FHL VIVE CENTER

FOR ENHANCED REALITY

ANNUAL REPORT 2020

FHL VIVE CENTER

FOR ENHANCED REALITY

MISSION

The main goals of the center are to sponsor critical fundamental research and high-impact applications in the emerging fields of Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI), and at the same time serve as the central hub to facilitate the deployment of disruptive VR, AR, and AI technologies across the Berkeley campus for cross-disciplinary research and education.

Contents

Message from the Executive Director,

Allen Yang

Dear Members and Friends,

As you are reading this annual report, everyone must have experienced tremendous and unique challenges for the passing year caused by the global pandemic. First, I would like to let you know that our thoughts and prayers are with those whose families have been impacted by the pandemic or other difficulties.

Our faculty and students have demonstrated deep commitment to learning, teaching, and the pursuit of cutting-edge research. In this report, you will read about stories from our members against the backdrop of many unprecedented challenges. You will also read about many innovative student projects and personal achievements by our students who have done the absolute fantastic job from their family living rooms and bedrooms around the world while remotely working with our faculty. In addition, many of our faculty, staff, and students volunteered to apply for and were granted essential worker status so that they could continue to conduct the necessary in-person tasks on campus. I am happy to report that our center faculty and staff have been diligently following the personal protection protocols as directed by the University, and such practice has enabled us to safely conduct essential research work even in the midst of the campus lock down.

In the coming year, the Center has planned for several exciting new programs to enhance our commitment to research in emerging technologies, innovative education, and our outreach to Berkeley and the community at-large. You will hear about these new programs via our social media posts and future center newsletters. I welcome your comments and suggestions to help us better prepared to face future scientific and social challenges.

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

Virtual and Augmented Reality in the Pandemic

What a year this has been. If there is a silver lining it is the maturation of technologies for virtual and enhanced reality which are allowing us to conduct business and education from homes. While we have crammed in several years worth of telepresence technology transition in the last year, a lot more needs to be done.

At the FHL Vive Center we had to pivot from our in person virtual reality 1/8 scale car racing to digital avatars of the race. However, we have still been able to prototype several race cars and they have been piloted remotely. Going forward, we believe that our Center will work out the right hybrid models of enhanced and virtual reality to enable better user interfaces for driving. In the area of telemedicine we have been working with the UCSF Children's Hospital of Oakland to provide telepresent environments for physical therapy and operation planning. Finally, we have been working on human robot teams collaborating to fly UAVs for mapping urban spaces.

Going forward, we will redouble our efforts to combine design and prototyping environments blending real and virtual environments seamlessly. We are beginning to engage with developmental psychologists to enhance learning outcomes on telepresence platforms in education, entertainment, and health care delivery.

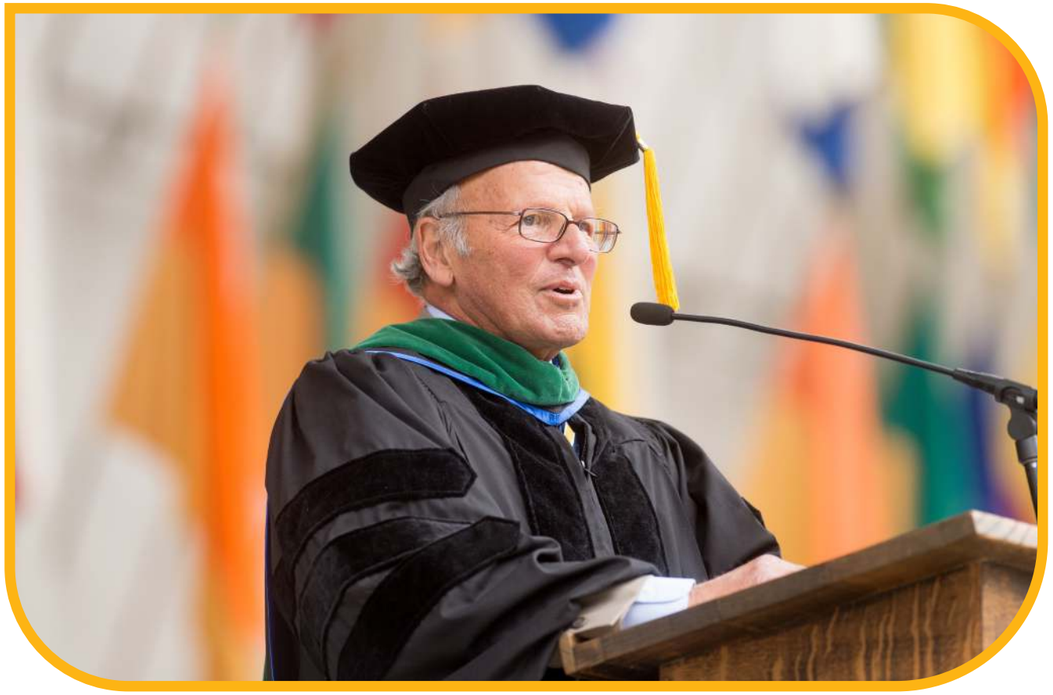
The newly launched Master of Engineering program in Autonomous Systems was launched this Fall in the midst of the pandemic and combined with our existing Master of Engineering in Augmented Reality, our Executive Director, Allen Yang has his hands full with supervising multiple capstone projects and teaching core material for these Masters' degrees.

We believe that we are at the cusp of a new revolution in telepresent environments and technologies and the FHL Vive Center is well poised to thrive in this milieu. All of us faculty, staff, and students in the FHL Vive Center wish you good health and a brighter future in 2021.

Shankar Sastry
Faculty Director, FHL Vive Center for Enhanced Reality

Message from the Founding Director,
Shankar Sastry

Remembering Dr. Bertram Lubin



The Vive Center would like to recognize the legacy, contributions, and accomplishments of Dr. Bert Lubin, who passed away peacefully in June 2020. While serving as the CMO of Vive Center, Bert spearheaded several collaborative projects bringing the most advanced 3D immersive technologies in the medical field.

Bert joined the Children's Hospital Oakland in 1973 and launched what became to be known as the Children's Hospital Oakland Research Institute. He dedicated his research toward the treatment of blood diseases and most notably sickle cell disease. In 2009, he became the president and CEO of Children's Hospital Oakland and became the driving force behind the affiliation between Children's Hospital Oakland and University of California, San Francisco before his retirement in 2018.

Dr. Lubin loved working at Oakland Children's Hospital and was on first-name basis with a lot of the employees. He also made significant gifts to a variety of causes, including First 5 California, East Bay Asian Local Development Corporation, Oakland Leaf, Oakland Community Pools Project, East Bay College Fund, and the Notes and Words fundraiser, as well as founding the Center for Community Health and Engagement (CCHE) at UCSF Benioff Children's Hospital Oakland. He continued to be active in many local service organizations and served on more than a dozen boards.

We are grateful for all of Bert's contributions to our center, our partners, and the College of Engineering. Bert will be remembered fondly for his smile, warmth, and dedication toward helping those in need. His guidance to everyone at the Vive Center will be deeply missed.

Executive Director, Allen Yang

Björn is an Associate Professor of Electrical Engineering and Computer Science (EECS) at UC Berkeley. His research in Human-Computer Interaction focuses on novel design, prototyping, and implementation tools for the era of post-personal computing.

His group investigates how better software and hardware can facilitate the exploration of interactive devices that leverage novel from factors and technologies. They also investigate how software can help students, designers, and makers to learn and share their expertise online, including through the use of Augmented or Virtual Reality.

His most recent work with Bala presents TransceiVR, a system that that utilizes VR platform APIs to enable asymmetric communication interfaces for third-party applications without requiring source code access.

Björn is also the Faculty Director of the Jacobs Institute for Design Innovation, where he has been integral to the success of the institute. He oversees the Institute's curriculum, public programs, and maker space, rethinking the nature of hands-on learning in the twenty-first century. The institute focuses on the intersection of design and technology by equipping UC Berkeley students from a range of different disciplines with maker spaces for hands-on prototyping, iteration, fabrication, and testing.

Learn more about Jacobs Institute's initiatives at **jacobsinstitute.berkeley.edu.**

> *Immersive 3D interface enabled by the emerging AR/VR systems and applications brings great challenges and opportunities in the field of HCI, Bjorn and the Jacobs Institute that he directs will bring world-class research expertise and forward-looking visions to guild the further development of the Vive Center and its many faculty projects. We are very enthusiastic to welcome him joining the team.*
>
> *Executive Director, Allen Yang*

Introducing our new Chief Design Officer,

Björn Hartmann

Building AR/VR Technologies

ROAR vehicle models and their controllers.

Testing out the VR prototype for ROAR.

Our physical ROAR test-track in RFS.

Virtual S1 Series (Fall 2020)

FALL 2020 ROAR COMPETITION RESULTS AND EXPANSION

Even with restrictions imposed due to COVID-19 pandemic, the inaugural Robot Open Autonomous Racing (ROAR) competition was an overall success with 8 teams joining us from multi-disciplinary areas. Student teams put their hardware and software designs to a virtual test as they competed for speed. ROAR will further expand to 3 leagues: S1 Series (Software simulation)*, V1 Series (Virtual Reality), and A1 Series (Autonomous Racing) in the coming years.

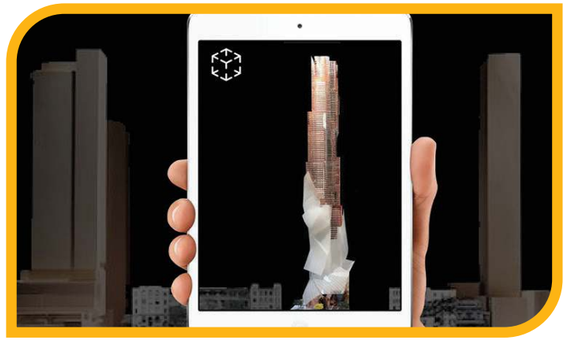
We are very pleased to announce the winners for the 2020 ROAR S1 series:
Grand Prize: Alfredo De Goyeneche, Alvin Tan, Sihao Chen, Wesley Wang, Aman Sidhant (Record: 813.92s)

Second Place: Shuwen Deng, Zheyuan Wu, Linfeng Zang (1104.00s)

Third Place: Michael Wu, Flaviano Christian Reyes, James Cheney, Marleah Puckett, Jonathan Wong(1207.45s)

Special Awards:
Fastest Single Lap: Shuwen Deng, Zheyuan Wu, Linfeng Zang (Record: 77.15s)

Prime Directive (Fastest system that had zero crashes during competition): Michael Wu, Flaviano Christian Reyes, James Cheney, Marleah Puckett, Jonathan Wong (Record: 1207.45s)



(PHOTO BY KING ST. DEVELOPMENT IN TORONTO BY FRANK GEHRY)

PROFESSOR LUISA CALDA'S INSIGHTXR

InsightXR is a Berkeley Changemaker Technology Innovation Grant winner. Funding for this project will allow the development of a virtual, augmented and mixed reality (VR/AR/MR) tool at the College of Environmental Design (CED). This tool will allow innovative remote design collaboration techniques by giving faculty and students working off-campus the ability to interact with each other's 3D models and provide multimodal feedback in synchronous or asynchronous mode. Designers will be able to collaborate with the recipients of their designs, as the app will generate highlighted areas displaying the most stakeholder interactions.

Caldas has said that InsightXR will enrich the online learning experience for students in design disciplines across campus, allowing them to better develop and evaluate the impact of their design proposals. Caldas, along with fellow awardee Elnaz Tafrihi Bailey, a Ph.D. student in architecture, aim to bring the app to the public for use by summer 2021 in both educational and professional applications of remote collaborative design across different domains and disciplines.

PROFESSOR LUISA CALDA'S BAMPFA AR PROJECT

BAMPFA AR explores new modes of narrative and storytelling using augmented reality as a medium. The project tells the story behind the new BAMPFA, from the building's inauguration in 1940 as the university printing press, to an abandoned structure covered with graffiti by local artists, to a contemporary museum. An augmented timeline allows the user to navigate through time, following the history of the construction of the new museum. The AR experience further renders visible hidden narratives such as the building's role during World War II, the architecture concepts behind Diller Scofidio + Renfro design, and the workers who built the building.

BAMPFA AR—Augmented Time explores the potential of AR as a device to store the past and a platform to harvest the future, a living record that embodies the built space in its continuing collection of events and narratives.

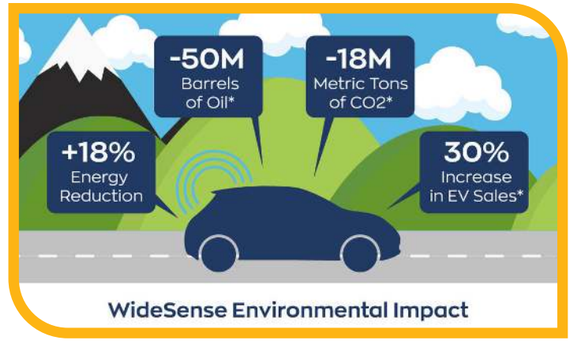
PROFESSOR BJÖRN HARTMANN'S PROJECT VRTUTOR

Professor Björn Hartmann's Project VRTutor was also awarded a Berkeley Changemaker Technology Innovation Grant. The grant is focused on awarding "transformative ideas with real applications that benefit the Berkeley campus."

Two modalities are being considered in this project: In one, the instructor records a video ahead of time, such as a tutorial on how to use a 3D drawing or sculpting application, so that students can view and interact with the video while they are using the VR application. In the other, an instructor can remotely view a live feed of a student working in VR and give guidance and feedback by drawing on the student's video feed on a tablet. These drawings then get re-projected into the student's VR scene in 3D. His project aims to make teaching and learning easier in Virtual Reality. Students taking CS294-137 Immersive Computing and Virtual Reality in Fall 2020 were the first test group.

TRANSCEIVR

A project with Björn and Bala, TransceiVR is a system that utilizes VR platform APIs to enable asymmetric communication interfaces for third-party applications without requiring source code access. TransceiVR allows external users to explore the VR scene spatially or temporally, to annotate elements in the VR scene at correct depths, and to discuss via a shared static virtual display.



PROFESSOR FRANCESCO BORRELLI'S WI-DESENSE

Professor Francesco Borrelli cofunded WideSense-WideSense is a spinoff from UC Berkeley focused on the digital transformation of the mobility industry. The WideSense platform delivers Real-time Mobility Contextual Intelligence to drivers, owners, location commerce partners and vehicle computers - transforming the Digital Experience by driving engagement across all OEM digital assets and enabling a recurring revenue relationship with the consumer.

TUTORIVR

Another project with Björn and Bala, TutoriVR is a video-based tutorial system for design applications in VR. TutoriVR supplements video tutorials with 3D and contextual aids directly in the user's VR environment. An exploratory evaluation showed users were positive about the system and were able to use the proposed system to recreate painting tasks in VR.

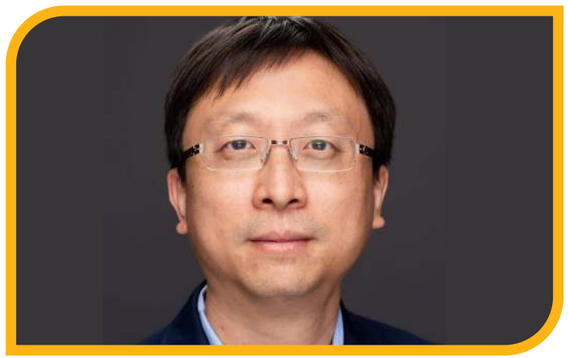
Faculty Awards

PROFESSOR RUZENA BAJCSY'S AWARDS

Professor Ruzena Bajcsy has won a couple of awards in 2020. One of those awards was the 2020 NCWIT Pioneer in Tech Award. This award "recognizes technical women whose lifetime contributions have significantly impacted the landscape of technological innovation, amplifying the importance of capitalizing on the diverse perspectives that girls and women can bring to the table." Recipients continue to serve as role models and inspire generations of young women.

She has also won the 2021 Institute of Electrical and Electronics Engineers (IEEE) Medal For Innovations In Healthcare Technology. The award was first established in 2009 and is presented "for exceptional contributions to technologies and applications benefitting healthcare, medicine, and the health sciences."

Ruzena Bajcsy is the NEC Distinguished Professor of Electrical Engineering and Computer Sciences (EECS) at the University of California, Berkeley. Bajcsy has been a pioneer in the field of robotics throughout her long career, with research interests that include Artificial Intelligence; Biosystems and Computational Biology; Control, Intelligent Systems, and Robotics; and Human-Computer Interaction.



PROFESSOR YI MA'S BUSY YEAR

Professor Yi has had a tremendously productive year. He has been busy hosting and presenting at multiple workshops throughout the year including ECCV and CDTI. Just in 2020 alone, he has published at least 15 publications!

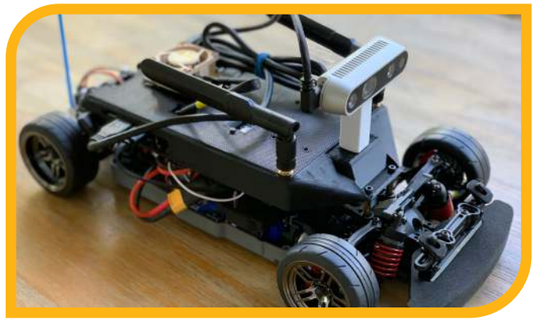
Professor Yi was elected 2020 Society for Industrial and Applied Mathematics (SIAM) Fellow for "for contributions to the theory and algorithms for low-dimensional models and their applications in computer vision and image processing."

Professors Yi Ma and John Wright also published their book: High-Dimensional Data Analysis with Low-Dimensional Models: Principles, Computation, and Applications, Cambridge University Press, 2021 and will be available online soon.

PROFESSOR CLAIRE TOMLIN NAMED ONE OF 2020 IFAC FELLOWS

Professor Claire Tomlin was recognized by the 2020 International Federation of Aviation Control (IFAC) Fellow Award that is given to "persons who have made outstanding and extraordinary contributions in the field of interest of IFAC, in the role as an Engineer/Scientist, Technical Leader, or Educator." Professor Claire was recognized for her contributions in "cyber-physical and hybrid systems with application to safety in autonomy and learning."

Our Research



ROBOT OPEN AUTONOMOUS RACING (ROAR)

Led by its faculty members Francesco Borrelli, Koushil Sreenath, Shankar Sastry, and Allen Yang, Berkeley is proud to announce and host a new AI racecar competition in 2020. The Robot Open Autonomous Racing (ROAR) competition will pit multiple student racing teams to compete for speed and vehicle skills at the heart of the iconic Berkeley campus.

The participating teams will adopt the set of common 1/10 RC car hardware as regulated by a rules committee. The regulations aim to ensure the competition to be affordable and fair to our target students. Different teams are allowed to upgrade their car hardware as permitted by the regulation and to develop and deploy their own autonomous driving software.

ROAR will further expand to 3 leagues: S1 Series (Software simulation)*, V1 Series (Virtual Reality), and A1 Series (Autonomous Racing) in the coming years.

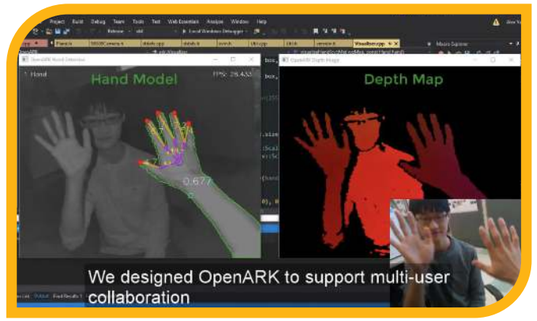
IMMERSIVE SEMI-AUTONOMOUS AERIAL COMMAND SYSTEM (ISAACS)

ISAACS has begun flight tests at B164 and B100 in Richmond Field Station (RFS). These flight tests prove the capability of our software beyond what can be achieved in simulations. We have conducted tests on the DJI Matrice M200 and M600 series with various payloads, single drone, and multi drone configurations.

Starting Fall 2020, ISAAC software is being migrated onto a central server that will enable our solution to effectively scale. A central server will make it easier to connect new drones and VR clients to our platform and enable the world of true multi-drone flight control.

We are also in the process of making our work available for the open source community to use. With the new Server Architecture, we can easily support drones from different manufacturers.

Most recently we began development on new Ardupilot and MavROS drones. We expect the hardware to be arriving in Spring 2021.



OPENARK

OpenARK is an open-source wearable augmented reality (AR) system founded at UC Berkeley in 2016. The C++ based software offers innovative core functionalities to power a wide range of off-the-shelf AR components, including see-through glasses, depth cameras, and IMUs.

OpenARK is a open-sourced Augmented Reality SDK that will allow you to rapidly prototype AR applications. This year, we presented an updated OpenARK tutorial at IEEE International Symposium on Mixed and Augmented Reality (ISMAR) 2020.

Learn more about OpenARK here: **vivecenter.berkeley.edu/research1/openark/**

ATLAS PROJECT

Vive Center Faculty from EECS and Architecture Departments are pursuing an ambitious project to create a high-resolution 3D digital model of the entire Berkeley campus. We use a hybrid hardware platform that fuses LIDAR, depth cameras, and RGB cameras to record multi-modality 3D data for both indoor and outdoor environment throughout Berkeley, and we carefully label the semantics of both 3D structural primitives and high-level object shapes. Our aim is to open-source both the raw multi-modality data and the semantic labels of the Berkeley data and encourage the community at large to best utilize the campus-wide data to perform larger-scale AR/VR research and applications.

Education

MASTER OF ENGINEERING PROGRAM

One of the fastest growing industries in the past five years is at the intersection of AI, Robotics, and Computer Vision. In particular, Silicon Valley has become a hotbed for research and commercialization of autonomous driving. Leading logistics and retail corporations have started delivering packages via unmanned aerial vehicles. Collaborative robot arms and legs are being experimented in compliant co-working applications. In this Capstone Design Experience Proposal, we will describe the above related topics under the broad umbrella name of Autonomy.

Due to the multidisciplinary nature of Autonomy and its emerging markets, we believe prospective MEng applicants will have broad interest in selecting Autonomy curriculum and its capstone project. The FHL Vive Center has proposed a concerted effort by its center members to spearhead the creation of a new Capstone Design Experience at the Fung Institute.

Read more about the program: **eecs.berkeley.edu/academics/graduate/industry-programs/meng/requirements/vccg**

CS 297-137 CONTINUED SUCCESS

Many students continue to explore the abilities of virtual reality and augmented reality technologies in the CS 294-137 course taught by Björn Hartmann and Allen Yang. Students focus on inventing new solutions that can address existing or new needs of different industries. The course will continued to be offered at UC Berkeley!

Please visit the project page **behance.net/immersivecomputing** to see student projects from Fall 2020.

By the Numbers

61 New Publications

Please visit **vivecenter.berkeley.edu/vivepublications/** for a full list of all our publications.

7 Faculty Awards

While we highlighted some of our important faculty awards, many of our other researchers and faculty have continued to receive new funding for their projects.

10 Graduates

Our students at the Vive Center continue to excel and we had 10 Ph.D. students graduate in May 2020. While we couldn't celebrate with you all physically, we did want to honor our graduates below:

Oladapo Afolabi, Ph.D. in Electrical Engineering and Computer Sciences
Nicholas Antipa, Ph.D. in Electrical Engineering and Computer Sciences
Somil Bansal, Ph.D. in Electrical Engineering and Computer Sciences
Margaret Chapman, Ph.D. in Electrical Engineering and Computer Sciences
David Fridovich-Keil, Ph.D. in Electrical Engineering and Computer Sciences
Sylvia Herbert, Ph.D. in Electrical Engineering and Computer Sciences
Joseph Menke, Ph.D. in Electrical Engineering and Computer Sciences
Kamil Nar, Ph.D. in Electrical Engineering and Computer Sciences
Dexter Scobee, Ph.D. in Electrical Engineering and Computer Sciences
Sarah Elizabeth Seko, Ph.D. in Electrical Engineering and Computer Sciences

Leadership

S. Shankar Sastry
Founding Director, FHL Vive Center for Enhanced Reality
Faculty Director, Blum Center for Developing Economies
Co-director, C3.ai Digital Transformation Institute
Thomas M. Siebel Professor in Computer Science
Professor of Electrical Engineering and Computer Sciences, Bioengineering, and Mechanical Engineering

Allen Yang
Executive Director, FHL Vive Center for Enhanced Reality

Shannon Jackson
Chief Creative Officer, FHL Vive Center for Enhanced Reality
Associate Vice Chancellor for Arts + Design
Cyrus and Michelle Hadidi Chair in the Humanities
Professor of Rhetoric and of Theater, Dance and Performance Studies

Yi Ma
Chief Scientist, FHL Vive Center for Enhanced Reality
Professor of Electrical Engineering and Computer Sciences

Björn Hartmann
Chief Design Officer, FHL Vive Center for Enhanced Reality
Faculty Director, Jacobs Institute of Design
Associate Professor of Electrical Engineering and Computer Sciences
Paul and Judy Gray Alumni Presidential Chair in Engineering Excellence

Researchers

Ruzena Bajcsy
Professor Emerita of Electrical Engineering and Computer Sciences

Francesco Borrelli
Professor in Mechanical Engineering
FANUC Chair in Mechanical Systems

Luisa Caldas
Professor of Architecture
Director of XR Lab

Lee Fleming
IEOR Professor
Faculty Director of Fung Institute

Richard Hernandez
Associate Professor of Journalism
Bloomberg Chair

Jack McCauley
Innovator in Residence at Jacobs Institute

James O'Brien
Professor of Computer Sciences

Ren Ng
Professor of Electrical Engineering and Computer Sciences

Kathryn Quigley
Senior Digital Producer
Lawrence Hall of Sciences

Koushil Sreenath
Assistant Professor in Mechanical Engineering

Claire Tomlin
Professor of Electrical Engineering and Computer Sciences
Charles A. Desoer Chair in the College of Engineering

Stella Yu
Director of Vision at ISCI Vision Group

Advisory Board

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Former Executive VP of Technology and Research, Microsoft Corp.

Thank you to our Partners

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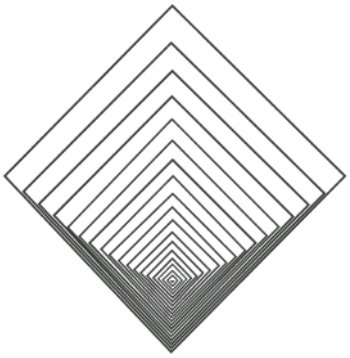
JOIN US

With your generosity, the potential of our faculty and students are limitless. For more information on how to support education and innovation initiatives with the Vive Center, please contact:

Allen Yang, Executive Director, allenyang@berkeley.edu



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