



## Joint PhD Program Description

The description for the Joint PhD program will be posted online as a sub-page to

[Joint/Dual PhD Programmes | Graduate College | NTU Singapore.](#)

Name of Partner University	KTH
Country	Sweden
Year of Establishment	2015
Program	<input checked="" type="checkbox"/> Joint Degree <input type="checkbox"/> Joint Supervision
Description of the Program	<p>The NTU-KTH Joint PhD Program was established in 2015, aiming for cutting-edge research on smart transportation, in response to worldwide mobility needs.</p> <p>Built upon the success of Phase 1 Program, the second phase is expected to start in January 2023, with a significantly extended scope that includes all exciting fields related to smart cities and sustainability.</p> <p>Candidates in this program are expected to fulfil standard coursework requirements at the host institution and complete a PhD dissertation in relevant areas in four years. In addition, candidates are also expected to fulfil a residency requirement at the partner institution for 12-13 months during the candidature period.</p> <p>Candidates will have opportunities to work with renowned scholars in relevant fields and enjoy world-class research facilities of both institutions. In addition, there are opportunities for candidates to interact with big companies that have established collaboration relationships with the program to understand real industrial needs and the state-of-art technologies.</p> <p>There will be hackathons organized by the program to allow candidates to demonstrate their cutting-edge technologies and most innovative ideas.</p>
Disciplines	All disciplines that are related to smart cities and sustainability, e.g., electrical engineering, mechanical engineering, civil engineering, computer engineering, computer science, material science, biochemical engineering, social science and psychology.
PMC Names	NTU: Su Rong, Wang Zhiwei, Timothy John White KTH: Stefan Ostlund, Bo Wahlberg, Bjorn Berggren
PMC Emails	NTU: <a href="mailto:rsu@ntu.edu.sg">rsu@ntu.edu.sg</a> , <a href="mailto:WangZhiwei@ntu.edu.sg">WangZhiwei@ntu.edu.sg</a> , <a href="mailto:tjwhite@ntu.edu.sg">tjwhite@ntu.edu.sg</a> KTH: <a href="mailto:stefano@kth.se">stefano@kth.se</a> , <a href="mailto:bo@kth.se">bo@kth.se</a> , <a href="mailto:bjorn.berggren@abe.kth.se">bjorn.berggren@abe.kth.se</a>



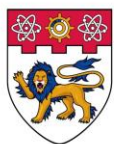
## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Tang Yi	Wang Xiongfei
School	School of Electrical and Electronic Engineering	Division of Electric Power and Energy Systems
Email	<a href="mailto:yitang@ntu.edu.sg">yitang@ntu.edu.sg</a>	<a href="mailto:xiongfei@kth.se">xiongfei@kth.se</a>
Website	<a href="https://dr.ntu.edu.sg/cris/rp/rp00875">https://dr.ntu.edu.sg/cris/rp/rp00875</a>	<a href="https://www.kth.se/profile/xiongfei">https://www.kth.se/profile/xiongfei</a>
<b>Project Title</b>	<b>Next Generation Grid-Forming Converters for Grid Integration of Renewable Energy</b>	
Project Description (200-300 words)	<p>Modern power systems are evolving from fossil fuel-dominated carbon-intensive energy systems into renewable energy-dominated low-carbon energy systems. Power electronic converters, as the grid interface of renewable energy, play a pivotal role in underpinning the transformation and decarbonization of modern power systems. Conventionally, grid-tied converters apply grid-following (GFL) control and operate as AC current sources that passively follow the power grid frequency. However, the large-scale integration of power electronic converters in utility grids with GFL control may introduce a number of new scientific challenges. On one hand, power systems need to establish voltage and frequency first for GFL converters to connect, which cannot be achieved by GFL converters themselves. On the other hand, GFL converters may face instability issues under weak grid conditions. These concerns stimulate the demand for a novel grid-forming (GFM) control, with which power converters can establish their own voltage and frequency and synchronize with other power sources autonomously. This PhD project aims to study the modelling and control of grid-tied GFM converters and understand their behaviours under different operating scenarios such as small/large signal stability, synchronization stability, transient stability, fault ride through, etc. The goal is to develop innovative next-generation grid integration technologies for renewable energy, thereby paving the way for the clean energy transition in the power sector.</p>	
Program/Center Website(s)	Centre for System Intelligence and Efficiency <a href="https://www.ntu.edu.sg/csie">https://www.ntu.edu.sg/csie</a>	
Additional Information (e.g., files with project details)	Nil	



## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Su Rong	Vladimir Cvetkovic
School	School of Electrical & Electronic Engineering	School of Architecture and the Built Environment
Email	<a href="mailto:rsu@ntu.edu.sg">rsu@ntu.edu.sg</a>	<a href="mailto:vdc@kth.se">vdc@kth.se</a>
Website	<a href="https://personal.ntu.edu.sg/rsu">https://personal.ntu.edu.sg/rsu</a>	<a href="https://www.digitalfutures.kth.se/person/vladimir-cvetkovic/">https://www.digitalfutures.kth.se/person/vladimir-cvetkovic/</a>
<b>Project Title</b>	Game-Theoretical Approach for Control of Multi-level Systems with Social Influence	
Project Description (200-300 words)	<p>To ensure sustainability of a smart city, it is vital to achieve social optimality, whenever possible. For example, in intelligent transportation systems, good driving behaviors of individual drivers can significantly increase network throughput and reduce inroad fuel consumptions. In smart buildings, good energy usage habits of occupants can significantly reduce the overall building energy consumptions. All these will eventually contribute to zero carbon emission efforts. However, how to effectively influence individual persons' behaviors towards socially desirable ones is one challenge faced by the scientific community. In this PhD project, the student will explore game-theoretical approaches, which aim to embed the social optimality goals in daily social interactions at different levels of a hierarchical system, modelled by suitable game-theoretical models, and by using social influence and minimum incentive/penalty means to reshape certain behavior patterns to enhance long-term sustainability goals, in particular, in terms of energy sustainability. This research will require substantial knowledge of game theory and systems and control, and some relevant knowledge of psychological modelling. The student is expected to develop theoretical works such as modeling, analysis and controller design, and illustrate them in a realistic testbed, which could leverage on an existing smart building testbed on the campus of KTH. The candidate may rely on a simulated testbed to carry out theoretical development at NTU, and then carry out an onsite testbed development during his/her residency at KTH, which typically takes place in Year 4.</p>	
Program/Center Website(s)	<ul style="list-style-type: none"><li>- KTH-NTU Joint PhD Program</li><li>- Centre for System Intelligence and Efficiency (CSIE): <a href="https://www.ntu.edu.sg/csie">https://www.ntu.edu.sg/csie</a></li><li>- Cyber Physical Intelligent Systems Group: <a href="https://intelligentsystemseee.ntu.edu.sg/cpisrg/index.html">https://intelligentsystemseee.ntu.edu.sg/cpisrg/index.html</a></li></ul>	
Additional Information (e.g., files with project details)	None	

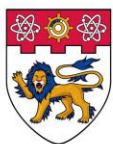


## Joint Projects

Home University	NTU	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Yong Liang GUAN	Ming XIAO
School	EEE	KTH EECS
Email	<a href="mailto:eylguan@ntu.edu.sg">eylguan@ntu.edu.sg</a>	mingx@kth.se
Website	<a href="https://dr.ntu.edu.sg/cris/rp/rp00129">https://dr.ntu.edu.sg/cris/rp/rp00129</a>	<a href="https://www.kth.se/profile/mingx">https://www.kth.se/profile/mingx</a>
<b>Project Title</b>	Intelligent Joint Radar Communications with Millimeter Wave	
Project Description (200-300 words)	<p>The PhD research project aims to design and optimize JRC (joint radio and communication) waveforms/sequences and network resources for improved sensing and communication capabilities in beyond 5G (6G) mobile networks. Traditionally, the functionalities of sensing and communications are separate technologies, which lead to low efficiency, long latency, and substantial waste of resources. JRC can simultaneously sense around environments and transmit information messages. However, in existed JRC schemes, sub-6GHz frequency bands are normally used, which often lead to low resolution sensing (in radio tomography), high interference and limited communication rates. To address the problem, in the project, we will exploit mmWave (millimeter wave) for JRC, which has the frequency of about 20GHz to 100GHz. The advantages of mmWave for JRC are multi-folded, e.g., higher-resolution sensing results and high data rates. However, there are also severe challenges for mmWave JRC. (1), Limited transmission distance and low peak-to average power ration; (2), Difficulty in channel estimation, mainly due to complexity and high wide band of mmWave signals, and especially pronounced in moving environments; (3), High processing complexity, which increases with frequency nonlinearly; (4) Due to high directional signals of mmWave, it is hard to support multi-user multi-objective systems for mmWave JRC. Thus, in our project, the main objectives are to design and optimize mmWave JRC with long range and high resolution for radar detection, accurate channel estimation capability, high spectrum and power efficiency, and supporting for multi-user operation and with limited complexity. For the purpose, the project shall join forces of researchers of KTH and NTU with complementary strength. KTH researcher (Ming Xiao and his student) has long-term studied and solid achievements in mmWave communications and resource allocation. NTU researchers (Yong-Liang Guan and his student) has very solid achievements in signal processing, especially in waveform design and radio detection. The project will have two work packages (WPs). (1) WP1, Radar and communication waveform optimization, led by NTU. To reduce complexity and to support multi-user JRC, communication waveforms will be optimized and sequence property bounds and performance limits for radar signals will be analyzed. Mathematical tools including but not limited to number theory, group theory, and coding theory will be used to address the challenges of complexity and multi-user access; (2) WP2, resource optimization, led by KTH. Power and spectrum resources will be optimized to improve the sensing/transmission distance and channel estimation. Optimization theory and machine learning approaches will be used. We should note the project is a true</p>	



	<p>collaboration one. Both KTH and NTU partners will participate in two WPs. At least two Ph.D. students respectively at KTH (Ph.D1) and NTU (Ph.D2) will work for the project in full time during the project period. The project teams will meet regularly online, at least once per month. The mobility plan is as follows: Month 6-12, Ph.D1 will visit NTU. Month13-18, Ph.D2 will visit KTH. As such, Ph.D1 and Ph.D2 will continue to visit partner universities 3 times of 6-month period. Meanwhile, Xiao and Guan will also visit each other 1 month per year.</p>
Program/Center Website(s)	NTU, EEE, CISS, COSMO Lab
Additional Information (e.g., files with project details)	Nil



## Joint Projects

Home University	NTU Singapore	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Chen Yu-Cheng	Kristinn Gylfason
School	School of Electrical & Electronic Engineering	Department of Intelligent Systems, Division of Micro and Nano Systems
Email	<a href="mailto:yucchen@ntu.edu.sg">yucchen@ntu.edu.sg</a>	<a href="mailto:gylfason@kth.se">gylfason@kth.se</a>
Website	<a href="https://www.ntuimp.com/">https://www.ntuimp.com/</a>	<a href="https://www.kth.se/profile/gylfason">https://www.kth.se/profile/gylfason</a>
<b>Project Title</b>	<b>Development of Micro-Lasers on Chip for Biomedical Applications</b>	
Project Description (200-300 words)	<p>Cells are key building block for all lives. Sensitive analysis of cellular activities and inhomogeneities is critical in biology and industries. Characterization of multicellular models, which consists of a collection of cells embedded in a complex microenvironment, has become an important area for tumor analysis, drug screening, and diseases modeling. However, optical sensing signal is oftentimes weak and masked by strong background noise from scattering and auto-fluorescence of cells, which makes it challenging or even unable to detect small but biologically critical dynamics in complex cell environment. To address the challenges, optofluidic lasers has come into the spotlight recent year for its potential to amplify subtle biological signals. However, current state-of-art biolasers remain at the proof-of-concept stage, without being able to carry into real world device. Hence, this collaborative PhD project aims to develop an on-chip integrated optofluidic laser system for multicellular screening and analysis. This includes the development of on-chip optofluidic cellular laser for medical analysis (NTU side) as well as integrated system on-chip (KTH side). Focus will be put on the design and implementation of different optofluidic photonic chips for cellular detection and analysis. The proposed project is envisioned as a new technology which aims to complement current state-of-art assays and readers. The significantly enhanced sensitivity and multi-parameter analysis enabled by laser emission allows us to analyze minute quantum effects in biomolecules, which may otherwise remain undetectable with classical light. Beyond biology and biomedicine, this project will provide in-depth understanding of how light interacts with living organisms and biological materials, which will be significant for the development of novel bio-control photonic devices.</p>	
Program/Center Website(s)	<a href="https://www.kth.se/is">https://www.kth.se/is</a>	
Additional Information (e.g., files with project details)		



## Joint Projects

Home University	NTU Singapore	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Chen Yu-Cheng	Wouter Metsola van der Wijngaart
School	School of Electrical & Electronic Engineering	Department of Intelligent Systems, Division of Micro and Nano Systems
Email	<a href="mailto:yucchen@ntu.edu.sg">yucchen@ntu.edu.sg</a>	<a href="mailto:wouter@kth.se">wouter@kth.se</a>
Website	<a href="https://www.ntubimp.com/">https://www.ntubimp.com/</a>	<a href="https://www.kth.se/profile/wouter">https://www.kth.se/profile/wouter</a>
<b>Project Title</b>	<b>Smart Living Laser Systems- From Biosensors to Bioinformation Systems</b>	
Project Description (200-300 words)	<p>Since the outbreak of global pandemic, drug screening has become one of the most critical processes in curing and understanding many infectious diseases nowadays. However, conventional tools usually suffer from low dynamic range and signal-noise ratio, making it very challenging to accurately quantify the efficacy of drugs and outcomes. An important technological bottleneck in the detection and readout analysis of these 3D complex cellular systems. To address the current challenges, a new screening modality is needed for high-throughput 3D cellular analysis and drug screening. This includes the development of new image sensor (NTU side) as well as integrated system (KTH side). Hence, this collaborative PhD project aims to overcome the current challenges by developing intelligent living lasers. Through the strong light-matter interactions between multiple cells and resonators, the intrinsic biological features will be converted into complex laser signals, delivering biochemical and structural information. Investigations of different physical mechanism and materials will be studied. In the third year, laser fingerprints will be collected and investigated on this platform due to the high heterogeneity of 3D cellular organoids. Organoid function can also be profiled for the investigation of specific bioactivities or drug screening. Laser wavelengths will be used as barcodes to investigate the relation among various biofunctions. Eventually an integrated lasing system will be built and scaled up to extend to downstream applications for high-content drug screening. The implementation of highly sensitive 3D cellular living laser will lead to rapid screening of large compound libraries to extract high-throughput digital sensing information and novel drug candidates. Developing living lasers with intelligent functions offers the potential to unlock new avenues of discovery in health sciences and health informatics.</p>	
Program/Center Website(s)	<a href="https://www.kth.se/is">https://www.kth.se/is</a>	
Additional Information (e.g., files with project details)		



## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Cesare Soci	Val Zwiller
School	SPMS/EEE	School of Science, Department of Applied Physics
Email	<a href="mailto:csoci@ntu.edu.sg">csoci@ntu.edu.sg</a>	<a href="mailto:zwiller@kth.se">zwiller@kth.se</a>
Website	<a href="http://www1.spms.ntu.edu.sg/~oson/">http://www1.spms.ntu.edu.sg/~oson/</a>	<a href="https://www.kth.se/profile/zwiller?l=en">https://www.kth.se/profile/zwiller?l=en</a>
<b>Project Title</b>	<b>Time-tagging camera based on Superconducting Nanowire Single Photon Detectors (SNSPD)</b>	
Project Description	<p>Future communications and imaging systems will rely on quantum photonics to push beyond the limits achievable by classical systems and realize the next generation of communication networks.</p> <p>Detection of light at the single photon level is therefore essential for the implementation of all of these systems as more and more fields require large arrays of time-resolved single photon detectors.</p> <p>In addition to allowing the development of new technologies, time-resolved single photon sensors allow a significant improvement in quantum vision techniques such as:</p> <ul style="list-style-type: none"><li>- Ghost imaging</li><li>- Time-resolved Raman spectroscopy,</li><li>- Sub-shot-noise imaging</li><li>- Fluorescence lifetime imaging microscopy,</li><li>- Quantum LiDAR</li><li>- Quantum astronomy</li><li>- Time-of-flight (ToF) imaging</li></ul> <p>All these techniques require single photon detection and high temporal resolution with low noise and high sensitivity. To date, superconducting nanowire single photon detectors (SNSPDs) are the best single photon detectors in terms of efficiency, time resolution, dark count rate, and wavelength sensitivity range. They appear to be the most promising candidates to build large-scale devices in which high temporal resolution is a crucial parameter.</p> <p>This PhD project will focus on the design, realization and testing of SNSPD arrays and builds on the existing multidisciplinary expertise available at KTH and NTU.</p> <p>The first part of the work will be to build a multipixel detector interfacing and multiplexing SNSPDs with each other. This detector would include a hundred pixels, the goal being to achieve very high temporal resolution and a sensitivity range extending in the infrared for each pixel rather than to match the pixel number of classical CCD/CMOS cameras.</p> <p>The most critical performance criteria for our application being the temporal resolution and the ability to extend the structure to several hundred pixels, the use</p>	





of amorphous materials such as molybdenum silicide (MoSi) for the fabrication of the superconducting film seems to be the most appropriate choice. Indeed, since this type of material does not have a crystalline structure, it is less sensitive to film imperfections and structural defects, and is therefore the ideal candidate for integration on a larger scale.

The second part of the work will be to use the SNSPD arrays to image, measure and retrieve the arrival time of each photon hitting each pixel. At this stage, by means of post-processing, we will be able to measure correlations between photon pairs by realizing a large number of entangled states between each pixel. Because quantum light sources emit photons as correlated photon pairs, extracting temporal and spatial correlations between photons can lead to significant improvements beyond classically achievable limits in imaging systems. For instance, the availability of SNSPD arrays would greatly benefit the field of astrophysics, where measuring coherence through the second order autocorrelation function allows to gain information on location, size and composition of the sources. Through temporal correlation spectroscopy one could also detect non-classical light (photon bunching) emitted by celestial light sources.

The multi-pixel camera we envision is also very interesting in the context of quantum communications. Indeed, with detector bandwidth of the order of 10 MHz, the interfacing and simultaneous operation of 1000 detectors allows for the detection of single photons with 10 GHz of bandwidth.

Building such an imaging system would greatly increase the possibility for quantum imaging technologies to take hold in real-world applications, but also would make it possible to meet the current environmental challenges by considerably reducing the operating power of a superconducting single photon detector. Indeed today the power required for the operation of the cryostat is the main source of power consumption. By co-locating a large number of detectors in the same cryostat, the energy footprint of each detector will be considerably reduced.

This project is truly interdisciplinary as it requires several fields of complementary expertise, from photonics to quantum optics, from systems engineering to nanofabrication and materials engineering. The two groups that will co-host the PhD project have complementary areas of expertise in nanofabrication and spectrometry (NTU) and superconducting detectors design and quantum optics characterization (KTH). This exchange would be an exceptional opportunity to carry out this project and initiate a collaboration on large-size integrated superconducting detector arrays, which none of the two groups is currently pursuing.

The student identified to carry out the IGP Collaborative Initiative project, Pierre Brosseau, is an ideal candidate with prior knowledge and experience in several areas relevant to the proposed research program. After training in a major engineering school in France in systems engineering as well as in photonics, Pierre conducted a master project related to the operation of superconducting detectors SNSPD in the Quantum NanoPhotonics group of Val Zwiller in the applied physics department of KTH in Stockholm. His prior knowledge and expertise will allow him to lead the effort on the development of SNSPD arrays and to work independently at both NTU and KTH from the very beginning of the project.



## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Zhao Ou	Zuheir Barsoum
School	CEE	School of Engineering Science
Email	<a href="mailto:ou.zhao@ntu.edu.sg">ou.zhao@ntu.edu.sg</a>	<a href="mailto:zuheir@kth.se">zuheir@kth.se</a>
Website	<a href="https://zhaouu.weebly.com/">https://zhaouu.weebly.com/</a>	<a href="https://www.kth.se/profile/zuheir">https://www.kth.se/profile/zuheir</a>
<b>Project Title</b>	<b>Fatigue and Fracture of High Strength Steel Structures</b>	
Project Description (200-300 words)	<p>Compared with normal strength mild steels (e.g., grades S235, S275 and S355), high strength steels possess superior mechanical strengths. The use of high strength steels in construction brings the possibility of designing and constructing structures with smaller sizes, lighter weight, higher storey and longer span, being in line with the concept of sustainable construction. However, on the other hand, high strength steels suffer from low ductility, which has negative influences on the fatigue and fracture behaviour of structures. This project aims at investigating the fatigue and fracture behaviour as well as design of high strength steel structures. Laboratory tests and numerical simulations will be conducted to generate an extensive data pool. Based on the test and FE data, the fatigue and fracture behaviour of high strength steel structures will be investigated, each key influencing parameter will be examined and quantified, and design guidelines will be proposed.</p> <p>Objective: (i) Investigate the fatigue and fracture behaviour of high strength steel structures at material, member, joint and structural levels, (ii) Examine and quantify each key influencing parameter, and (iii) Propose design guidelines.</p> <p>Timeline/plan: The PhD candidate will spend his first 2-2.5 years at NTU for conducting testing and numerical modelling, and then go to KTH for another set of testing as well as design analyses.</p> <p>The main supervisor, Asst Prof. Zhao Ou, is an expert in the field of high strength steel structures. The co-supervisor, Prof Zuheir Barsoum, is an expert in the field of fatigue and fracture of engineering materials and structures. The proposed project titled 'Fatigue and Fracture of High Strength Steel Structures' combines the expertise from both of them. The resources and knowledge from both faculty's labs and schools will certainly contribute to the success of the project.</p>	
Program/Center Website(s)	<a href="https://zhaouu.weebly.com/">https://zhaouu.weebly.com/</a>	
Additional Information (e.g., files with project details)	NIL	



## Joint Projects

Home University	Nanyang Technological University, Singapore	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Wei Wu	Stefan Larsson
School	Civil and Environmental Engineering	Architecture and the Built Environment
Email	wu.wei@ntu.edu.sg	stefan.larsson@byv.kth.se
Website	<a href="https://dr.ntu.edu.sg/cris/rp/rp00944">https://dr.ntu.edu.sg/cris/rp/rp00944</a>	<a href="https://www.kth.se/profile/stelar">https://www.kth.se/profile/stelar</a>
<b>Project Title</b>	<b>Understanding and mitigating rock burst in deep rock excavation</b>	
Project Description (200-300 words)	Creating urban underground space and extracting deep natural resources are the next frontiers for social development and environmental sustainability. However, these anthropogenic disturbances deep underground may perturb the initial equilibrium of rock masses and lead to the occurrence of unpredictable geohazards. At great depth, rocks are subjected to high in-situ stresses. Field observations indicate that rock failure under high in-situ stress conditions can be either conditionally stable, which is accompanied by the progressive formation of layered structure (e.g., spalling failure), or abruptly unstable, which occurs along with the violent release of strain energy (e.g., rock burst). The objective of this study is to investigate the mechanisms of rock bursts under extreme environments. Laboratory experiments and numerical simulations will be performed to study the occurrence of rock bursts in intact and fractured rocks under various high stress and temperature conditions. The study is expected to improve our capability to predict and mitigate the risks of rock bursts during deep underground projects.	
Program/Center Website(s)	NA	
Additional Information (e.g., files with project details)	NA	

## Joint Projects

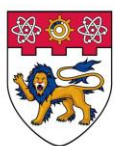
Home University	Nanyang Technology University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Tan Eng Leong	Oscar Quevedo-Teruel
School	EEE	EECS
Email	<a href="mailto:eeltan@ntu.edu.sg">eeltan@ntu.edu.sg</a>	<a href="mailto:oscarqt@kth.se">oscarqt@kth.se</a>
Website	<a href="https://personal.ntu.edu.sg/eeltan/">https://personal.ntu.edu.sg/eeltan/</a>	<a href="http://www.etk.ee.kth.se/personal/oscarqt/">http://www.etk.ee.kth.se/personal/oscarqt/</a>
<b>Project Title</b>	<b>Design, analysis and optimization of lens antennas for future satellite and 6G communications</b>	
Project Description (200-300 words)	<p>Mobile communications have evolved rapidly during the last few decades. This evolution has significantly changed the way we see our modern societies, and how we interact with each other.</p> <p>To meet the expected data rate demands, new satellite constellations and 6G are aimed to operate in millimeter-wave (mm-wave) frequency bands and sub-THz range. Unlike antennas at lower frequency ranges in previous generations, the antennas used with mm-waves and sub-THz frequencies must be highly directive in order to mitigate the free space attenuation, and they must be able to reconfigure their radiation patterns in real time with extreme angles of scanning.</p> <p>In this context, conventional antenna solutions, such as planar arrays, may not be compliant in terms of cost and scanning. Consequently, the main goal of this project is to investigate the opportunities of lens antennas to produce cost-effective solutions, with large the scanning capability and reduced losses. The research shall investigate various aspects of novel design, analysis and optimization of advanced lens antennas.</p>	
Program/Center Website(s)	EEE, CISS	
Additional Information (e.g., files with project details)	Nil	

## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Chau Yuen	Emil Björnson
School	School of Electrical and Electronic Engineering	School of Electrical Engineering and Computer Science
Email	<a href="mailto:chau.yuen@ntu.edu.sg">chau.yuen@ntu.edu.sg</a>	<a href="mailto:emilbj@kth.se">emilbj@kth.se</a>
Website	<a href="https://dr.ntu.edu.sg/cris/rp/rp02157">https://dr.ntu.edu.sg/cris/rp/rp02157</a>	<a href="https://www.kth.se/profile/emilbj">https://www.kth.se/profile/emilbj</a>
<b>Project Title</b>	<b>Holographic MIMO Systems</b>	
Project Description (200-300 words)	<p>The PhD research project aims to investigate holographic multiple-input and multiple-output (MIMO) systems, which take the 5G massive MIMO technology to new heights. Holographic MIMO refers to dense surfaces that can transmit, receive, reflect, and manipulate wireless signals. The ability and flexibility of holographic MIMO to improve spectral efficiency through intelligent environment configuration have been proved theoretically using simplified models. Holographic MIMO is expected to boost performance in many fields, including terahertz and mmWaves bands, multi-antenna communications, and localization. However, the full exploitation of holographic MIMO is still challenging due to many non-trivial technical issues. On the one hand, the closely spaced patch antenna induces serious mutual coupling effects, which will reduce spatial diversity and system capacity greatly, unless methods to mitigate them are developed. On the other hand, the conventional analysis tools in wireless communications are not applicable anymore in holographic MIMO systems due to the complicated electromagnetic scenarios. These concerns stimulate the demand for novel but effective approaches for performance evaluation for holographic MIMO systems, targeting providing a physical interpretation of holographic MIMO systems. In this PhD project, we will study the modeling of holographic MIMO systems, investigate the theoretical performance bounds in different scenarios (such as super-gain and super-directivity holographic MIMO), and develop an understanding of the fundamental physical limits of practical adoption of holographic MIMO that takes size and spacing into account, thereby paving the way for the more efficient and low-cost wireless communication technologies.</p>	
Program/Center Website(s)	NTU, EEE, CISS	
Additional Information (e.g., files with project details)	Nil	

## Graduate College

61 Nanyang Drive, Academic Block North, ABN-01b-11, Singapore 637335, [www.ntu.edu.sg](http://www.ntu.edu.sg)



## Joint Projects

Home University	Nanyang Technological University	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Wei Yang Bryan Lim	Carlo Fischione
School	School of Computer Science and Engineering	Division of Network and Systems Engineering
Email	<a href="mailto:bryan.limwy@ntu.edu.sg">bryan.limwy@ntu.edu.sg</a>	<a href="mailto:carlofi@kth.se">carlofi@kth.se</a>
Website	<a href="https://sites.google.com/view/wyb">https://sites.google.com/view/wyb</a>	<a href="https://people.kth.se/~carlofi/">https://people.kth.se/~carlofi/</a>
<b>Project Title</b>	<b>Federated Learning for Foundation Models</b>	
Project Description (200-300 words)	<p>With the increasing need for privacy safeguards, Federated Learning (FL) has emerged as a promising privacy-preserving distributed machine learning paradigm. In FL, data owners (i.e., clients) conduct the model training locally and then communicate their updated local model parameters or gradients to a parameter server or model owner for aggregation. This approach has demonstrated substantial success, notably in sectors like healthcare and finance where sensitive user data are involved.</p> <p>Recently, Artificial Intelligence (AI) is undergoing a transformative phase with the rise of foundation models. These models, which are pre-trained on large amounts of data, have the adaptability to be fine-tuned for specific downstream tasks. The convergence of FL and foundation models can democratize AI development by offering a privacy-preserving collaborative fine-tuning process. However, there are pressing challenges that need to be addressed.</p> <p>The primary challenge arises from the sizeable nature of foundation models, making them storage and computation intensive. This becomes a hurdle for clients involved in the collective training of a global foundation model, which could also render the process vulnerable to the straggler effect, thereby hampering the effectiveness of collaborative training. Another concern surfaces with model-partitioned training methods necessitated by the large size of foundation models. In such cases, different segments of the model training occur at distributed clients, which can potentially raise significant privacy issues. The aim of our project is to resolve these challenges to harness the full potential of FL in the evolving landscape of AI.</p>	
Program/Center Website(s)	NA	
Additional Information (e.g., files with project details)	NA	



## Joint Projects

Home University	NTU	
<b>Supervisors</b>	<b>Home</b>	<b>Partner</b>
Name	Dusit Niyato	Zhibo Pang
School	College of Computing and Data Science	Department of Intelligent Systems
Email	dniyato@ntu.edu.sg	zhibo@kth.se
Website	<a href="https://personal.ntu.edu.sg/dniyato/">https://personal.ntu.edu.sg/dniyato/</a>	<a href="https://www.kth.se/profile/zhibo">https://www.kth.se/profile/zhibo</a>
<b>Project Title</b>	<b>Safety communication over intelligent wireless networks for critical cyber physical systems</b>	
Project Description (200-300 words)	<p>The objective of the project is at the safety-critical message delivery over deterministic and real-time wireless network in scale without the expense of availability. Deterministic and real-time wireless communication is expected to play a key role in the industrial digitalization to enable e.g., mobile robots and machines, flexible deployment and maintenance, and more autonomous operation by integrating vast number of devices and data into the automation systems. However, there are still major concerns about safety, security, and availability before the wireless technology can be used in safety-critical applications.</p> <p>In this project, we aim to address these concerns with two complementary directions:</p> <ol style="list-style-type: none"><li>1) Safety-aware wireless: make the wireless network prepared when the safety-critical messages are going to be transmitted and special care should be given by the underlying network proactively.</li><li>2) Wireless-aware safety: make the functional safety application on the top prepared when the underlying network is wireless which is not as ideal as the wired network and special care should be given by the safety application proactively, too.</li></ol> <p>Our goal is to guarantee both functional safety and uptime of the safety-critical automation systems controlled over wireless networks. The use cases include mobile machines and robots, automated mobile vehicles for automotive manufacturing, hoisting and ventilation systems for underground mining, remote operation of cranes at container terminals, heavy duty grinding motors and drives, and large petrochemical systems, just to name a few.</p>	
Program/Center Website(s)	NA	
Additional Information (e.g., files with project details)	See attachment.	

## **Safety communication over intelligent wireless networks for critical cyber physical systems**

**Vision statement:** our long-term vision is safety-critical messages can be seamlessly transmitted over deterministic and real-time wireless network in scale without the expense of availability.

Deterministic and real-time wireless communication is expected to play a key role in the industrial digitalization to enable e.g., mobile robots and machines, flexible deployment and maintenance, and more autonomous operation by integrating vast number of devices and data into the automation systems. However, there are still major concerns about safety, security, and availability before the wireless technology can be used in safety-critical applications. In the existing solutions, once the latency and reliability of wireless communication exceed the limits set according to the system safety response time, the system is automatically turned into safe state e.g., stop working. This causes unacceptable huge downtime. **This challenge has become even more crucial for sustainability, human, and environment because we need to cope with the impacts of not only the unintentional interferences in the wireless channel but also the malicious attacks.** We could say the safety concern is the root cause of the stringent requirements on latency, reliability, security, and resilience in general.

In this project, we hope to crack this "hard-nut" by systematic innovations in two complementary directions:

- 1) **Safety-aware wireless:** make the wireless network prepared when the safety-critical messages are going to be transmitted and special care should be given by the underlying network proactively.
- 2) **Wireless-aware safety:** make the functional safety application on the top prepared when the underlying network is wireless which is not as ideal as the wired network and special care should be given by the safety application proactively, too.

Our goal is to guarantee both functional safety and uptime of the safety-critical automation systems controlled over wireless networks. The use cases include mobile machines and robots, automated mobile vehicles for automotive manufacturing, hoisting and ventilation systems for underground mining, remote operation of cranes at container terminals, heavy duty grinding motors and drives, and large petrochemical systems, just to name a few.

### **Specific ideas**

We will focus on the technical work including both theoretical and practical activities. Iterative approach will be applied, i.e., an iteration is started from a new Concept, followed by theoretical modeling, analysis, and simulation, then the Concept will be implemented and validated on a real-life testbed, and finally, we will decide to refine the Concept or turn to another Concept for the next iteration based on the validation result. We have already two Concepts in the queue to be explored. We will start the Concept-1 and the testbed development in parallel first, and then decide the starting time of the Concept-2 based on the progress of the Concept-1.

- **Concept-1: joint error detection and correction by the cyclic redundancy check code (CRC).** The CRC code has been used for decades in all the safety communication standards of today, but only for error detection. Our previous work has shown, unprecedentedly low error floor (residual error rate) can be achieved if the CRC code is utilized for error correction as well, thanks to the emerging GRAND (guessing random additive noise decoding) techniques. We will continue this exploration with



specific focus on the thermotical bounds of different CRC polynomials and optimization of decoding algorithms aided by machine learning.

- **Concept -2: safety semantic communication.** More and more machine intelligences are being added to industrial automation systems, thanks to the rapid penetration of computer vision (CV) and large-language models (LLM) to industries. Transmitting the vast amount of raw data of the CV and LLM applications over wireless networks is difficult if they are safety critical. We will explore the emerging semantic extraction and reasoning techniques so that we can segment the raw data into safety-meaningful objects and apply different transmission strategies according to their different level of importance according to the safety logic. Moreover, we will utilize a generative AI method, i.e., generative diffusion model, to extend semantic extraction from the content generation perspective. Through using noise addition and denoising process, the diffusion model is able to generate an optimal communication policy, e.g., to prioritize different types of information to be transmitted, to achieve the best performance in terms of safety and efficiency.
- **Testbed development: end-to-end safety channel over software defined wireless user equipment.** To validate the above concepts in real-life, we will develop a testbed for end-to-end safety channel based on the best of the art building blocks. This will include the emerging functional safety standard, the OPC UA Safety stack from ABB, over the open-source implementations of the main-stream wireless standards such as 5G (e.g., the OpenAirInterface project) and WiFi (e.g., the OpenWiFi project). The open and software defined nature (using software defined radio) of these projects provides a new possibility of making the wireless user equipment for the industrial automation domain. During this work, we will also identify the functional gaps of those projects which could motivate future collaborations with external partners.