iUROP no	Proposer name	Project title	Project Scope	Nature of Work	Tasks and responsiblities	Time Commitment	Number of Student Participants Required
IU2015-001	Erik Wilhelm	SENsg: Large-scale Internet of Things Sensor Deployment in Singapore	By empowering inquisitive young minds with a highly interactive connected sensor and engaging them in national participatory geo-localized SENsg experiments, this project aims to contribute significantly to the promotion and advancement of science and technology among school children in Singapore. To enable large-scale experiments to engage Singaporean students and inspire young and old alike, we propose a low-cost, outwardly simple, scalable 'SENsg' sensor system and an accompanying set of experiments in this whitepaper. The sensors will allow various physical parameters such as temperature, light, humidity, noise levels, motion, images, and location to be recorded at meaningful intervals. Additional sensors can be included as needed as the project progresses, due to the modular and scalable design. The collected data will be transmitted wirelessly to a central server, where it is anonymously stored. The raw data is preprocessed, and can then be accessed by means of a simple and intuitive Graphical User Interface (GUI) or Application Programming Interface (API - for the more advanced user) to achieve various learning objectives themed around Singapore's natural environment. The hardware and software are designed for their ease of use, low cost (<35 SGD), and robustness to shock, ingress, vibration etc. The sensors themselves are pocket-sized, and include both USB-recharging as well as solar-powered trickle-charging. They can be deployed both indoors and outdoors to enable a wide range citizen-driven science experiments. The proposed platform will also be designed to scale into future scientific research to answer questions about harnessing adaptive algorithms for robust communication, analysis of changing environmental conditions, traffic and urban noise studies, among other things. The data will at all times be handled to protect privacy as well as to support public policy goals.	The Motion, Energy, and Control Lab at the SUTD is looking for candidates to support the development of low-cost, mesh-networking 802.11 sensor nodes for connecting people and data. The goal of the SENsg project is to inspire students to pursue education to become future engineers. The SenSing sensor nodes are an instance of 'internet of things' technologies designed to be: - cheap, non-invasive, and ubiquitous, - provide simple, intuitive ways to gather environmental data, play games, and communicate. Embedded system design, as well as machine learning and ad hoc networking will feature prominently in this work, as will the ability to design, test, and validate PCB and electronic systems. Some mechanical and case design aspects will also be important.	This position exists to support the work of graduate students and PI's investigating the design of cheap wireless sensors. There are lot of options for motivated students to expand the scope of work to cover their personal interests. A short sample of responsibilities include: - designing the fourth generation SenSing, with emphasis on robustness and cost reduction measures, - developing and validating the network data transmission techniques, - proposing and testing sensing and inference algorithms, - running field trials and gathering data. Required Skills - passion, motivation, curiosity, and independent problem solving abilities are a must -experience with embedded system design, including PCB prototyping and troubleshooting is a big plus -strong microcontroller and general programming skill required - experience with mechanical design a plus Google 'Internet of Things' and the first page will be full of similar topics	6 hr/week in term, 20 hr/wk during break	2
IU2015-002	Massimiliano Colla	Plotter-like wall painting for commercial and housing estates	An external structure on rails meant to guide a spray painting system to repaint the facade of commercial and residential housing estates. The system would be as disguised as possible, remotely controlled by a computer that will guide the painting nozzle much like a plotter is moved to produce large size prints. Students will conceptualise this idea and create a scale model that can be computer guided. Initially we require only a uniform coverage of the facade that leaves only a very small surface area uncovered. These areas will eventually be hand painted. Protruding or intruding elements of the building will be identified and excluded from the process. The system should be designed to allow more complicated patterns to be printed in the future The goal is to make minimal use of human resources that are costly and reduce the risks associated to this kind of operations. Ultimately, buildings will be able to maintain themselves clean (the system should be used for pressurised water jets as well) semiautonomously. Once complete, we will consider commercialising the system for new and existing buildings.	The students will initially identify all possible constrains and factors that could limit the efficacy of this idea especially on more elaborate buildings and those with more ornaments. They will proceed to construct a scale model and a 2D grid along which an electrically powered unit connected to a flexible hose will transport water and a pump will eject it through a nozzle whilst being guided along the rails. Sensors will detect any obstacles along the path and feed back to the guiding system so that the obstacle can be avoided. The students will identify all problems with the operation of the system and decide on the necessary modifications necessary to scale up the system. Importantly they will identify the risks associated with the operation and propose measures to ensure the safety of the residents and passers by.	Create a working prototype by sourcing the parts to be assembled and coding as necessary to operate the spraying nozzle and sense and avoid the obstacles. Designing a system of minimal visual impact that can be easily and cheaply installed on existing buildings. Create a fail-safe protocol and counter measures to prevent accidents to people and all the mechanical parts	each student should probably spend about 6 hours/week on regular term (average) on the project and about 20 hours during the break.	5 to 6
IU2015-003	Jun Sun	Auto-Testing Your Tutor Submissions	In this project, we will look at how to automatically test a given program. The student will be applying an in-house Java testing tool developed by my group to evaluate their seniors' Java programs submitted through Tutor. With the evaluation result, the student is encouraged to propose new approaches on automatically generating test cases, automatically locating where the bug is and automatically generating scores based on testing coverage, etc.	In this project, we will look at how to automatically test a given program. The student will be applying an in-house Java testing tool developed by my group to evaluate their seniors' Java programs submitted through Tutor. With the evaluation result, the student is encouraged to propose new approaches on automatically generating test cases, automatically locating where the bug is and automatically generating scores based on testing coverage, etc.	The student is responsible for 1. pre-processing the student Java programs so that they can be the subject of our study; 2. applying an in-house Java testing tool developed by my group to evaluate the Java programs; 3. generating a report on the evaluating result and comparing it to the result obtained through manually created test cases 4. proposing new approaches on automatically generating test cases, automatically locating where the bug is and automatically generating scores based on testing coverage, etc.	6 hours per week	2
IU2015-004	Chong Keng Hua	Community Design in Singapore	The need to forge social cohesion, identity and belonging, and subsequently community, has always been an explicit agenda in the planning and design of public housing estates, urban amenities and facilities in Singapore. In the past 50 years there were many attempts in constructing community by various government agencies, through urban planning as well as development of various public spaces and public buildings. This project thus aims to map out and analyze the design and development of community spaces in Singapore, including housing precincts, community centres, playgrounds, parks, swimming pools, public libraries, hawker centres, etc.	Fieldworks; understanding the psychosocial aspects of community space in order to engage users for data collection (surveys, interviews, observations and any new methods derived); community space analysis; administering data collection; creative and graphical data representation.	To be trained on public/community space analysis; pilot test and improve existing data collection methods; develop graphical and/or digital methods of data collection and representation; test prototype with a sample of the public; write final report.	12 hours per week during term time + 35 hours per week during term break	8
IU2015-005	Joel Yang	Coding A GUI For Printing of Colors with Nanostructures	We have developed a revolutionary technology for printing color images, e.g. photos, and graphics, using nanostructures instead of inks. The result is that color prints are extremely high resolution, and colors don't fade. The project will involve developing a GUI in Matlab and produce a portable .exe file that takes in a color palette with a lookup table for what nanostructure each color corresponds to, and generating a layout that can be used by an electron beam lithography system to print out color micro-images. Student will be able to apply good GUI design, understand the basics of nanostructural color printing, and participate in a cutting edge research topic.	Coding, software and GUI design. If interested, work can be published as a technical report.	Matlab coding, learning the syntax needed for some common e-beam lithography systems, and generating a GUI.	Depends on the coding skill level of the student, it could be 2-3 hours per week or 6 hours per week.	1 to 2
IU2015-006	Massimiliano Colla	Light harnessing for commercial and civilian use	Singapore is blessed with 12 hours of natural light a day. Yet we do not make much use of that having to rely on artificial lights in most public buildings and many private and public estates. I propose to use a set of self adjusting parabolic telescopes to guide visible light into optical pipes to be used instead of the inefficient and costly artificial lighting. The collectors will be fitted with IR filters that will remove the infrared component and guide the visible component to staircases, garages and possibly individual apartments and houses. There is an option to integrate this idea into the bricks that are used for the constructions that could even be fitted with LED's that would become a "pixel" of a large canvas in the cityscape.	Energy savings and reduce impact on the environment are the driving motivations of this project. A simple calculation can show that it is possible to have relatively high levels of light collection (20 times the light emitted by an ordinary bulb) in 4 rooms with a collector of modest diameter (1.5m) The students will model analytically the maximum extractable amount of visible energy and will design or use a readily available design to control the movement of the collector using a stepper motor.	Students are responsible for procuring the raw materials, design the systems in all its parts, test it and suggest improvements. I will supervise them and share my knowledge on the materials to be used and their possible sources for materials and technology.	During the regular term:4 hours/week During recess: 15 hours/week	4
IU2015-007	Foong Shaohui	Portable Spherical Amphibious Robot	Forested terrains and mudflats surrounded by water bodies such as rivers, lakes, and swamps are difficult to manoeuvre around, especially for man-made automations and robots. The lack of reliable robotic platforms often hinders operations such as search-and-rescue, surveillance, and research efforts made in these terrains. Whereas most developments are focused on improving manoeuvrability on either land or water, little has been done in developing robotic platforms with amphibious capability. To address this design gap, an amphibious spherical rolling robot design is proposed. A spherical rolling robot is advantageous in terms of its self righting capability, balancing capability, and minimum damage to the surroundings during its mobilisation. The objective of this UROP was to further develop the current Portable Amphibious Spherical Robot. The proposed plan would to enhance its capabilities in implementing autonomy to the robot, live feedback in tracking of its position via Google Maps, better live-streaming capability in low light conditions, optimising its movement on ground and water and so on. Most of the robot's features are highly modular, facilitating customisation depending on the users' needs.	This project will involve prototype development, numerical simulation and experimental investigation.	To achieve the proposed goals, the team have made plans to do the following: • Implementing a PixHawk, using the mission planner to achieve autonomy • Using the DJI GPS/ Compass hardware together with 3DR's 433MHz telemetry as the client to communicate with another 3DR 433MHz telemetry at the Ground Station to monitoring the direction and position of the robot using Google Maps • Using design techniques to further optimise the performance of the robot to move on land and water • The robot could also mounted onto a Quadcopter for more applications as a whole	6 hours per week.	2 to 3
IU2015-008	Foong Shaohui	Inductive Charging of Aerial Crafts	The hassle about flying drones are usually about changing the batteries. The pilot will always have to change the battery the moment it is fully discharged and if he wishes to fly the drone again. Even with a good design of drone and good piloting skills, he will always have to change the battery no matter the circumstances. So Instead of changing batteries, charging it on the drone seems like a less troublesome solution! Having to charge a drone wirelessly could be the future of drone design. Current advances in technology have drones with fully autonomous capabilities, less the battery changing. With the implementation of a good induction charging landing pad, drones of the future could just be fully autonomous with little human interaction needed.	Hypothesis1: The power consumption rate of a drone in flight can be reduced to a point that its inductive charging rate as supplied from a power source is significantly larger than it so that flight can be sustained indefinitely. Data collection process: a. Theoretical data calculation for power consumption of drone and power rating of charging base b. Experimental data collection for power consumption of drone and power rating charging of base c. Implementation of correction factors for data calculations	Integration of inductive charging components Design and development of the base charger Optimization of the design. Experimental testing, verification and evaluation.	6 hours per week	4 to 5

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IU2015-009	Massimiliano Colla	The Portahouse	To design a simple house that can be easily dismantled and transported by homeowners to allow them to move their houses easily when they are living in areas with various and common occurrences of natural disasters or living conditions deteriorate because of conflict or harsh wether conditions. The ability to easily move their properties would also allow many people to avoid having to witness their homes being destroyed and greatly save them the costs of having to buy a completely new house and relocate. This project can also help the save space on the planet, as previously uninhabitable places can now have small communities living on them.	The students will have to design the Porterhouse completely, from the materials that are most suitable for the environment in which they will be used, to outsourcing them at the best market price to implement their idea into a final prototype that might attract industry partners. Basic technical drawing will complement the project which will also include basic wiring. In brief, this structure will consist of the following sections: 1) Flooring: A foldable flooring will be developed, with the concept of a pop-up book in mind, where some of the framing of the house will "pop-up" when the floorboards are opened. The flooring will also have a frame around it's perimeter which is where the walls of the house will be set in. Material: Nylosheet for the top (width=0.08m) and bottom (width=0.01m) layers, with thick foam in between for insulation (width=0.025m), amounting to a total floor width of approximately 0.043m. Framing that "pop-ups" will be made up of thin acrylic pieces (approximately 0.01m) 2) Walls: Polyvinyl chloride (PVC) with paper insulation or E.V.A. foam inside. The walls will also hold the wiring of the house 3) Roof: The roof of the house will be made up of a metallic umbrella shaped frame where the material of the roof can be obtained and made from local materials in the living area. The metallic rods will be made out of a lightweight metal that can be extended like a telescope. These extendable rods will be attached to a central column in the middle of the house, which will have attachment points at the top. There will also be another round metal piece that will be attached to the ends of the extendable rods, which will help the frame to keep its semi-spherical shape that will form the roof. The material of the roof can be made from anything that can provide insulation and shelter, from a simple tarp to straw roofing. The idea is that the owners will have to move a smaller number of items. The owners can purchase any material they like that they can use to form a new roof, this materials can be easily obtained from any part of the world as there are also many natural resources which can be used to make sustainable roofs that also provide very good insulation. One example would be straw roofs, which provide a good amount of insulation and protection from the weather. Straw roofs are also very long lasting and only need to be changed every one hundred years.	The students will design and build a working prototype as well as document their project with technical drawings (albeit simple) and the choice of materials, suppliers, fabrication time and costs.	4 hours/wee during normal term and 10 during the break.	6
IU2015-010	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (1) Multi-shape actuation by 4D printing	Three dimensional (3D) printing is attracting more and more attention within both scientific community and engineering applications for a series of advantages compared to traditional subtractive manufacturing. Besides of rapid prototyping, by which both time and cost can be saved greatly, 3D printing is being used for rapid manufacturing, by which the actual end user product can be fabricated directly. Due to precise placement of materials at micrometer resolution, 3D printing essentially has no restrictions on the geometric complexity of spatial arrangement, some of which cannot be created by traditional methods. All type of materials including metal, ceramic and polymer, although not all materials so far, can be printed. Most of 3D printers at present can only process one model material, namely single-material printing, which brings limitations to applications. As such, multi-material printing is becoming more and more popular as it provides options that products are able to have spatial variable mechanical properties, functions, and colors etc., which is difficult to be realized by conventional fabrication methods. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a right stimulus is applied [1]. This is known as shape memory effect (SME). Now that 3D multi-materials printing is able to control the microstructure of materials exactly, some more interesting SME could be discovered in 3D printed composites. By combing SME in materials with 3D printing technology, four dimensional (4D) printing technology has been proposed and demonstrated via multi-material printing[2]. In other words, the configuration of a printed work is able to change under stimulus after a thermo-mechanical programming progress, which creates time dependence of the configuration——the 4D aspect. This is a new research area. A lot of research work is necessary to be carried out along this direction to find more interesting phenomena and demonstrate more exciting achievements in applications.	In comparison with the conventional dual-SME, multiple-SME is more attractive, which significantly enhances the technical potential of active materials for a wider range of applications. Multi-SME can be achieved by means of incorporation of additional component(s) with different transition temperature(s)[3, 4], or by utilizing one transition which has a relatively wide temperature range[5]. Generally speaking, n-shape actuation (n is the number of actuation times) involves n steps of programming. Although Behl et al. claims that the triple-SME can be programmed in one-step[3], it is actually a process of step-by-step shortening/recovery with no shape changing trend. Here our proposed concept of one-step programming for multi-shape actuation is completely different from any existing literature, as we are able to realize not only multi-shape actuation by one-step programming, but also a powerful shape changing, such as elongating-bending-straitening-shortening. Our some experiments have shown that this kind of active materials completely works. However, limited by the number of primary model materials in our old Objet 350 printer, multi-shape actuation of such materials is also limited. We recently got a new Objet 500 Connex 3 printer, which is able to deal with 3 primary model materials in one single printing. This will definitely bring this kind of multi-shape actuation into a new stage. Much more complicated multi-shape actuation could be realized. Much more interesting applications could come true, such as robotic hand, robotic face with expressive emotions	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipment; design and print new models for potential application; publication of research results on scientific journals.	12 hours per week during regular term and up to and 35 hours during term break	2 to 3
IU2015-011	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (2) Multi-shape reversible actuation by 4D printing	Three dimensional (3D) printing is attracting more and more attention within both scientific community and engineering applications for a series of advantages compared to traditional subtractive manufacturing. Besides of rapid prototyping, by which both time and cost can be saved greatly, 3D printing is being used for rapid manufacturing, by which the actual end user product can be fabricated directly. Due to precise placement of materials at micrometer resolution, 3D printing essentially has no restrictions on the geometric complexity of spatial arrangement, some of which cannot be created by traditional methods. All type of materials including metal, ceramic and polymer, although not all materials so far, can be printed. Most of 3D printers at present can only process one model material, namely single-material printing, which brings limitations to applications. As such, multi-material printing is becoming more and more popular as it provides options that products are able to have spatial variable mechanical properties, functions, and colors etc., which is difficult to be realized by conventional fabrication methods. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a right stimulus is applied [1]. This is known as shape memory effect (SME). Now that 3D multi-materials printing is able to control the microstructure of materials exactly, some more interesting SME could be discovered in 3D printed composites. By combing SME in materials with 3D printing technology, four dimensional (4D) printing technology has been proposed and demonstrated via multi-material printing[2]. In other words, the configuration of a printed work is able to change under stimulus after a thermo-mechanical programming progress, which creates time dependence of the configuration——the 4D aspect. This is a new research area. A lot of research work is necessary to be carried out along this direction to find more interesting phenomena and demonstrate more exciting achievements in applications.	SMAs are stiff at high temperatures and soft at low temperatures, so that SMAs with one-way SME are ideal for thermally induced cyclic actuation, biased against either an elastic element or another piece of SMA [6]. Such cyclic actuation is termed as mechanical two-way SME. In addition, after training, SMAs are able to switch between two shapes, one corresponding to high temperatures and the other to low temperatures[7]. Correspondingly, this is called material two-way SME. However, the actuation strain in materials two-way SMAs is very small, and such SMAs is also very limited. SMPs are hard and tough at low temperatures but soft and flexible at high temperatures. Hence, mechanical two-way SME is only achieved in some special polymeric materials, such as liquid crystalline elastomer with alignment-induced stiffer upon heating[8], special semicrystalline network with crystallization-induced elongation upon cooling and melting-induced shrinkage upon heating[9, 10]. From engineering application point of view, materials two-way is more desirable than mechanical two-way SME. Here we propose a new concept of materials two-way SME in polymeric composites, which has not been reported in literature so far. Some of our previous work has demonstrate the feasibility of this concept. Besides further investigating and optimizing the structure of two-way shape memory composites, we will design and print some articles for application. These articles are able to execute complicated cyclic actuation without the assistance of a motor, that is, the printed material is just like a machine. By our new powerful Objet 500 Connex 3 printer, we could print a vivid colorful flower which is able to mimic the natural flower in its life term: sprout in spring, bloom in summer, blade in autumn, and hibernate in winter. It will sprout in next spring again, and its life will be cyclic and never ends up. We will further develop this two-way actuation in both principle and application. Tri-shape two-way actuation has been reported [11]. However it is a kind of mechanical two-way. By carefully designing our two-way composite structure, we could realize multi-shape materials two-way actuation, which has never been reported.	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipments; design and print new models for potential application; publication of research results on scientific journals.	12 hours per week during regular term and up to and 35 hours during term break	2 to 3
IU2015-012	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (3) Voxel printing	Most of 3-D printers is able to print one material with single stiffness and color. The standard printing in Objet 500 Connex 3 can print some digital materials with different stiffness and colors, but this capability is limited. Voxel printing allows us to control the material depositing process to create complex digital materials and color texture. We can print models with more interesting functions by 4-D voxel printing.	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipments; design and print new models for potential application; publication of research results on scientific journals.	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipments; design and print new models for potential application; publication of research results on scientific journals.	12 hours per week during regular term and up to and 35 hours during term break	2 to 3
IU2015-013	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (4) 4-D printing by FDM printer	Three dimensional (3D) printing is attracting more and more attention within both scientific community and engineering applications for a series of advantages compared to traditional subtractive manufacturing. Besides of rapid prototyping, by which both time and cost can be saved greatly, 3D printing is being used for rapid manufacturing, by which the actual end user product can be fabricated directly. Due to precise placement of materials at micrometer resolution, 3D printing essentially has no restrictions on the geometric complexity of spatial arrangement, some of which cannot be created by traditional methods. All type of materials including metal, ceramic and polymer, although not all materials so far, can be printed. Most of 3D printers at present can only process one model material, namely single-material printing, which brings limitations to applications. As such, multi-material printing is becoming more and more popular as it provides options that products are able to have spatial variable mechanical properties, functions, and colors etc., which is difficult to be realized by conventional fabrication methods. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a right stimulus is applied [1]. This is known as shape memory effect (SME). Now that 3D multi-materials printing is able to control the microstructure of materials exactly, some more interesting SME could be discovered in 3D printed composites. By combing SME in materials with 3D printing technology, four dimensional (4D) printing technology has been proposed and demonstrated via multi-material printing[2]. In other words, the configuration of a printed work is able to change under stimulus after a thermo-mechanical programming progress, which creates time dependence of the configuration——the 4D aspect. This is a new research area. A lot of research work is necessary to be carried out along this direction to find more interesting phenomena and demonstrate more exciting achievements in applications.	Research on 4-D printing is mainly focused on Polyjet printer so far. The capability of 4-D printing via FDM printer is basically an unknown area. Different from Polyjet printer which employs thermoset polymers, FDM printer uses thermoplastics. As such, the products from FDM printer are more flexible and robust, which is able to put the printed work from FDM into real application directly, not only prototyping. UAV with morphing wings by 4-D printing is a research direction. In other hand, a lot of parameters for FDM printer can be adjusted, such as slice height, surface finishing, and the bonding between filaments. For optimization of the printer's setting, a lot of work needs to done. The FDM printer has some special functions. Some external parts can be embedded in the models during printing. We can try to embed some metal layers in order to develop some active printing work actuated by electricity. Currently our FDM printer can only print one model material. We can try to employ the potentials of the printer and print two or more model materials in order to develop more advanced multi-functional printing work.	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipments; design and print new models for potential application; publication of research results on scientific journals.	12 hours per week during regular term and up to and 35 hours during term break	2 to 3
IU2015-014	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (5) Active metallic composite by 4D printing	Three dimensional (3D) printing is attracting more and more attention within both scientific community and engineering applications for a series of advantages compared to traditional subtractive manufacturing. Besides of rapid prototyping, by which both time and cost can be saved greatly, 3D printing is being used for rapid manufacturing, by which the actual end user product can be fabricated directly. Due to precise placement of materials at micrometer resolution, 3D printing essentially has no restrictions on the geometric complexity of spatial arrangement, some of which cannot be created by traditional methods. All type of materials including metal, ceramic and polymer, although not all materials so far, can be printed. Most of 3D printers at present can only process one model material, namely single-material printing, which brings limitations to applications. As such, multi-material printing is becoming more and more popular as it provides options that products are able to have spatial variable mechanical properties, functions, and colors etc., which is difficult to be realized by conventional fabrication methods. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a right stimulus is applied [1]. This is known as shape memory effect (SME). Now that 3D multi-materials printing is able to control the microstructure of materials exactly, some more interesting SME could be discovered in 3D printed composites. By combing SME in materials with 3D printing technology, four dimensional (4D) printing technology has been proposed and demonstrated via multi-material printing[2]. In other words, the configuration of a printed work is able to change under stimulus after a thermo-mechanical programming progress, which creates time dependence of the configuration——the 4D aspect. This is a new research area. A lot of research work is necessary to be carried out along this direction to find more interesting phenomena and demonstrate more exciting achievements in applications.	Shape memory alloys(SMAs) are able to provide a high actuation stress (up to 500 MPa), but a limited recoverable strain (less than 8%)[12]. On the other hand, shape memory polymers (SMPs) have a high recoverable strain but a low actuation stress (normally only a couple of MPa at the most)[13]. The underlying mechanism behind the SME in SMAs is a reversible solid-solid phase transformation between austenite and martensite, while the SME behind SMPs is based on elastic memory, namely the elasticity is fixed/released by a constraint. Here we prose a brand new concept, that is, shape memory metallic composite, which underlying principle of SME is completely different from conventional SMAs but similar to SMPs. This composite will combine advantages of both SMAs and SMPs, such as high recoverable strain and high actuation stress, and even have some benefits which both SMAs and SMPs are not able to provide, such as high transition temperature, fast actuation speed. Multiple-SME, which is quietly difficult to be shown in SMAs, will also be investigated.	Carry out research as scoped above; design/optimize proposed system by CAD software and build models by the up-to-date professional 3-D printer for research; characterization and demonstration of system by scientific equipments; design and print new models for potential application; publication of research results on scientific journals. Proposed Field of Research: Smart materials/Additive manufacturing	12 hours per week during regular term and up to and 35 hours during term break	2 to 3

iUROP no	Proposer name	Project title	Project Scope	Nature of Work	Tasks and responsiblities	Time Commitment	Number of Student Participants Required
IU2015-015	Martin L. Dunn	Designing, building, characterization and application of active materials by four dimensional printing - (6) Projection Microstereolithography	Three dimensional (3D) printing is attracting more and more attention within both scientific community and engineering applications for a series of advantages compared to traditional subtractive manufacturing. Besides of rapid prototyping, by which both time and cost can be saved greatly, 3D printing is being used for rapid manufacturing, by which the actual end user product can be fabricated directly. Due to precise placement of materials at micrometer resolution, 3D printing essentially has no restrictions on the geometric complexity of spatial arrangement, some of which cannot be created by traditional methods. All type of materials including metal, ceramic and polymer, although not all materials so far, can be printed. Most of 3D printers at present can only process one model material, namely single-material printing, which brings limitations to applications. As such, multi-material printing is becoming more and more popular as it provides options that products are able to have spatial variable mechanical properties, functions, and colors etc., which is difficult to be realized by conventional fabrication methods. Shape memory materials (SMMs) are featured by the ability to recover their original shape from a significant and seemingly plastic deformation when a right stimulus is applied [1]. This is known as shape memory effect (SME). Now that 3D multi-materials printing is able to control the microstructure of materials exactly, some more interesting SME could be discovered in 3D printed composites. By combing SME in materials with 3D printing technology, four dimensional (4D) printing technology has been proposed and demonstrated via multi-material printing[2]. In other words, the configuration of a printed work is able to change under stimulus after a thermo-mechanical programming progress, which creates time dependence of the configuration——the 4D aspect. This is a new research area. A lot of research work is necessary to be carried out along this direction to find more interesting phenomena and demonstrate more exciting achievements in applications.	This project involves building a new 3D printer based on a digital micro mirror projector. It involves taking an existing prototype of the printer and turning it into a machine that can possibly be turned into a consumer product and commercialised. This is in the spirit of many low-cost fused deposition modelling machines that are now on the market, but makes use of a technology that can provide much higher resolution. An additional part of the project is redesigning the machine to admit extra-fast printing speed. Interested students should be interested in mechatronics, control and 3D printing	1) Development of test speed 3D printing system based on projection micro stereo lithography. 2) Evaluation of final prototype 3) System Optimization	12 hours per week during regular term and up to and 35 hours during term break	2 to 3
IU2015-016	David Braun	Numerical Simulation of Constrained Dynamical Systems: A Stability Investigation	Numerical simulation of constrained systems, modeled with differential algebraic equations (DAEs), is required in many engineering disciplines. However, unlike ordinary differential equations (ODEs), that can be effectively integrated with explicit numerical methods (e.g., Runge-Kutta), integration of differential algebraic equations often require sophisticated implicit integrators in addition to a computationally expensive iterative constraint stabilization [1,2]. In this project we focus on explicit numerical integration schemes which can be used to efficiently and accurately simulate constrained dynamical systems modeled with DAEs without any iteration. By assuming that the computational environment is inherently error contaminated, one such integration schemes was recently presented in [3]. This method was numerically demonstrated to provide significant improvement in solution accuracy over long time simulations of DAEs. The focus of this project is to provide analytical arguments on the stability property of the explicit numerical integration scheme introduced in [3]. Understanding the stability property [behavior of the integrator under small random machine generated perturbations] is vital to certify this method for commercial applications. [1] J. Baumgarte, Stabilization of constraints and integrals of motion in dynamical systems, Comp. Methods Appl. Mech. Eng., 1, pp. 1–16, 1972. [2] C.W. Gear, B. Leimkuhler, G.K. Gupta, Automatic integration of Euler–Lagrange equations with constraints, J. Comput. Appl. Math. 12–13, pp. 77–90, 1985. [3] D.J. Braun and M. Goldfarb, Eliminating Constraint Drift in the Numerical Simulation of Constrained Dynamical Systems, Comp. Methods Appl. Mech. Eng., 198(37–40), pp. 3151–3160, 2009.	Mathematical analysis of a numerical solver. In particular, stability analysis of an explicit numerical integration method developed to simulate constrained dynamical systems.	1) Students should have good mathematical and analytical skills. 2) Students should have strong interest in numerical analysis, differential equations and linear algebra. 3) Familiarity with MATLAB environment is indispensable. 4) Students should be willing to learn about stability of numerical integration methods. 5) Students are expected to be self-motivated to complete the project and own the work. 6) At the end of the project, students are expected to prepare a concise summary report. 7) Upon successful completion of the project guidance will be provided in getting the work published.	12 hours per week. Also, students are required to meet the PI once a week (preferably on Monday) to update the progress and set deliverable for the week.	1
IU2015-017	David Braun	Walking Robot: A Testbed to Investigate Motor Control Aspects of Bipedal Locomotion	Robots can be used as models of biological systems to test hypotheses regarding their unobservable internal functions or observable external behavior. Experiments with robots in this context often provide new insight into the true nature of the considered problem e.g., assessment on postural stability or quantification of locomotion efficiency. However building a robot that can be useful for experimental investigation of this kind is a challenging task. The aim of this project is to develop a real-time control interface for a walking machine which has been previously used in our experimental studies [https://youtu.be/ML6QQ7WDqv0] and is currently under revitalization. The project will provide students the opportunity and support to redesigning the control interface of this robot by replacing the currently used off-board realization with a newly built self-contained on-board electronic control implementation. The outcome of the project is expected to be an enhanced locomotion platform i.e., a new test-bed for experimental investigation of bio-mechanical aspects of legged locomotion in particular and motor control in general. The long term goal of this work is to discover the physical reasons and control principles that govern movements of humans and animals and to utilize these findings in building next generation robotic devices i.e., intelligent prosthetic devices that can better restore healthy biological functions of people after injury.	Electronic control interface design and programing. PCB design for real-time motor control and sensing. During this project, students will be guided by members of the Dynamics and Control Group while making design decisions and developing, fabricating and testing the hardware.	1) Students should have good PCB design skills. 2) Students should have good C(++) programming skills. 3) Experience with brushed and brushless DC motor control as well as various sensors (encoders, inertial measurement units and strain gauges) is a plus. 4) Students should have strong interest in electronic control interface design. 5) Students are expected to be self-motivated to complete the project and own the work. 6) At the end of the project, students are expected to prepare a concise summary report. 7) Students will be supported in publishing their work.	12 hours per week. Students are required to meet the PI once a week (preferably on Monday) to discuss project related matters and provide an update on the progress.	2
IU2015-018	David Braun	Understanding Biological Control Strategies from First Principles of Optimality	The goal of this project is to predict and interpret biological control strategies from first principles of optimality. We aim to focus on the optimal control aspect of this problem, in particular, looking at how motor control strategies emerge from first principles of optimality and how these strategies can be applied on robots driven by variable stiffness actuators. As part of the project, students will be introduced to powerful computational optimal control tools capable of devising controllers through mathematical simulations and numerical computation. Using these tools, known impedance control strategies, adapted by humans in everyday tasks (reaching, holding and stabilizing a given position [1]) will be reproduced on minimalistic mathematical models. The essential features of these models, required to replicate biologically plausible behavior, will then be identified. Using these models, predictions will be made on systems performing more complex dynamic tasks where experimental observations are lacking and where intuition often breaks down. It is expected that through this exercise a useful insight is gained on the behavior of compliantly actuated variable stiffness systems. These findings will find their use in next generation robots built to assist humans [https://youtu.be/BJn21ib97Tk]. [1] E. Burdet, R. Osu, D. W. Franklin, T. E. Milner, and M. Kawato, "The central nervous system stabilizes unstable dynamics by learning optimal impedance," Nature, vol. 414, pp. 446–449, 2001.	Mathematical analysis and optimization of minimalistic limb models. During this project, student(s) will closely work with other members of the Dynamics and Control Group while developing the mathematical model and performing the numerical optimization.	1) Students should have good mathematical and analytical skills. 2) Students should have strong interest in numerical optimization, non-linear dynamics and control systems. 3) For this project, familiarity with MATLAB environment is indispensable and experience with C(++) programing is a plus. 4) Students should be willing to learn about variable stiffness actuation. Resources and guidance will be provided. 5) Students are expected to be self-motivated to complete the project and own the work. 6) At the end of the project, students are expected to prepare a concise summary report. 7) Guidance will be provided in getting the work published.	12 hours per week. Students are required to meet the PI once a week (preferably on Monday) to discuss project related matters and provide an update on the progress.	1
IU2015-019	Stylianos Dritsas	Creativity and Robotic Fabrication	The objective of this project is to explore the creative potential of robotic systems for digital design and fabrication. Students will learn how to design artifacts that cannot be made by hand, develop custom tools, use visual programming and operate robotic fabrication machines. The core challenge is to merge subtractive manufacturing such as CNC milling with additive processes such as 3D printing to achieve large scale artifacts.	The project is suited for students with stong desire for hands-on design and making, for exploring new ideas and bringing them to life. We will design and build prototypes and exhibit and publish the results.		The time commitement is based on the desire of students to reach their objectives.	2 to 10
IU2015-020	Subburaj Karupppasamy	Design and Development of Low-Cost Gantry for Ultrasound Imaging of Hand	Problem: Musculoskeletal ultrasound has many advantages over other imaging techniques, including low-cost, no radiation exposure, ability to carry out rapid assessment of many widely spaced joints, and the ability to move and stress musculoskeletal structures while imaging (Javadzadeh et al., 2014). Trigger finger (tenosynovitis), is a common disorder characterized by catching, snapping or locking of the involved finger flexor tendon, associated with dysfunction and pain. A systematic approach would be a full examination of extra-articular structures, including skin, subcutaneous tissue, the tendon and tendon sheath, and the enthesis and associated bursae. It is traditionally performed with a heaped-up gel mound or stand-off pad. This technique is highlighted by easy access, reproducibility, and safety (Blaivas et al., 2004). However, the complex curved surfaces of the hands often yield suboptimal contact between the transducer and the skin (Krishnamurthy et al., 2013). To compensate for curvatures of the digits and other portion of distal extremities the ultrasound transducer should be angled when possible. However, the linear transducer by its nature does not allow conformation to small body curvatures. Additionally, a relatively small field of view afforded by the stand-off pad and the small footprint of the transducer, compression of clinically relevant superficial structures by the transducer and patient discomfort caused by contact of the transducer with the pathology, resulting in motion and a lack of cooperation (Javadzadeh et al., 2014). One Solution: A modification of traditional water-bath technique combined with high-frequency transducers could overcome these limitations. In this method, the affected the hand is immersed in lukewarm water with scanning is performed using high-resolution linear transducers without touching the skin, simulating the use of conventional ultrasound gel or stand-off pad (Fig. 1). This technique has been proven to be useful for evaluation of a painful distal extremity or an area that simply does not allow for easy access using the direct contact technique. In addition to being no discomfort to patient, this technique offers a large field of view of the entire cross-section of the hand, and superior quality images due to the water bath properties (Blaivas et al., 2004). Also the technique has been shown to produce superior quality images than the standard technique in various conditions, including depiction of vascular malformations, trauma and evaluation of soft tissues. However, image quality depends on selecting appropriate scanning frequency, focal zones, and Doppler frequencies similar to the standard scanning. Keeping the transducer at a constant distance from the surface of the hand is important in ensuring image quality while maintaining transducer is immersed in the water. So the quality of ultrasound images is often dependent on the skill of the sonographer. Also in 3D ultrasound, for automated processing of the images for clinical evaluation of tendons and bone erosion, the images obtained are usually acquired by a series of 2D image planes that are rendered to a volume 3D image. Motion or vibration of the targeted anatomical sites during the acquisition of a volume introduces a motion artifact into the volume. The motion artifact affects the overall quality of a volume. Not only there are artifacts inherent to 2D imaging present in 3D ultrasound but additional artifacts specific to volume. Goal of the Project: We propose to build a low-cost system by combining (1) traditional water-bath ultrasound imaging technique, (2) a robotic gantry to aid in ultrasound image acquisition, and (3) an image analysis system for visualization of anatomical structures of hand and measurement of biomechanical variables. In this UROP project, the 2nd objective on design and developing of a robotic gantry to aid in ultrasound image acquisition should be carried out.	Mechanical system design and development; control system design Mechanical System Design: One of the main aims is to keep the cost as low as possible, so we expect the developed the gantry (modified style of Cartesian robot) should be simple, maximum work volume should be 18 x 18 x 12 inches (Tabletop size of clinical office use), and the end effector should be a custom holder to place the high frequency ultrasound transducer of a commercial bed-side ultrasound machine. Control System Design: Each axis is based on a linear actuator (OEM or a pre-assembled actuator) to allow for combination of good speed, long stroke, and high positioning accuracy. These combination is driven by the required of image quality, scanning frequency, and focal zones. The scanning procedure should be controlled from a tablet or laptop via Bluetooth or wi-fi. Transducer scanning path will be optimized based on parameterized hand anatomy and initialization of prominent anatomical landmarks. We will also use an adjustable hand holder (immobilizer) to make the positioning of hand more robust. Single image slices with extended field of view should be obtained by translating the transducer along the image plane. 3-D images orthogonal to the image plane should be created using the same methods with simple linear sweeps through a volume of tissue (hand).	1) For prototyping and testing, students may decide to development the system stand-alone, instead of full integration with the other elements of the system. 2) Students will be working with clinicians to get their feedback at the early stage of design/development itself to incorporate necessary steps to make the system usable in clinical settings not just in the lab. 3) Students should be self-motivated to learn fundamental of medical imaging to understand the clinical requirement and necessary programming language to develop the path planning and control system. 4) Students are expected to be self-motivated to complete the project and own the work.	12 hours / week Students are required to meet SUTD PIs once a week (probably on Monday) to update the progress and set deliverable for the week.	2 to 3

iUROP no	Proposer name	Project title	Project Scope	Nature of Work	Tasks and responsiblities	Time Commitment	Number of Student Participants Required
IU2015-021	Subburaj Karupppasamy	Biomechanics of Finger Motion using Ultrasound Images	BACKGROUND: Hand function requires interaction of muscles, tendons, bones, joints and nerves. The unique construction of the hand provides a wide range of important functions such as manipulation, sense of touch, communication and grip strength. The hand is used in many ways, and in many different situations in our daily lives; so injuries, diseases or deformities of the hand can affect our quality of life. Several of our most common injuries and diseases affect hand function. Therefore, it is very important to understand how healthy and diseased hands work in order to be able to design optimal rehabilitation or treatment strategies pursuant to hand injury, disorder, or disease (Krishnamurthy et al., 2013). CLINICAL PROBLEM: There are many subjective methods used today for evaluating hand and finger functions. In clinical settings, joint range of motion (ROM) measurements are used to determine impairment ratings when a patient is unable to return to his or her prior level of function and to monitor patients' rehabilitative status and progress (Norkin and White, 2003). Goniometers are used to measure ROM at instant conditions which are not reflectivie of real-life hand functionality. This is because hand functions in daily living involve dynamic hand movements acutuated by muscles and tendons. These measurements are known for low reliability and sensitivity due to simulataneous measurement of ROM of all the main finger joints, in addition to the errors introduced by the examiner and instrument. Based on these considerations, it is important to develop a quantitative method of hand evaluation that had reliable precision (Yoshii et al., 2011). PROPOSED SOLUTION: Integrated 3D motion analysis is being used in research to understand the kinematics but the reliability of surface markers in representing the true kinematics of underlying tissues is questionable. One potential source of error would be movement of skin surface markers and high variability due to motion and ridges at the dorsal aspect of the skin. To overcome the constraints of surface skin markers, we propose to perform in vivo 3D motion capture, using non-surface contact ultrasound probes (water-bath ultrasound imaging technique), by tracking movement of bones and tendons in ultrasound images. OBJECTIVES: 1. Devise a workflow of optimal image filtering and boundary enhancing algorithms to de-noise, enhance, and pre-process the ultrasound images. 2. Design and implement an algorithm to segment finger bones and tendons in ultrasound images of the hand. 3. Design and implement an algorithm to track and quantify the movement of bones by establishing a dynamic coordinate system.	Medial Image Analysis, Image Processing, and Algorithm Development	1) Students are required to meet SUTD PIs once a week to update on the progress and set deliverable for the week. 2) Students will be working with clinicians to get their feedback on the results and incorporate necessary steps to make the system usable in clinical settings. 3) For prototyping and testing, students may decide to develop the system stand-alone instead of full integration with the clinical ultrasound imaging system. 4) Students should be self-motivated to learn fundamental of medical imaging to understand the clinical requirement and necessary programming expertise. 5) Students are expected to be self-motivated to complete the project and own the work.	12 hours / week.	2 to 3
IU2015-022	David Braun	Nonlinear Oscillators for Energy Harvesting Applications	Vibration energy harvesting devices are built to convert kinetic energy into useful electricity. Most of these devices are linear oscillators, capable of large gain amplification at resonant excitation, but have limited effectiveness under more typical broadband ambient vibrations [1]. The goal of this project is to develop a non-linear oscillator for adaptive energy harvesting from natural vibrations. Previous work in this area provided useful insight into possible mechanism to improve the effectiveness of linear harvesters using essential non-linear devices. In this project we aim to explore the design aspect of this problem by fabricating controllable electromechanical resonators which are optimized for energy harvesting applications. In doing so, our aim is to exploit fundamental but silent physical features of nonlinear oscillators to challenge the current state-of-the art in energy harvesting applications. [1] F. Cottone, H. Vocca and L. Gammaitoni, Nonlinear Energy Harvesting, Phys. Rev. Lett., 102, 080601 (2009).	Mathematical analysis of non-linear oscillators. Design and fabrication of a controllable electromechanical resonator. During this project, student(s) will be guided by the PI and supported by members of the Dynamics and Control Group while performing the numerical investigations and developing the prototype resonator.	1) Students should have good mathematical and analytical skills. 2) Students should have strong interest in non-linear dynamics, control systems and compliant mechanism design. 3) For this project, familiarity with MATLAB environment is indispensable and experience with LabVIEW is a plus. 4) Students should be willing to learn about non-linear oscillators and their practical applications. Resources and guidance will be provided. 5) Students are expected to be self-motivated to complete the project and own the work. 6) At the end of the project, students are expected to prepare a concise summary report. 7) Guidance will be provided in getting the work published.	12 hours per week. Students are required to meet the PI once a week (preferably on Monday) to discuss project related matters and provide an update on the progress.	1
IU2015-023	David Braun	Walking Robot: Biofeedback based Teleoperation	Walking robots can be used as models of biological systems to test hypotheses regarding their behavior. Experiments with robots in this context often provide new insight into the true nature of the considered problem e.g., assessment of postural stability or quantification of locomotion efficiency. However building a robot that can be useful for experimental investigation is a challenging task. In this project we aim to develop a locomotion platform to investigate biofeedback based robot stiffness control for the purpose of rehabilitation in general and to improve quality of life of disable due lower limb malfunction in particular. The first part of the project is focused on the design aspect of this problem where the aim is to develop a test-rig for a walking machine which has been previously used in our experimental studies [https://youtu.be/ML6QQ7WDqv0] and is currently under revitalization. The second part of the project focuses on the control aspect of this problem. In particular, our goal here is to develop a biofeedback based stiffness controller and use this controller to make the robot mimic a human operator using teleoperation. We envision this approach being useful in developing intelligent prosthetic and orthotic devices that are integrated with the user and as such can help better restore healthy biological functions in people after injury.	Mechanical design. PCB design for electromyography (EMG) measurements. Real-time motor control for teleoperation. During this project, students will be guided by members of the Dynamics and Control Group while making design decisions and developing, fabricating and testing the controller for teleoperation.	1) Students should have good mechanical design skills. 2) Students should have good MATLAB programming skills. 3) Experience with EMG sensors is a plus. 4) Students should have strong interest in electronic control interface design. 5) Students are expected to be self-motivated to complete the project and own the work. 6) At the end of the project, students are expected to prepare a concise summary report. 7) Students will be supported in publishing their work.	12 hours per week. Students are required to meet the PI once a week (preferably on Monday) to discuss project related matters and provide an update on the progress.	2
IU2015-024	Tan U-Xuan	Powered exoskeleton for lower limbs as a walking aid for the elderly	The main purpose of the project is to develop a powered exoskeleton for the lower limbs to serve as an aid for walking for the elderly. The exoskeleton is meant to provide a boost of those with problems walking through amplifying the user's lower body strength and reducing the effort to carry out basic human leg movements like walking and standing. This will allow the elderly with problems walking to be able to move with their own power, thus increasing self-reliance and reduce the burden of their caretakers, as well as allowing them more confidence in life as they are less reliant on others. A series of sensors will be used to detect the user's movements, and the information will be processed by an on-board computer. It will then process the information and controls motors to provide a boost in strength. Spring-loaded systems can be employed to complement the motors and optimize the system. The target users for this are elderly who have impaired walking ability due to insufficient leg strength, either due to age or disease. The fully functional powered exoskeleton will be designed with comfort, ease of use, visual appeal and power efficiency in mind.	This project involves design, development and performing experiments.	The main purpose of this project is to develop a powered exoskeleton for lower limbs as a walking aid for the elderly. The main aspects that will be focused on will be: 1. Able to sense the user's intended movements and carry it out. The exoskeleton has to be able to carry out the user's intentions while being natural for the user to use. 2. Reduce the strain and effort of the user while carrying out tasks such as walking and standing. It has to provide a boost to compensate for the user's lack of lower body strength. 3. Will not in any way cause injury to the user. Injuries may be caused by pinching due to mechanical joints, motors acting too fast or the joints hyperextending. 4. The exoskeleton needs to be easy to use, as the elderly may have less fine motor control, hand-eye coordination and worse eyesight. These factors have to be taken into consideration as being able to put it on themselves also contribute to their self-reliance. 5. The exoskeleton should be as silent and unobtrusive as possible. Having the exoskeleton being loud, noisy and visually obtrusive will be a source of embarrassment for the elderly. Having it being unnoticeable will serve to make them less conscious of the exoskeleton and not draw the attention of others to it, thus preserving their pride.	8 hours per week	2
IU2015-025	Yuen Chau	Understanding student movement within hostel	Our project focuses on improving the efficiency of student movement within the hostel. We have noticed that when students want to utilise common rooms, such as Meeting Rooms or Think Tanks, they often find them occupied and have to move themselves to another common room, possibly in another block. Given how group discussions are part and parcel of life in SUTD, we wish to address this inconvenience by introducing a system to track the usage of the common rooms that the students can check before heading there. There are existing solutions in the corporate world, but many involve a tablet outside the room that updates a central server. This is probably not cost-effective enough to scale to our entire campus. A purely web-based solution, where bookings are made on a web page or app, may be cumbersome and would lead to inaccuracy in the feed data if it is not seamless (laziness to book, or last minute changes). Some of the solutions that we have thought of include utilizing the security camera video feeds from these common rooms for motion detection, or a motion sensor in the room. Alternatively, if students feel that their privacy is at stake, there could be a button that the students can press to indicate that the room is occupied.	Data collection using various tools, e.g. sensors. Perform data analysis and build a platform to inform the analyzed outcome.	Designing the sensor devices. Build the data collection platform. Perform data analysis. Build a user interface to display outcome.	12 hours per week.	2