Research Statement of SangHyun Chang

Throughout my Ph.D. studies at the University of Southern California (USC) and my post-doctoral period at the California Institute of Technology (Caltech), my research has been primarily focused on developing Ultra-Wideband (UWB) radar and radio systems. Compared with computer vision, LADAR, and infrared imagers, UWB radar can provide a complementary technology for detecting and tracking humans, particularly in poor visibility or through-wall conditions, as it is minimally affected by dust and moisture [1][2]. My research goal is to advance UWB radar sensing and communication technology to the point where it can be widely applied in intelligent human and environment information sensing. The scope of my research has spanned from fundamental RF propagation studies and signal processing algorithm development, to system-level RF chip simulation/design as well as the system integration of RF CMOS chip and developed algorithms. My current work mainly focuses on developing algorithms to detect and track multiple humans in a complex environment using a single-chip UWB CMOS radar sensor and its collaborative sensor network [3].

During my Ph.D. years in the UltRa Lab at USC, I completed the fundamental polarimetric study in a multipath propagation channel for UWB radar and communication systems [4]. The study demonstrated the characterization of all UWB double-directional multipath channel parameters¹ throughout channel model development, experimental measurement, and high time-resolution array signal processing algorithm design. In addition to my research on antennas and propagation, over the 5 years of the UWB MURI project period, I was exposed to research programs of top investigators from USC, UC Berkeley, and UMass, who lead broad investigations into emerging technology research ². This experience highlighted the importance of collaborative research, and also introduced me to the practically important issues of regulation and standards settlement associated with a new technology.

As a post-doctoral scholar at Caltech, I started working on UWB radar for human detection and tracking within a research group primarily devoted to robotics, control, and bioengineering. Feeding on the intimate and strong interdisciplinary nature of the Caltech community, I gained exposure to various robotics-relevant projects and inspiring society meetings on sensing. After spending a year on preliminary UWB radar study, I was awarded a multidisciplinary research grant as a co-principal investigator for UWB human detection RF CMOS chip and algorithm development for border security with Prof. Hossein Hashemi at USC and Prof. Joel Burdick at Caltech. Concentrating on algorithm development at Caltech, I developed a method to track the ranges and 1D velocities of a variable number of human targets in near real-time using a UWB monostatic radar in an environment containing clutter, temporary occlusions, and target merging/splitting [1]. Also, in combination with my tracking method, I developed a human presence detector to discern humans from other non-human objects by sensing human gait and breathing features. The experimental results showed better than 80% detection probability ~1.6% false alarm rate in a simple, but realistic outdoor environment [2]. Jointly working at USC, I collaborated with USC

¹ The parameters consist of time-of-arrival, angle-of-departure, angle-of-arrival, waveform shape, and wave polarization of each multipath component in the propagation channel.

² The research area covered position location algorithms, communication receiver architectures, antenna design, waveform and modulation design and implementation, channel characterization, and synchronization schemes.
researchers to enhance radar sensing capability by designing and implementing a RF CMOS radar chip and integrating the CMOS radar chip with the algorithms I developed at Caltech via a custom data acquisition system interface. We successfully demonstrated a UWB impulse-based CMOS radar sensing capability [5]. Through my diverse experience in programs combining hardware and algorithm development, I came to believe that I can be a leading researcher for UWB radar sensing technology, and I’ve set my goal to pioneer a new society in the UWB radar research area.

UWB radar has several advantages for sensing, such as high time/depth-resolution, robustness in poor visibility and weather conditions (rain, fog, smoke, and dust), low power consumption (less than a few Watts), and small size. Embedded in the environment, or on mobile platform, and networked with the existing wireless infrastructure, UWB radar can create intelligent and responsive sensing solutions for various applications³. However, compared with conventional narrowband radar, the complex multipath scattering behavior of short UWB electromagnetic pulses and the large variation in dynamic observation patterns between scans pose interesting academic challenges in control and signal processing, such as data association, feature extraction, and pattern recognition. I have established the framework of human detection and tracking algorithm in 1D on a single node and have a solid understanding of fundamental radar and radio system limitations. Hence, I can elevate the sensing capability from “a single antenna system for 1D sensing” to “array antenna system for 2D/3D sensing” and from “a single node sensing” to “multi-node sensing”. To advance the sensing technology, my current and near-future research focuses are as follows:

- **Human detection and tracking using statistics and machine learning**
- **Collaborative multi-static sensing over multiple network sensor nodes**
- **Human gesture monitoring with multi-modal sensing**
- **Simultaneous Localization And Mapping (SLAM) system**

My long-term research plans are described as follows:

- Develop the **multi-modality sensor** of stereo-camera vision and UWB radar to dramatically improve performance of a human detector and a SLAM system by jointly exploiting the high angular-resolution in stereo-camera and the high depth-resolution in UWB radar.
- Integrate communication with UWB electromagnetic wave transmitted for sensing purposes to offer the promise of energy-efficient sensor network solutions for joint radar and communications.

³ (1) Medical care – monitoring the health condition, activity, and behavior of children, patients, and the elderly; (2) military, security – national border surveillance system, weather condition-free autonomous robot sensing on the battlefield, ground penetrating radar, intruder detector, and through-wall imaging system; (3) automobile safety via remote pedestrian detection; (4) health care in obesity – calorie consumption monitoring; (5) customer behavior analysis in marketing – tracking the line of customer flow in wholesale and retail shop.
• Combine the SLAM technique and the synthetic-aperture radar (SAR) imaging to deploy **UWB radar sensor on mobile platform**, such as automobile, robot, and micro air vehicle (MAV).


[3] [http://robotics.caltech.edu/~sanghyun/](http://robotics.caltech.edu/~sanghyun/)
