for testing these algorithms, and worked on a journal publication for these studies to be submitted in Spring 2023.

Patient-Centric Design of Pediatric Inpatient Rooms: Engaging with Children using Immersive Virtual Environments

HariPriya Sathyanarayanan,, PhD student in Architecture

Advisor: Luisa Caldas

Immersive Virtual Environments are powerful instruments for participatory design of healthcare built environments, allowing new levels of patient engagement. This research addresses the specific needs of pediatric populations by engaging with children of different age groups to better understand how spatial design supports patients during hospitalization, as well as their needs, perceptions, and preferences regarding the built environment. Virtual reality and biosensors such as eye tracking, facial electromyography, and heart rate variability are used to determine patient room design preferences, through physiological and emotional responses to the spatial and environmental design of different inpatient room alternatives. The Vive Pro Eye headset is used for that end, with an EMG insert. Hospital room 3D models are provided by Kaiser Permanente and Shepley Bulfinch Architects, Boston. Variables under study include connection with the outdoor environment, positive distractions, privacy, and social support. The study outcome includes advancing knowledge on the pediatric population's unique perspective on the healthcare built environment and their physiological response in real-time, enabling the creation of design solutions that resonate more equitably with children. Results were presented at IVRHA, UPenn Medical School, Philadelphia.

Synthesis and Generation for 3D Architecture Volume with Generative Modeling

Xinwei Zhang, PhD student in Architecture, working with Yi Ma, Allen Yang and Luisa Caldas

This research project explored the possibility of convolutional neural networks to synthesize and generate 3D architecture envelopes with quantitative evaluation. The research is among the first of several applications with data-driven design in 3D in the architectural field. In the fall of 2022, additions were made with a specific emphasis on the interpretation of the latent space of the network. The results of the research are currently under review for the special issue "AI, Architecture, Accessibility, & Data Justice" in the *International Journal of Architectural Computation*.

FACULTY UPDATES

Shankar S. Sastry appointed as Founding Chancellor at Plaksha University

Mohali based Plaksha University has announced the appointment of S. Shankar Sastry as the founding chancellor. According to an official statement, Sastry was the Dean of Engineering for over a decade (2007-2018) at the University of California (UC), Berkeley. He currently works as professor, Computer Science, at UC Berkeley.

“Sastry is a respected academic leader and an institution builder globally. He epitomises the idea of reimagining higher education and building a vibrant higher education ecosystem that supports high-impact research. His in-depth professional experience, knowledge, and leadership will guide Plaksha University to craft a unique learning experience for curious tinkerers,” Neeraj Aggarwal, chairman, Asia Pacific, Boston Consulting Group (BCG) and founder, chairperson, Board of Trustees, Plaksha University, said.

Yi Ma to lead Institute of Data Science at Hong Kong University

Professor Yi Ma will take a sabbatical at Berkeley to serve as the director of a new Institute of Data Science at Hong Kong University. Ma’s top research level in the field of computer vision has brought him many honors. He was elected IEEE Fellow in 2013, ACM Fellow in 2017 and SIAM Fellow in 2020. He has been ranked as one of the World’s Highly Cited Researchers since 2016 by Clarivate Analytics of Thomson Reuters. He has also been ranked as one of the Top 50 World’s Most Influential Authors in Computer Science by Semantic Scholar, reported by Science Magazine in April 2016.

In the past few years, Yi Ma has also engaged in a range of industrial activities. He is a co-founder of light-field 3D acquisition startup company DGene Digital Technology (previously known as Plex-VR), established in early 2016. He has served as senior advisor to the ByteDance Research Lab in Silicon Valley from 2017 to 2020. He has been on the Technical Advisorial Board (TAB) of Malong Technologies (a computer vision startup company in Shenzhen, China), since June 2018. He has also served as an independent director on the Board of Directors of Cheetah Mobile Inc. since March 2018.

The Institute of Data Science of Hong Kong University was established in January 2022 and received a donation of HK\$150 million (\$19 million) from The Musketeers Education and Culture Charitable Foundation. According to its official website, the institute aims to explore frontier research and application of data sciences, computing, mathematics and statistics by taking advantage of expertise across different disciplines. The goal of the institute is to establish a world-class institute in the field and to attract the best talent in the world. The advisory committee of the institute also includes famous researchers such as Harry Shum and Tang Xiaoou.



Professor Ruzena Bajcsy in her UC Berkeley Office (Credit to Franc Solina)

Ruzena Bajcsy receives Slovak Medal of Honor

EECS Prof. Emerita Ruzena Bajcsy has been awarded the Slovak Medal of Honor. Bajcsy was recognized for her scientific achievements, leading by example, and setting a positive image of the Slovak Republic abroad. The medal was presented at the Consulate in New York by Slovak President Zuzana Čaputová.

Professor Ren Ng's Oz Vision Expands to Involve 7 Faculty Across 3 Universities

Ren Ng's Oz Vision, which FHL Vive Center originally supported with a grant, is now in the second year of its MURI grant supported by the Air Force Office of Scientific Research (AFOSR), and involves 7 faculty across 3 universities.

Bala Kumaravel Completes Dissertation

Bala Thoravi Kumaravel, advised by Bjoern Hartmann, has completed his dissertation titled "InteractiveCross-Dimensional Media for Collaboration and Guidance in Mixed Reality Environments" over the summer, and is now a Senior Research Scientist at Microsoft Research in Redmond.

New OpenARK Tutorials for ISMAR 2022 Conference Released

This tutorial is a revised and updated edition of the OpenARK tutorial presented at ISMAR 2019 and 2020. The aim of the tutorial is to present an open-source augmented reality development kit, called OpenARK. OpenARK was founded at UC Berkeley in 2015.

OpenARK includes a multitude of core functions critical to AR developers and future products. These functions include multi-modality sensor calibration, depth-based gesture detection, depth-based deformable avatar tracking, and SLAM and 3D reconstruction. In addition to these functionalities, a lot of recent work has gone into developing a real time deep learning 3D object tracking module as a solution to the problem known as Digital Twin.

Another core component in OpenARK is its open-source depth perception databases. Currently we have made two unique databases available to the community, one on depth-based gesture detection and the other on mm-accuracy indoor and outdoor large-scale scene geometry models and AR attribute labeling.

Finally, the tutorial will discuss our effort in making depth-based perception easily accessible to application developers, who may not have and should not be forced to learn good understanding about 3D point cloud and reconstruction algorithms. The last core component of OpenARK is an interpreter of 3D scene layouts and its compatible AR attributes based on generative design principles first invented for creating architectural design layouts

LEADERSHIP

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Faculty Director, Blum Center for Developing Economies
Co-director, C3.ai Digital Transformation Institute
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Allen Yang

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Yi Ma

Chief Scientist, FHL Vive Center for Enhanced Reality
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UC Berkeley Robotics and
Intelligent Machines Lab



ROAR SUPPORT FUND



The global race to make vehicles more intelligent, safer, and more environmentally friendly has created a perfect playground for artificial intelligence research in complex, real-world conditions. The Berkeley ROAR program was created by EECS and mechanical engineering faculty to tackle challenging problems, including optimizing AI under extreme conditions (like high speeds and off-road) and collecting real-world data on complex AI systems to design for better performance and lower costs.

Your gift supports innovation and helps raise awareness of breakthrough AI applications by helping our students compete at the highest level of AI racing against the best university teams from around the world. It also supports students who will be the future leaders of the growing industry, and helps us host the ROAR Academy, a STEM program for K-12 students.



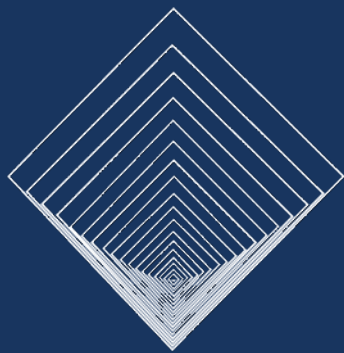
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Allen Yang, Executive Director, allenyang@berkeley.edu



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CONTACT

FHL Vive Center for Enhanced Reality
337 Cory Hall, Berkeley, CA 94720
fhlvivecenter@berkeley.edu
vivecenter.berkeley.edu