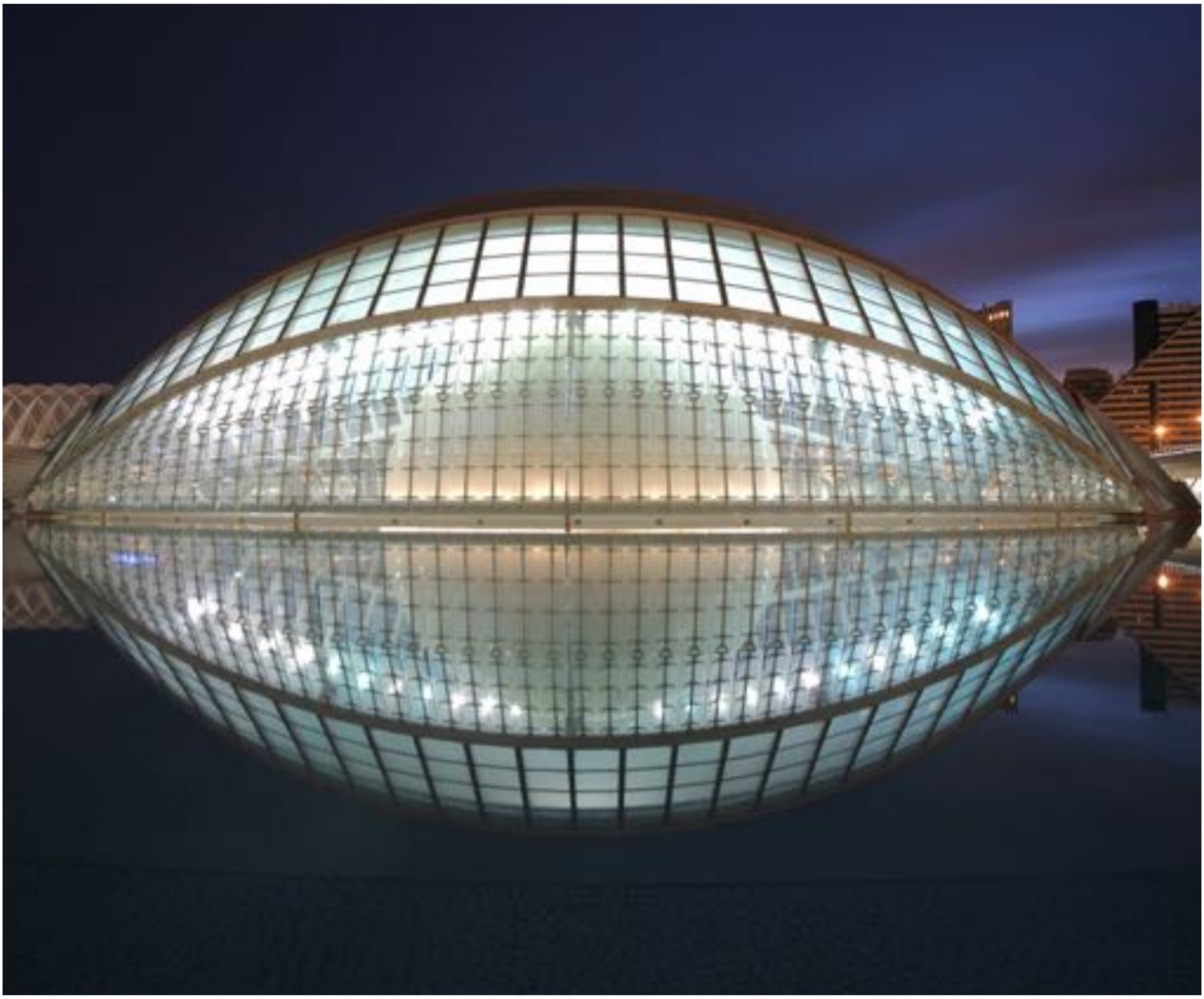
School of
Civil Engineering



Icarus Program

Projects, S1 2015

The University
Of Queensland
Australia

School of
Civil Engineering

Icarus Program 2015


Professor José Torero

The Icarus Program is a pilot undergraduate engagement program developed by the School of Civil Engineering. Icarus has two goals:

1 To develop a university environment that blurs the lines between an academic's 'teaching' and 'research' time and a student's 'curricular' and 'extracurricular' time. Academics and students are then willing and able to spend more time together on diverse and small-cohort projects.

2 To leverage this engagement to diversify and elevate student learning paths, student career outcomes, and UQ's national and international reputation. This is achieved by supplementing core civil learning material with civil research and non-civil extended learning material. In this way students can better achieve high-impact and diverse project outcomes.


Dr Joe Gattas

The 2015 program has four projects across structural, environmental, and transport civil engineering streams. Second-year civil engineering students can apply to participate in a single project and will complete project-specific activities which will complement their learning progress in CIVL2330 (structures), CIVL2130 (environmental), or CIVL2410 (transport). They may additionally participate in cross-project activities to develop interdisciplinary technical skills, an extensive set of professional skills, and a network of local, national, and international contacts.

Students interested in joining a 2015 project should complete the form on **page 031** and email to **icarus@civil.uq.edu.au**. Mentors interested in developing a 2016 project or following the progress of Icarus 2015 Projects should complete the form on **page 032** and email to the above address. We look forwards to working with you.


Dr Kevin Sevilla

Professor José Torero
Head of School

Dr Joe Gattas and Dr Kevin Sevilla
Icarus 2015 Coordinators

Cover Photo L'Hemisfèric, Valencia, Spain. Architect: Santiago Calatrava. Photographer: Javier Yaya Tur, 2006-11-27, https://www.flickr.com/photos/ciudadartesyciencias/8029351494/

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Contents

01 Concept rendering of Festi Flat drinks stand.

Project: The Festi Flat

Mentor: **Joe Gattas**

The Festi Flat is a fast-up, fast-down, solid-skin shelter, built exclusively from cardboard temporarily diverted on its way to the recycling plant. It uses an innovative orthogonal hinge arrangement to ensure speedy deployment and following use, is simple to flat-fold or crush to demonstrate that the house is ready for recycling. It was built as a concept disposable music festical shelter by first and second year undergraduates in just three weeks, during the Dyson Program 2014, a forerunner to the Icarus Program 2015.

Impressive progress was made on the initial design, however further development is required to generate a usable shelter. Students participating in this project would be expected to develop *rapid prototyping* and *experimental analysis* capabilities alongside their *structural mechanics* development in CIVL2330. They would use these capabilities to redesign and fabricate a Festi Flat with a stronger, stiffer, and lighter form and material. Students would subsequently field test the shelter to demonstrate its functionality.

Dyson 2014

The Dyson Program was a 3-week UQ workshop run in July 2014. Students were given the task of designing and prototyping a research-inspired application for submission to the James Dyson Award student design competition.

The Festi Flat was developed by second year student Evmen Wong and first-year students Daniel Brice and Joshua Owen. It utilised recent UQ research by Dr Joe Gattas into new types of folded plate structures and so generated an insulated, hard-shell structure with a 60-second deployment/packaging time and a sub-$100 price tag. The James Dyson award however is not simply assessed on novel technology. Rather, is requires entrants to identify a problem and articulate how and why the submitted design meets this.

Initial shelter prototype development was focused on developing a hard-skin tent for upscale camping applications, however interviews with experienced campers showed Dyson team members that such users enjoyed tents and were unlikely to be interested in an alternative. Students then reflected on their own, unfavourable, experiences with tents. Being non-campers, this was primarily at music festivals.

Thus, the Festi Flat was targeted towards music festival campers. This had two benefits for the student designers. One, their familiarity with festival tents allowed them to identify and design for user-generated problems. Two, research into music festical tents exposed that there was a huge problem with festival waste and tent disposal, suggesting avenues for improved Flat design, material use, and sustainability.

02 60-second Festi Flat deployment.

03a Aerial views of the estimated 150 tons of rubbish left at 2013 UK Reading Festival, *Daily Mail, 2013*.

Design Inspiration

Cheap tents and music festivals are a destructive mix: every year, hundreds of tonnes of festival waste is left on-site. 25% of this is discarded tents and 90% of these are dumped straight into landfill.

Young festival-goers aren't willing to pay more for tents and cheap tents aren't worth cleaning up and reusing, a cycle which can't easily be broken. It is also a problem that the Dyson team members were personally familiar with - they had been, for one reason or another, guilty of leaving bulky camping paraphernalia behind after music festivals.

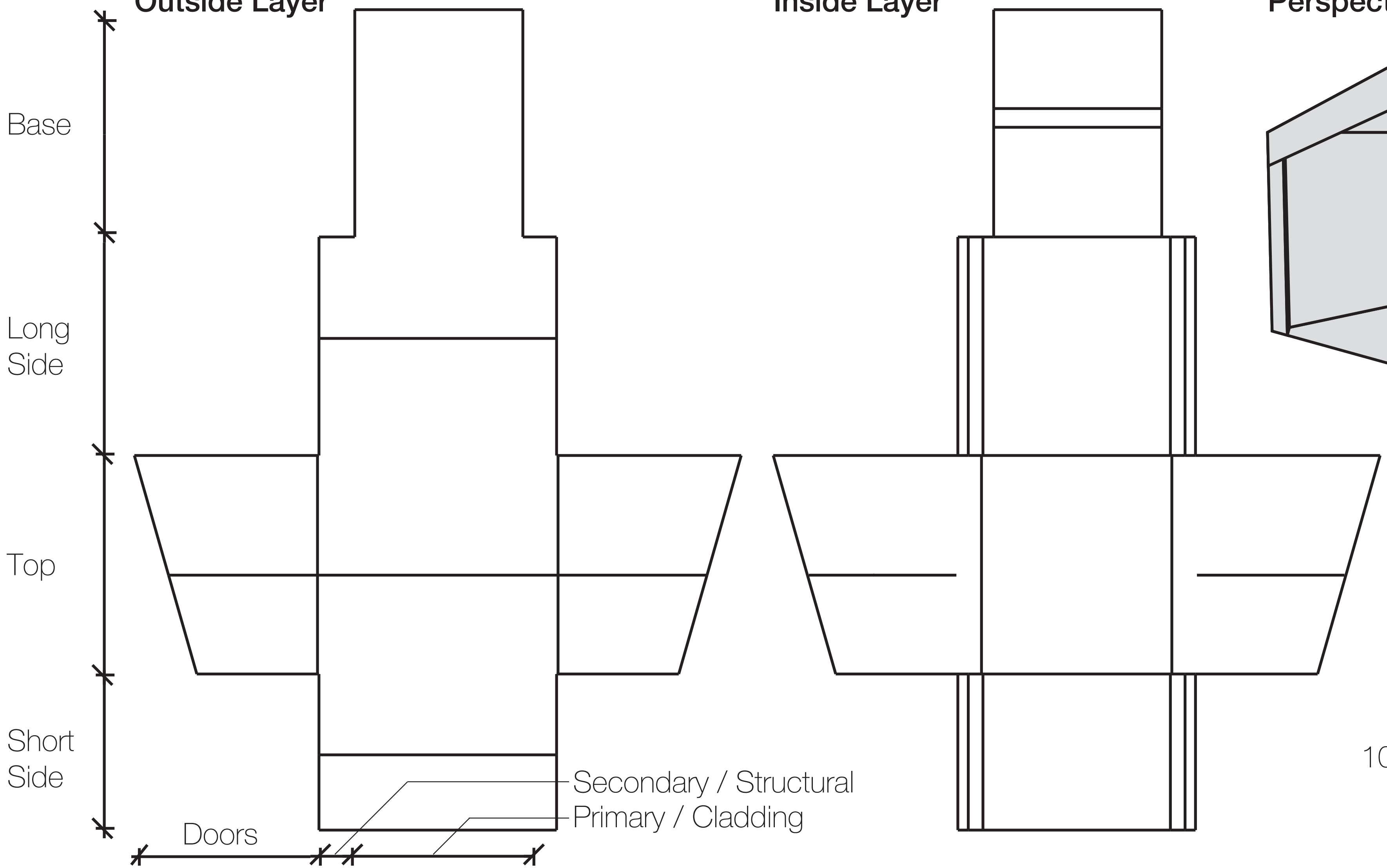
The design therefore grew from a desire to create a cheap festival house that embraced its path to destruction. The most ethical and sustainable for way for engineers to achieve this was to design a shelter that is both made from waste and could be entirely and easily recyclable following use. Thus, the current Festi Flat prototype uses a two-layer, double-flute, uncoated corrugated cardboard material. This material is usable for several days in wet weather, with the the outer layer sacrificial and the inner layer dry and insulative.

The Festi Flat flat design also considered numerous other elements. Volume and floor space requirements were chosen based on current available tents and comfort levels inside basic prototypes. Usage aspects, including speed of deployment, disposal motivation, weather conditions (temperature and wetness), and time of use were also considered to generate constraints that informed the final design. Large numbers of small-scale prototypes were constructed until a configuration was found that best met the usage requirements. Finally, community and festival culture factors were investigated, including customisation, modularity, and other festival waste (e.g. sleeping bags, chairs, tent pegs, etc.) disposal methods.

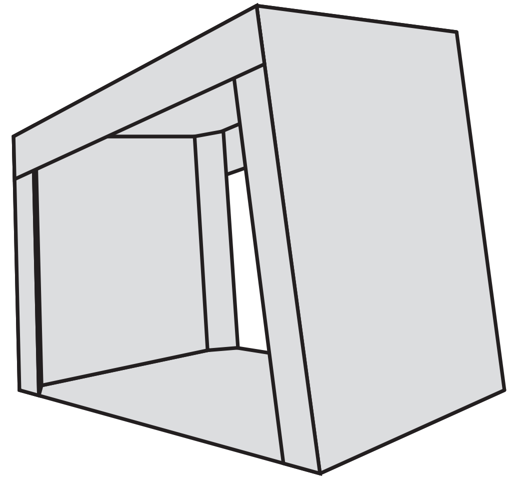
03b User comfort testing in early Festi Flat prototypes.

School of **Civil Engineering**
Icarus 2015 | Project: The Festi Flat

04 Outside and inside layer manufacturing outline.



Perspective



Technology and Development

The primary technology that enabled the Festi Flat was an innovative orthogonal hinge arrangement. A successful deployment was achieved, but more work is needed to improve the strength and stability of the structure. This is possible with knowledge gained in CIVL2330.

The current Festi Flat uses a bi-directional hinge configuration to form a rapid deployment mechanism. In the longitudinal direction, primary hinge lines allow rapid folding/unfolding of the major cladding panels. In the lateral direction, secondary hinge lines attach to minor structural panels. These are used to stiffen the final structure in two ways. First, the secondary fold lines suppress the primary fold lines when creased. Second, the attached minor panels fold into reinforcing frame elements, including a deep roof beam and triangular corner columns.

The initial Festi Flat prototype concentrated on usage requirements, and so the structure itself still requires much development to achieve a strong and stable shelter. Using principles learnt in CIVL2330, along with additional manufacture and experimental analysis skills, students participating in the present project will be expected to design, manufacutre, and test a Festi Flat v2 that has adequate structural performance. Below is a list of topics taught in CIVL2330 and the corresponding elements to be improved in the Festi Flat.

Engineers' theory of bending and properties of area
Design of corner column and roof beam (frame) elements.

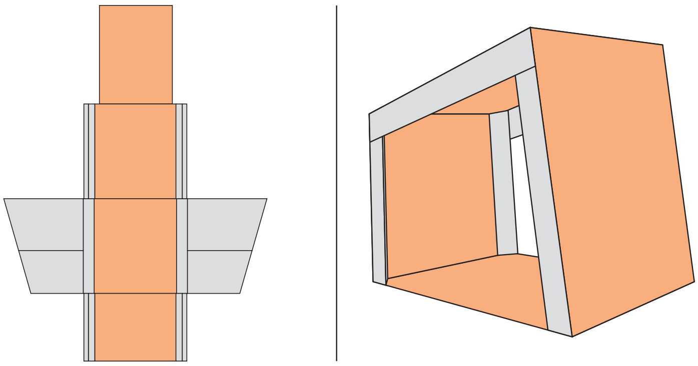
Beam shear stresses and shear centre
Refinement of frame elements and stability checks.

Deflections of beams and indeterminate structures
Design of cladding and bracing components. Linear elastic structural analysis including consideration of serviceability (deflection).

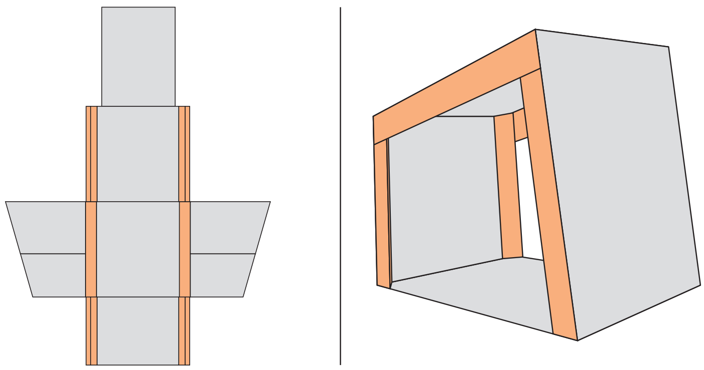
Column buckling
Buckling analysis and generation of final design.

Extensive use of manufacture and experimental methods will assist students in understanding CIVL2330 course content and its application to the design of the Festi Flat. Students are also expected to build and field test their final prototype to prove the structure is safe to inhabit.

04a Primary panels forming cladding and bracing elements.



04a Secondary panels forming column and roof beam (frame) elements.



Project Scope

The Icarus Festi Flat project will approximately follow the below activities and timetable.

Weeks 1-3: Prototype/CAD Skills
Develop preliminary manufacture and CAD capabilities and prototype current Festi Flat design. Complete project reading 1.

Weeks 4-6: Analysis Skills
Develop preliminary structural testing and analysis capabilities. Run material and section tests. Complete project reading 2.

Weeks 7-9: Refinement
Iterative application of principles from CIVL2330 to strengthen and stiffen Festi Flat design.

Weeks 10-12: Field Test Preparation
Engagement with industry to find suitable location for field test and manufacture of final prototype.

Weeks 13-16
No Icarus work during exam period.

Week 17+: Field Test
Travel to site and field test Festi Flat v2.

08 Dyson 2014 Festi Flat team.

Project reading 1:
- Origami Engineering: A Primer
- Rapid Prototyping and the UQ Co-Lab
- CAD: Rhino Introduction

Project reading 2:
- Structures: Introduction to iSA
- UQ Structures Lab Testing Methods
- Structures: Material Analyses

References

Brice, D., Wong, E., Owen, J., & Gattas, J.M. (2014) *Festy Flat: A fast-up, fast-down, recyclable festival shelter*. Design submission to James Dyson Award 2014, Available from: **http://www.jamesdysonaward.org/projects/festy-flat/**.

Daily Mail. (2013) *The festival's over... someone fetch a dustpan and brush*. Retrieved from http://www.dailymail.co.uk/news/article-2403467/Reading-Festival-2013--fetch-dustpan-brush.html.

Project: Station Simulation

Mentor: **Sanghyung Ahn**

Virtual planning technologies are systems-level simulation software used to simulate construction operations. One such technology is Discrete-Event Simulation (DES), which can be coupled with virtual reality (VR) to provide immersive, complex simulations. Construction planners can use these simulations to anticipate and solve problems before they arise, or to allocate and optimise on-site resources. Current research focuses on DES-VR applications in mining and construction industries, however there is potential to apply it to other, similarly-complex civil engineering systems.

One such system that many Brisbanites would be familiar with is a Bus Rapid Transit (BRT) station, **Fig. 01**. Students in the present project will be tasked with using virtual simulation technologies to simulate a BRT system and find operation scenarios that could reduce or remove peak hour congestion. Activities will include field data collection and video recording; input parameter modelling and DES-VR simulation; and operation analysis and optimisation. They will develop hands-on knowledge in the use of state-of-the-art simulation software tools to solve a serious local problem.

01 Bus Rapid Transit (BRT) Station - Cultural Centre, Brisbane.

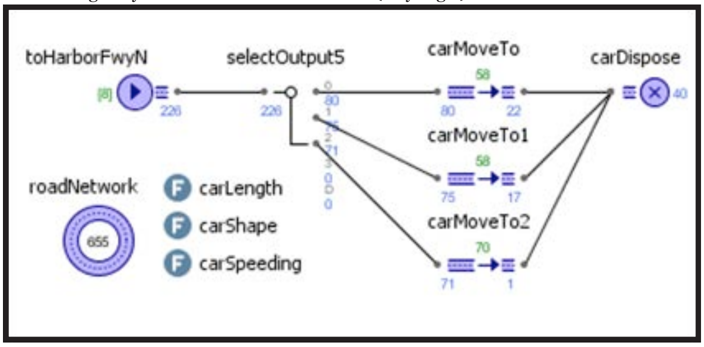
Simulation Modelling

Modelling is one of the many methods engineers employ to solve real-world problems. It is particularly useful for the many cases where we can't afford to find the right solutions by experimenting with real objects; building, destroying, or making changes may be too expensive, dangerous, or just impossible.

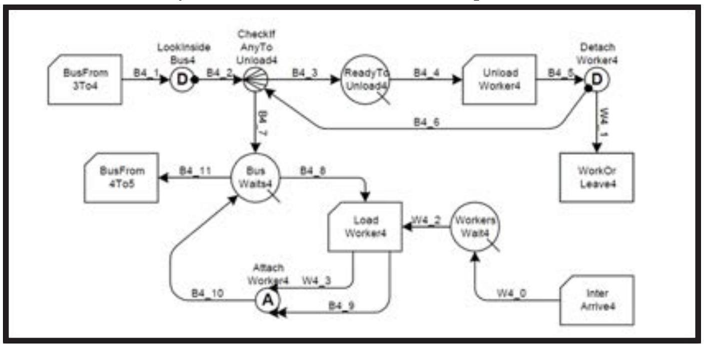
If this is the case, we leave the real world and go to the world of models as shown in **Fig. 02a** and **Fig. 02b**. We build a model of a real system: its representation in a modelling language. This process assumes abstraction as we omit the details we think are irrelevant and we keep those we think are important. The model is always less complex than the original system. A skilful modeller is able to use intelligent assumptions to find a way from a problem to a solution with an accurate and low-risk model world. While moving from problem to solution, the model allows us to make mistakes, undo things, go back in time, and start over again.

In simulation modelling, a method is a general framework we use to map a real world system to its model. A method suggests a type of language, a sort of "terms and conditions" for model building. To date, there are three methods: *System Dynamics* (SD), *Discrete-Event Modelling* (DEM) and *Agent-Based Modeling* (ABM). Each method serves a particular range of abstraction levels. SD assumes very high abstraction, and it is typically used for strategic modelling. DEM supports medium and medium-low abstraction. In the middle, there is ABM, which can vary from very detailed models where agents model physical objects (e.g., vehicles,

02a: A Highway Junction Simulation Model (AnyLogic).



02b: A Shuttle Bus System Simulation Model (Stroboscope).



animals, ships, etc.) to highly abstract models (e.g., agents can be projects which compete for company resources within a company).

This project aims to model a BRT system at operational level, which can be considered at a medium-low abstraction level to low abstraction level. Students will therefore learn both DEM and ABM by using general purpose simulation systems such as Stroboscope (Martinez 1996) and AnyLogic.

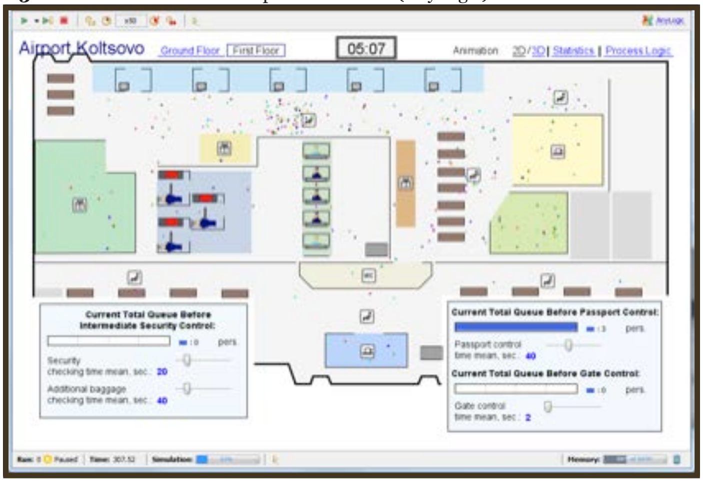
Visualisation

The capability to visualize modelled operations in 2D and 3D can be of substantial help in describing the intricacies of simulation models. Valuable insights can therefore be obtained into the subtleties of operations that are otherwise nonquantifiable and unpresentable.

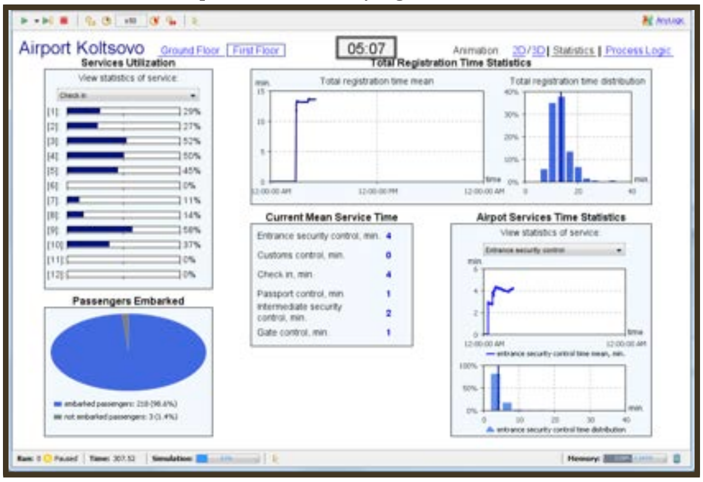
By communicating the logic and the inner working in a comprehensible manner, 2D/3D visualization can facilitate the validation and verification of complex simulation models, thus providing an opportunity to convince all parties involved that models indeed reflect reality. These are essential in establishing the credibility of simulation analyses, without which the results will not be used in decision-making.

03a: A 3D Animation of an Airport Simulation (AnyLogic).

03b: A 2D Animation of an Airport Simulation (AnyLogic).



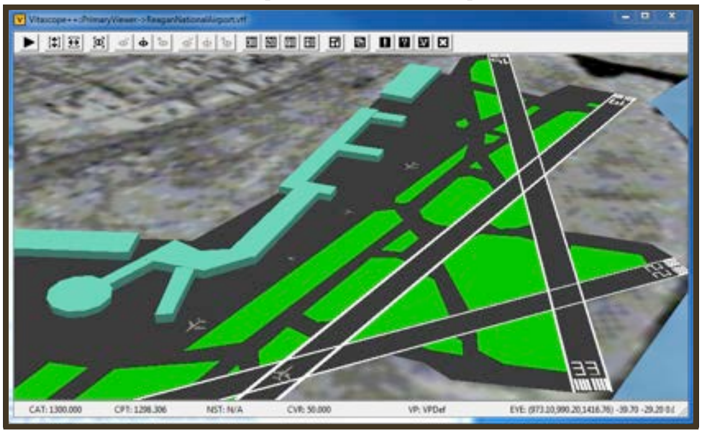
03c: Statistics of an Airport Simulation (AnyLogic).



Visualizing modelled operations in 3D is arguably the best form of communicating the logic and the inner working of simulation models and can be of immense help in establishing the credibility of analyses. **Fig. 03a, 03b, 03c** and **03d** show an airport simulation model. In this example, passengers arrive; pass through security controls, customs, check-in, passport control and gate control. There are four types of transportation that passengers arrive by: bus, fixed route taxi, personal car and coach. Flight schedules are randomly generated. This model can help analyse dependence between airport services parameters, registration time, and personnel utilization.

Simulation-based visualization techniques include charts and graphs of statistics. For example, service utilization, total registration, airport services time, current mean service time are example statistics shown in **Fig. 03c**. This project will introduce 2D/3D visualization tools Vitascope++ (Rakapalli 2008) and AnyLogic by which students can see the graphical depiction of modelled operations being carried out with the same logical and physical relationships that are embedded in the underlying simulation models.

03d: A 3D Animation of an Airport Simulation (Vitascope++).



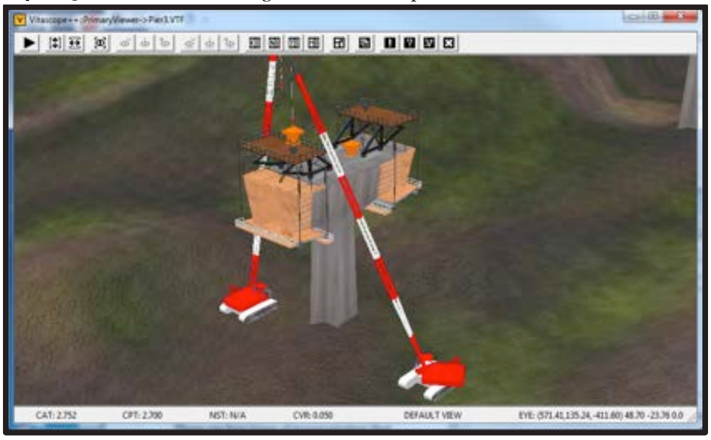
Application Breadth

Today's Architecture, Engineering, Construction and Facility Management (AEC/FM) industries have to deal with enormously complex obstacles. Examples include aging infrastructure, the protection of the natural environment, and the need for resilient infrastructure.

Among several technical fields that have been adopted and advanced, computer simulation has been widely researched and practiced for the effective delivery and maintenance of complex capital projects. With the help of 2D/3D visualization, computer simulation has thus demonstrated its usefulness in aiding AEC/FM engineers in designing, constructing and operating infrastructure systems. Some construction operations where simulation with visualization techniques can be applied are shown as examples in **Fig. 04a, 04b, 04c** and **04d**. A Vitascope++ showcase video (runtime 6:33) is also available at the following link **http://bit.ly/DESBasedVR_YouTube**.

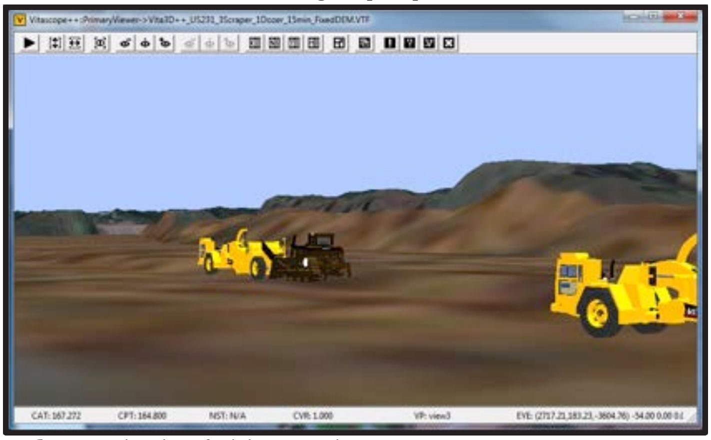
Computer simulation is not only limited to AEC/FM industries. We can conduct simulation studies in any situation where there are highly interdependent components subject to complex activity startup conditions. Similarly for situations where there are many resources with distinct properties and states that must collaborate according to highly dynamic conditions. Simulation tools and the skill to use them are exceptionally valuable components of a modern engineer's toolkit.

04a: A 3D Animation of a Bridge Construction Operations.



04b: A 3D Animation of Concrete Pouring Operations.

04c: A 3D Animation of Push-Loading Scraper Operations.



04d: A 3D Animation of Mining Operations.

Simulation Learning

Integrating simulation technologies into engineering curricula can greatly contribute to students' learning, enabling them to model real-world problems and experiment with what-if scenarios.

However, this integration poses significant challenges such as the need for computational resources to be constantly updated. The computational resources that most schools focus on are those that get frequently used and are needed to train students to meet workplace demands.

Therefore, the adoption of certain computational technologies has been gradual due to the fact that they have been slowly adapted by the industry. The availability of computational resource is directly linked to the need for manual interaction with models in a shared workspace that characterizes collaborative learning. This creates a challenge that is exacerbated by the misconceptions that model developers often have about how actual systems operate.

In order to avoid this major pitfall, models need to be validated in a process that recognizes and corrects modelling errors and determines how accurately a simulation model represents the real world. This process requires the involvement of practitioners and decision makers who have intimate knowledge of the actual system and can ensure its practical relevance.

Computational resources are extrinsic to the simulation model itself. An intrinsic challenge, then is the extent to which students understand the structure of the simulation. This understanding greatly impacts how they learn. The students' understanding of simulation structure is directly impacted by the transparency of the underlying simulation structure made available to them.

As a simulation introductory course, this project will provide students with example models that are completely transparent such that the model structures that drive their behaviour are visible to and understandable by students.

Project Approach

The specific focus of this project is on modelling a bus station where a simple queuing theory can be applied in describing bus arrival/ departure and queue forming/ dissipation mechanisms.

The project also entails data collection via field measurements and video recording (i.e., field surveys), input parameter modelling (e.g., probability distributions for arrival times and dwell times), analysis of the current system, and testing and suggestion of alternative operation scenarios.

A simulation model is to be developed by considering Cultural Centre station's configuration and operation **Fig. 01**. The parameters (e.g., bus headway, dwell time, drivers' reaction time during vehicle movement and from stationary position, etc.) for the simulation model will be calibrated with the real data collected via field survey. Thereafter, different scenarios are simulated and the data obtained is used to develop the model.

The objective of the simulation model is to empirically determine station limit state capacity for different flow, dwell time and its coefficient of variation. Upon completion of the project you will be able to design a new traffic system or improve an existing one by proper measurement of current performance, and modelling and analysis using computer simulation.

Project Scope

The Icarus Station Simulation project will approximately follow the below activities and timetable.

Week 1: Introduction
Understand concepts of modelling, simulation, visualization and analysis as related to transportation systems.

Weeks 2-3: Develop Modeling Skills for Discrete-Event Simulation (DES)
Create and analyse a discrete-event based factory simulation model with the model animation to learn a basic DES modelling strategy. Experiment with queuing theory with the simulation model.

Weeks 4-6: Develop Modeling Skills for Agent-Based Simulation (ABS)
Create and analyse an agent based gas station simulation model with the model animation to learn a basic ABS modelling strategy.

Weeks 7-8: Collection of field data and data processing
Collect field data from a BRT station. Perform probability analysis of field data to determine the best fit distribution form of observed data by estimating of parameters using Maximum Likelihood and Goodness-of-Fit testing (Chi-Square, Kolmogorov-Smirnov and Anderson-Darling).

Weeks 9-12: Design of Simulation Experiments and Output Analysis
Create a BRT station simulation model based on the field observation to analyse the current performance of the station and test alternative ways of running the system. Simulation experiments consider confidence intervals for system performance measures, determining the number of simulation runs, and comparing alternative configurations using common random numbers.

Software

AnyLogic
A simulation software tool that supports three simulation modelling methods: system dynamics, discrete-event, and agent-based modelling. It also allows for the creation of multi-method models.
Available at **www.anylogic.com**.

Stroboscope (Martinez 1996)
An advanced discrete-event simulation programming language and system based on Three-Phase Activity Scanning and extended Activity Cycle Diagrams.
Available at **www.ezstrobe.com**.

Vitascope++ (Rekapalli 2008)
A 3D animation system that can be used to animate previously simulated operations as well as concurrently animated operations where interaction with the animation can affect the remaining course of events in the simulation.
Available at **www.ezstrobe.com**.

References

Martinez, J. C. (1996). *STROBOSCOPE: State and resource based simulation of construction processes*. Ph.D. dissertation, Univ. of Michigan, Ann Arbor, MI.

Rekapalli, P. V. (2008). *Discrete-event simulation based virtual reality environments for construction operations*. Ph.D. dissertation, School of Civil Engineering, Purdue Univ., West Lafayette, IN.

Project: The Turbidity Challenge

Mentors: **Alistair Grinham, Simon Albert**

Turbidity is a key water quality parameter in environmental monitoring. It is a crucial component to ecosystem health monitoring programs as well as compliance obligations in industry, ranging from construction sites to capital dredge work programs. However, the current cost of turbidity probes greatly restricts the number of monitoring sites possible and, therefore, reduces our ability to understand the impacts of these industrial activities.

The challenge in this project will be to develop a low cost turbidity monitoring network for the same cost as a single commercial probe. A multidisciplinary approach is required to build such a novel monitoring system and if successful, it would address one of the *most pressing questions in coastal science*: how much terrestrial sediment is delivered to coastal water bodies.

Students in this project will address a *key issue in coastal management* by developing a novel, low-cost distributed turbidity sensor network across Moreton Bay's major catchment inflow points. They will have to design, build, deploy, and maintain this network for a one month period. In addition, students will have to undertake field and laboratory studies to inform data interpretation of the monitoring program.

01 Left panel - Clean, marine sand of Moreton Bay; Middle panel – Seagrass meadow in Eastern Moreton Bay; Right panel – Turtle and coral reef in Northern Moreton Bay.

Project Background

Moreton Bay is a large, shallow coastal embayment located in south east Queensland. Historically Moreton Bay has been dominated by clean sand substrates with extensive seagrass and coral habitats.

These support a diverse range of fauna such as turtles **Fig. 01**. Sediment input has been highly variable over both spatial and temporal scales but terrestrial loading has greatly increased in recent times. This is primarily due to historical catchment development, bay hydrodynamics, and regional weather patterns. The western and southern catchment areas have undergone significant modification, with less than 20% classified as pristine. The loss of riparian vegetation has resulted in gully erosion dominating waterways across the region. Oceanic water exchange occurs through a large passage to the north and two smaller passages to the east.

The delivery of terrestrial sediments occurs primarily during large flood events, heavy unpredictable catchment rainfall events, and gully erosion **Fig. 02**. This results in the east and north of the Bay being well flushed by clean oceanic water, whilst western and southern parts are subject to greater influence from turbid catchment run-off. A gradient of sediment quality currently exists where sediments in western and southern areas have higher terrestrial mud content compared with the clean marine sands of eastern and northern areas.

Delivery of terrestrial sediments to clean marine sands can have profound, negative impacts on benthic communities. Floral and faunal organisms are smothered and overlying water quality is reduced via increased persistence of turbid conditions following resuspension events. This is currently occurring in Moreton Bay where the negative impacts and increased sediment supply has been well documented.

02a: The University of Queensland Boating and Diving shed during January 2011 flood event.

02b: Brisbane River above Mt Crosby Weir. Note the turbid nature of flood waters indicating high sediment concentration.

Suspended sediment levels are estimated to have increased 4 fold over the last 80 years in the Brisbane River estuary alone, large-scale loss of seagrass meadows has occurred in western and southern areas as well as major changes to benthic microbial productivity and community composition. The decrease in mean sediment particle size will greatly reduce particle settling velocities allowing these sediments to persist in the water column for extended periods of time.

A recent survey conducted after the major floods in January 2011 indicates a large scale increase in mud distribution across the whole bay **Fig. 03**. The primary areas affected lie within the western and southern areas, but clear impacts were also observed in the northern and eastern areas. The impact of this alarming increase in mud distribution is relatively difficult to determine under the current monthly monitoring program. Proper impact assessment requires a completely different and more appropriate approach in order to understand both the current situation as well as future changes. Such as approach should include the installation of a permanent monitoring network in order to ensure unpredictable flood events can be captured.

The key question for managers, scientists and modellers is *what is the rate of increase in mud distribution*? This is especially important in light of the proposed regional catchment management actions. These are aimed at restoring riparian zones to reduce gully erosion and, therefore, sediment supply during large flood events. If management actions are successful, large flood events should carry lower sediment loads and the rate of increase in mud distribution will reduce.

To answer this question two crucial knowledge elements are required: 1. The current sediment distribution across Moreton Bay at an appropriate spatial resolution; and 2. Quantified catchment sediment loading, particularly during floods events where the majority of loading occurs and current monitoring systems fail.

The following two scientific objectives are therefore proposed to find this crucial knowledge:

1 Develop a low cost turbidity monitoring system of all major catchment inflow points and ocean passages. This should be capable of quantifying suspended sediment load across a wide range of hydrologic flow conditions but, in particular, during large flood events. *Outcome*: The capacity to accurately estimate catchment sediment loading to the system.

2 Conduct a field based sediment survey to date across Moreton Bay. *Outcome*: Determine the current baseline of sediment mud distribution both to account for past changes and allow future changes to be accurately estimated.

03: Images from Moreton Bay taken during January 2011 flood event: Left panel – Aerial view from Brisbane looking towards Moreton Island; Right panel – Sediment grab sample from main shipping channel.

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Project Approach

Students will complete two key project tasks to overcome current limitations in sediment loading estimates and to establish a comprehensive baseline of sediment type across the Bay. These tasks will be crucial in developing and validating a sediment transport model within the Bay.

Task 1 is to develop novel, low-cost turbidity monitoring network across Moreton Bay's catchment inflow points and ocean exchange passages. Current turbidity monitoring networks suffer from twin limitations, namely a high cost of instrumentation and a narrow measurement range. The net effect is a reduced number of sampling points as well as the potential to underestimate loading, as measurement ranges tend to be optimised to lower ranges (0 – 1,000 NTU). These ranges are suitable for general conditions, but not for larger flood events. For example, in the Brisbane River January 2011 flood, turbidity was in excess of 6,000 NTU.

The potential to develop a low cost distributed turbidity sensing network is now possible with the advent of cheap electronic hardware and mobile data streaming. Low cost industrial sensors have been developed with a wide sensitivity ranges (e.g. GE Sensing & Inspection Technologies 165D6042P003 sensor 0-10,000 NTU) which make these ideal for environmental sensing of flood events and allow a large number of sampling sites to be monitored. They can therefore overcome current limitations on monitoring networks.

Completion of Task 1 will create units for field deployment with the ability to log turbidity and time data on board and stream this data to central server. Critical steps in this process will be performance of sensors across a range of calibration solutions, as well as natural sediment suspensions. Practical field deployment considerations such as catchment mobile phone coverage, biofouling, power consumption, and sensor degradation will also need to be overcome prior to field deployment. This final task outcome is a valuable, robust turbidity monitoring network capable of quantifying sediment inputs during large flood events.

04: Postgraduate Researcher Paul Fisher on field deployment of monitoring device.

Task 2 is to establish the current baseline of sediment types across Moreton Bay. Comprehensive sediment surveys of Moreton Bay have been conducted only twice in the last 40 years and with the recent major floods (January 2011 and 2013). There is an urgent need to establish a current comprehensive baseline of sediment types across the Bay. This will allow the past changes to be determined and allow future increases in mud distribution to be more accurately quantified.

Students will assist in an intensive field campaign where sediment samples will be collected from over 200 sites across all areas of Moreton Bay. These samples will then be processed. Particle size distribution will be determined using the laser diffraction method and percent mud defined as less than the 63 micron fraction. The large number of sites will provide the most detailed spatial data set of sediment types in Moreton Bay to date and will directly inform the sediment transport model development currently occurring within the Healthy Waterways Ltd., a not-for-profit organisation looking to improve the freshwater and marine ecosystem health in Moreton Bay.

Project Scope

The Icarus Turbidity project will approximately follow the below activities and timetable.

Weeks 1-3: Literature review
Review turbidity monitoring design and familiarise yourselves with low cost sensing systems. In addition, a thorough review of sediment distribution and catchment loading points to Moreton Bay should be conducted.

Weeks 3-6: Monitoring network construction
Iteratively develop and prototype and monitoring devices and network.

Weeks 6-9: Sediment survey
At least 200 sites will be sampled in Moreton Bay to generate a current baseline and allow future changes to be quantifiable.

Weeks 9-12+ Monitoring Challenge
Field deployment, data collection, and analysis.

05: Field work conducted by researchers at the Centre for Water Studies.

Project: The Tianjin TOMMbot

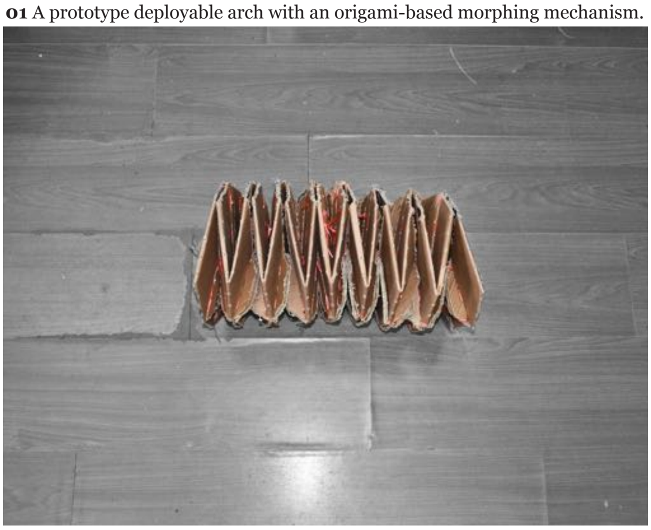
Mentor: **Joe Gattas**

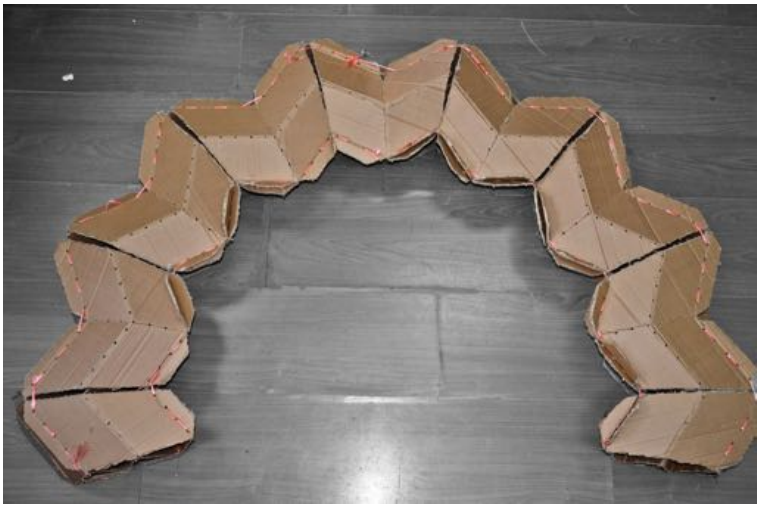
The TOMMbot project is a joint research investigation by the School of Civil Engineering at UQ and the Motion Structures Laboratory at Tianjin University in China. It's eventual goal is somewhat ambitious: to build structural Transformers.

In brief, it aims to achieve this with a hybrid origami mechanism that functions as a large, transformable sheet. Good progress is being made on technical challenges, with early development yielding a transformable origami (TO) manufacturing tool and morphing mechanism (MM) deployable arches. On going research is investigating methods to combine these features, however a large challenge facing the project is that of application: what uses should a fully-integrated TOMMbot target?

Students participating in this project would be expected to develop *creative*, *user-centred design,* and *rapid prototyping* capabilities at UQ to generate TOMMbot application ideas and build basic prototypes. They would subsequently travel to Tianjin University in July 2015 to build advanced, transformable prototypes.

01 A prototype deployable arch with an origami-based morphing mechanism.





02a Tianjin University, founded in 1895 as Peiyang University, is the oldest university in China.

MSL at TJU

The Motion Structure Laboratory (MSL) at Tianjin University (TJU) integrates kinematics and mechanics fundamental theories with aerospace, robotics, structural, and material engineering applications.

02b Professor Chen.

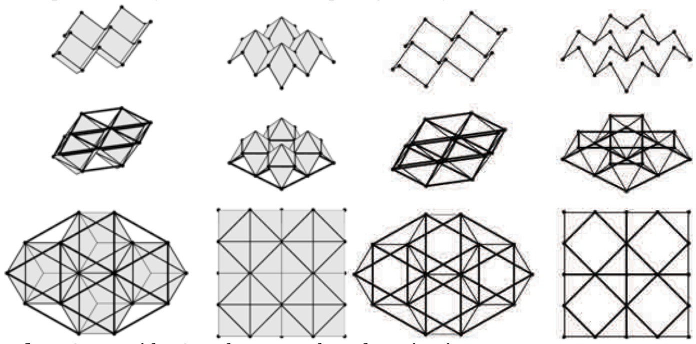
MSL is a rapidly-growing research group founded by Professor Yan Chen in 2012. Motion Structures is an emerging and advanced interdisciplinary research area. It encompasses the fundamental theories of deployable structures and advanced kinematics; and application of these theories to aerospace structures, robotics, and materials. Major MSL achievements include:

Deployable Structure Synthesis
Development of the tessellation method: the first synthesis method for deployable structures. A number of deployable units based on 3D overconstrained mechanisms have been found and used to construct large-scale deployables.

Overconstrained Linkage Discovery
Three families of spatial overconstrained linkages have been found. Novel types of spatial mechanisms have also been recently discovered, consisting of closed, bifurcated kinematic loops formed with multiple singular points.

Kinematics of Origami Mechanisms
The first application of kinematic synthesis processes to the study of origami and rigid origami. This has led to the development of several types of new rigid origami patterns, with potential engineering applications as structural materials and aerospace components.

03a Space frame synthesis from folded plate geometry.



03b Dr Gattas with TOMMbot research student Liu Xiang.

Programmable Matters

In 2014, Dr Joe Gattas from the University of Queensland visited MSL for two months to pursue joint research in hybrid bar/ plate structures, funded with the support of UQ's Confucius Institute and EAIT Faculty. Two research projects were launched from the collaboration: space frame synthesis from folded plate structures and the TOMMbot project.

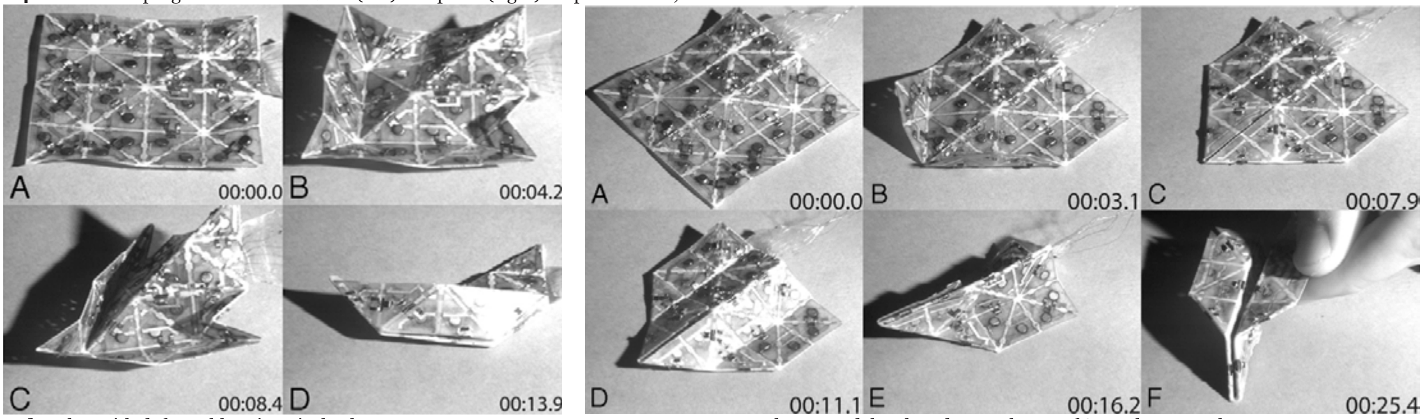
To understand the TOMMbot project, it is first useful to have a brief overview of the of origami engineering and origami-inspired robotics. Origami engineering is concerned with the use of folded plate geometries for engineering structures and devices. Origami-inspired applications have been developed in nearly every engineering discipline, including structural, aeronautics, aerospace, impact, biomedical, robotics, manufacturing, and materials. Dr Gattas is Australia's only origami engineer and his research is primarily concerned with origami-inspired architectural, structural, and impact engineering applications.

Recently, there has been explosion in research interest towards creating *self-folding materials* or *programmable matter*, stimulated by large grant rounds from US National Science Foundation, US Air Force Office of Scientific Research, and DARPA. A comprehensive and recent review of research progress is given in *Peraza-Hernandez et. al. 2014*, which classifies self-folding materials by many characteristics, including material, fold-inducing fields, purpose, reversibility, sheet thickness, and scale. Several examples are shown on the following page.

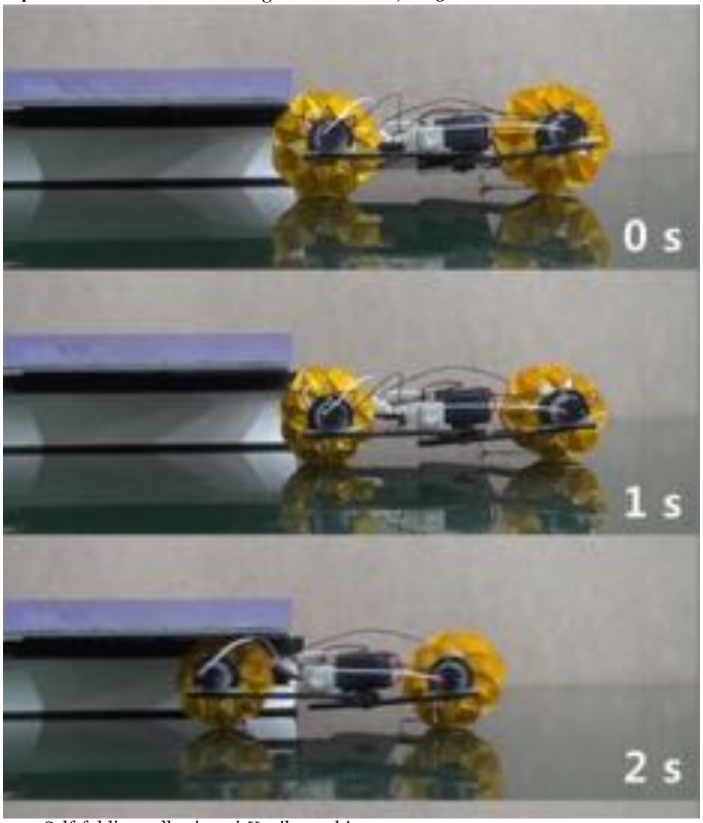
No dominant self-folding technology has yet emerged, but a broad trend is seen whereby one of two rationales determines the sheet hinge type. Some sheets use pre-engineered hinge locations. This simplifies design for a target application, however loses the multi-use capability of true programmable matter. Other sheets use continuous hinges that, theoretically, preserve the multi-use capability. However in practice these sheets are proving difficult to fabricate with a useful range of motion and the small crease resolution required to form multiple folded states.

A second broad trend is seen in the nature of programmable sheet applications currently being developed: all are at scales ranging from the micro (cellular) to meso (desktop) scales. Architects have investigated buildings and facades that use active materials to shape-change throughout the day. They lack programmable or multi-use capabilities and so cannot be considered programmable matter, however they suggest interesting, as yet unconsidered, applications of programmable matter at the macro (building) scale.

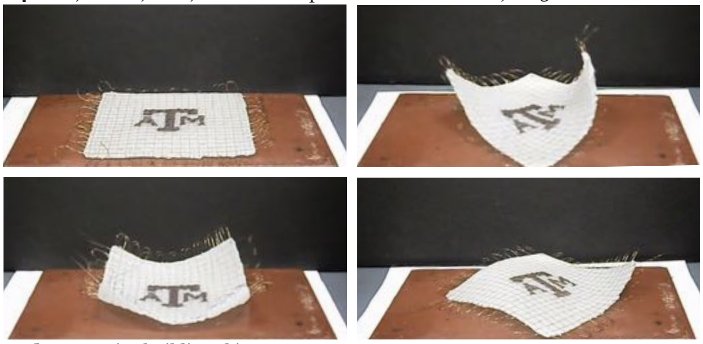
04a SMA sheet programmed to forn boat (left) and plane (right) shapes *Hawkes, 2010.*



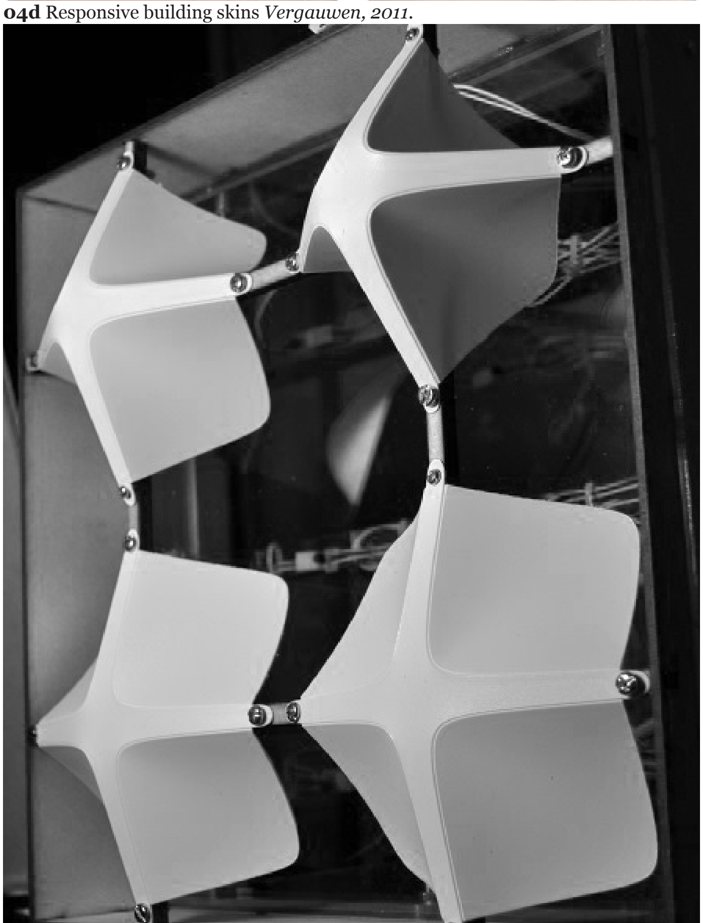
04b Robot with deformable origami wheels *Lee, 2013.*



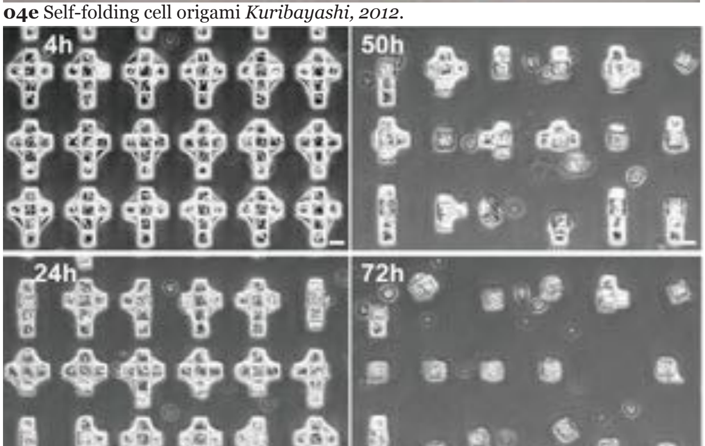
04c Flat, curved, bowl, and wave shapes of SMA sheet *Hartl, 2013.*



04d Responsive building skins *Vergauwen, 2011.*



04e Self-folding cell origami *Kuribayashi, 2012.*



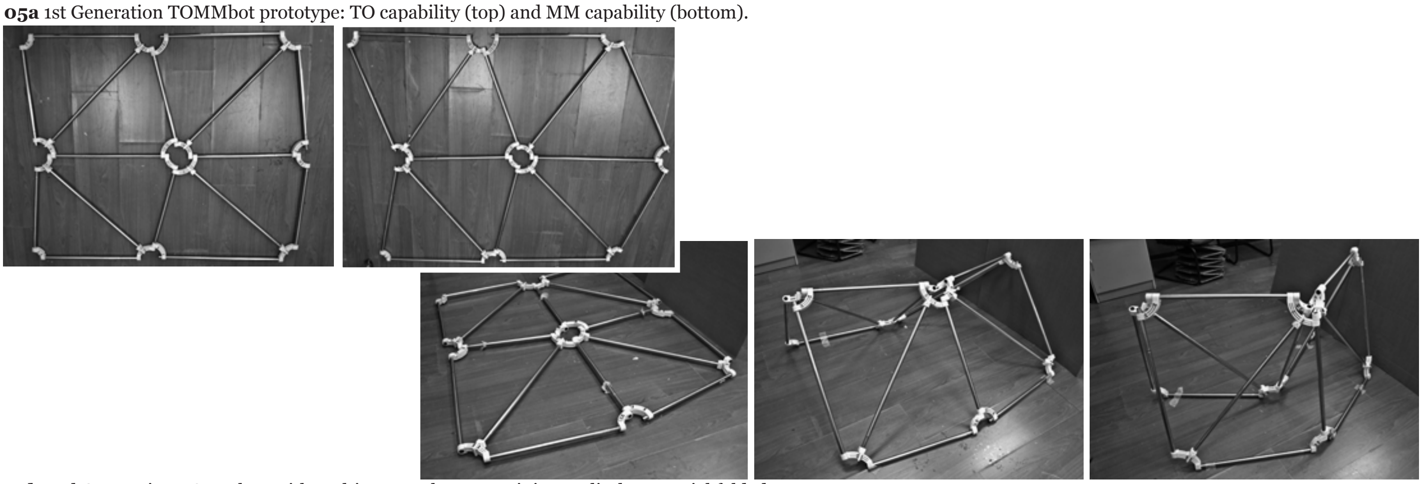
The TOMMbot project has two targets that would address gaps in current research. First, the technical target: the TOMMbot is a programmable sheet with pre-engineered, but transformable hinges. Such a sheet would, theoretically, preserve the multi-use capabilities of continuous hinge sheets but possess the constructability of discrete hinge sheets.

The TOMMbot technology involves developing two pattern capabilities: Transformable Origami (TO) paired with a Morphing Mechanism (MM). Morphing Mechanism refers to the pattern's ability to fold between different states with a zero-energy rigid-origami mechanism. Such behaviours are well understood from existing knowledge already developed by UQ and TJU in the design of deployable structures. Transformable Origami refers to the pattern's ability to locally-reconfigure the creases of the pattern.

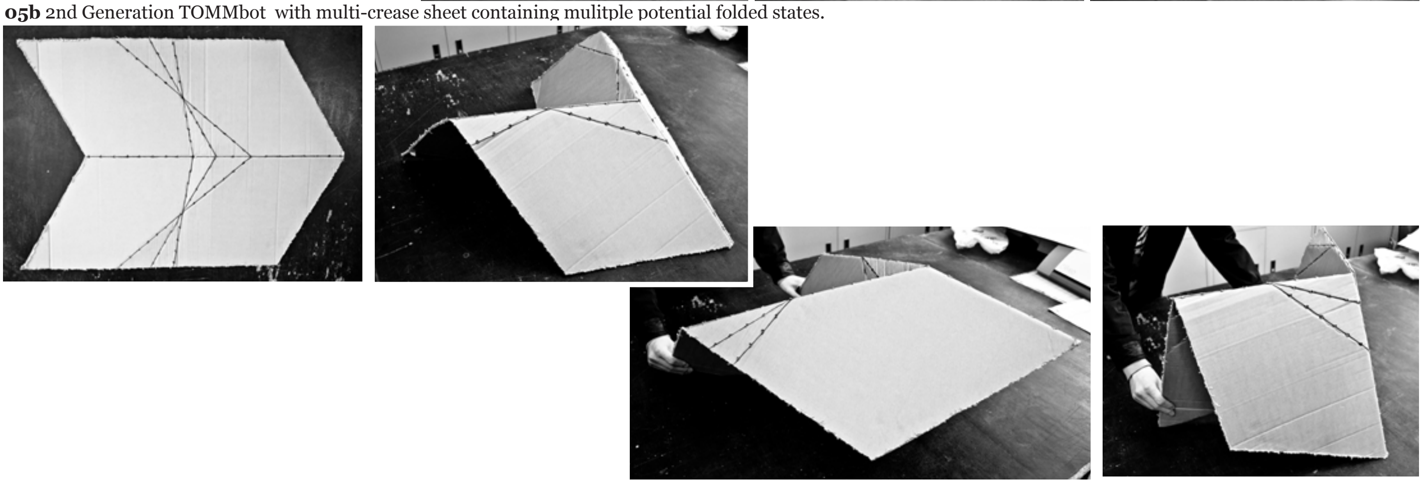
The ability to transform between crease patterns and rigidly-fold between different shapes means a huge range of geometric envelopes, shown on the following page, can be formed from a relatively coarse crease resolution. It also allows the use of relatively low-tech sheet materials. The current TOMMbot prototype uses creases composed of linear slides and connected by a transformable spherical linkage. The next TOMMbot prototype aims to use a multi-crease sheet whereby folding one crease kinematically-suppresses the remaining creases around a shared vertex, ensuring only the single target crease is folded in any given state.

While these features are technically promising, the TOMMbot project has a second target that is one of purpose: to find applications for the TOMMbot at structural scales.

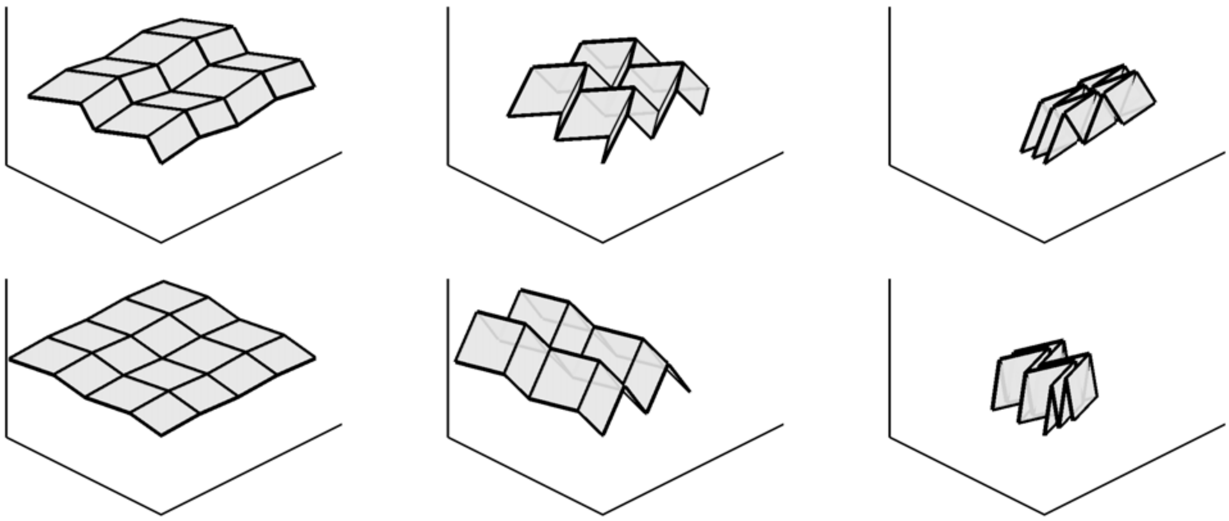
05a 1st Generation TOMMbot prototype: TO capability (top) and MM capability (bottom).



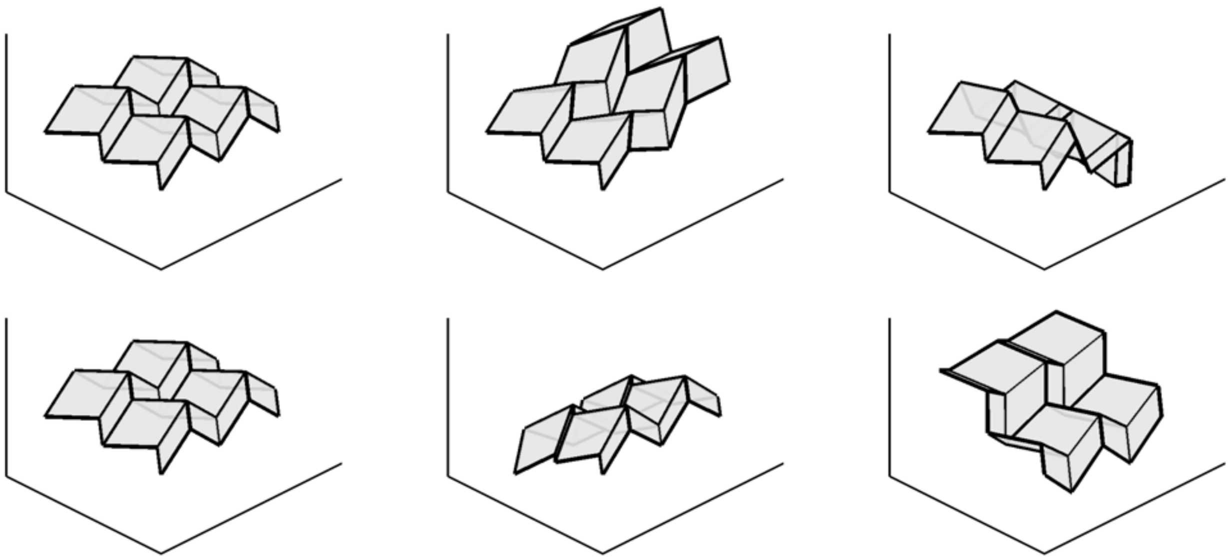
05b 2nd Generation TOMMbot with multi-crease sheet containing mulitple potential folded states.



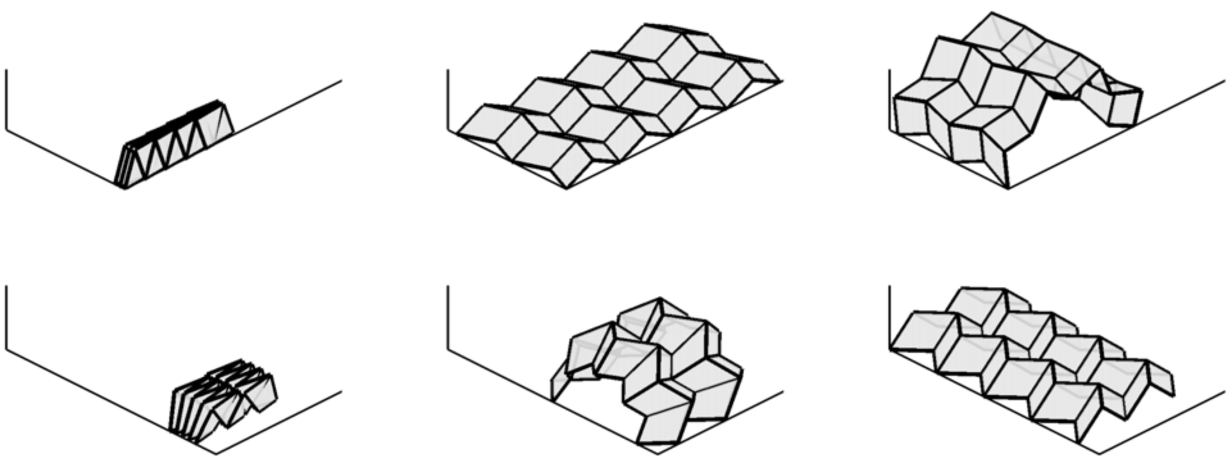
06a Example rigid-foldable sheets with 1DOF (MM) capability.



06b Example transformable sheets with 1DOF (TO) capability.



06c TOMMbot sheets with 1DOF (TO) + 1DOF (MM) capability.



TOMMbot Purpose

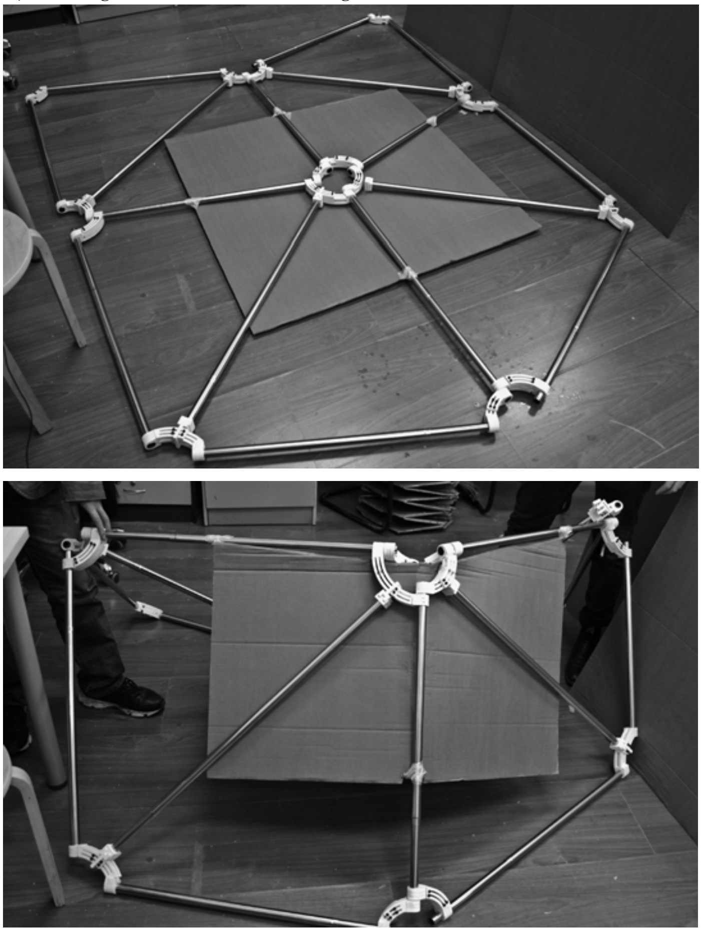
In addition to technical considerations, a large challenge facing TOMMbot development is that of application: how can a large, transformable sheet be useful? It is this question that Icarus students will be tasked with answering.

The current TOMMbot prototype is composed of transformable bars. It is useful as a manufacturing tool, as it is capable of transforming to fold numerous origami unit geometries. The next TOMMbot prototype aims to be composed of transformable plates, and so Dr Gattas and Professor Chen would like to students to develop several proof-of-concept applications whereby the TOMMbot is the material, not just the manufacturing tool.

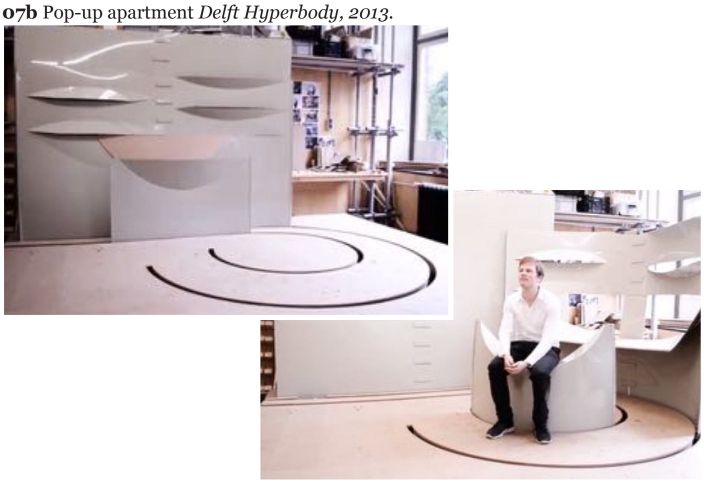
Researchers and designers have suggested some ideas that utilise static folded patterns. These are not true programmable sheets, but are useful in suggesting the type and scale of desired applications.

During Semester 1 2015, participating students will be first be trained in creative and user-centred design processes, origami engineering principles, and rapid prototyping. They will subsequently be able to manufacture and refine simple (non-transformable) applications, before travelling to Tianjin University in July 2015 to assist graduate students in advanced (transformable) applications.

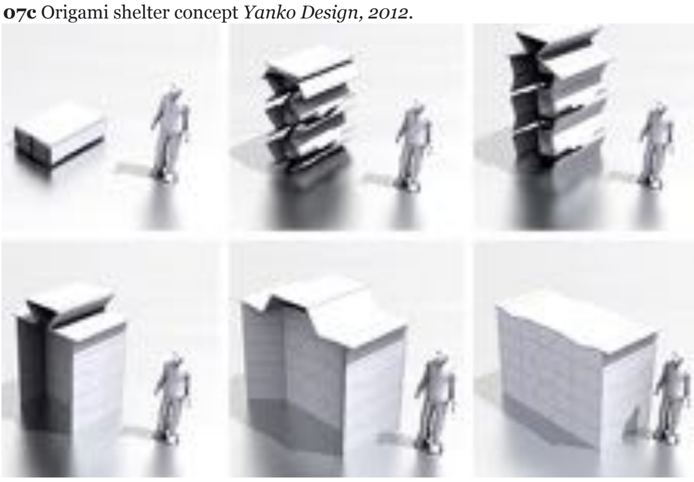
07a Existing tranformable manufacturing tool.



07b Pop-up apartment *Delft Hyperbody, 2013.*



07c Origami shelter concept *Yanko Design, 2012.*



Project Scope

The Icarus TOMMbot project will approximately follow the below activities and timetable.

Weeks 1-2: Design Skills
Develop preliminary creative and user-centred design capabilities and a list of early application ideas. Complete project reading 1.

Weeks 3-6: Prototype/CAD Skills
Design and prototype range of 'static' folded plate geometries from the generated application ideas. Build parametric models of folded plates in CAD or MATLAB. Complete project reading 2.

Weeks 7-12: Refinement
Use principles learnt in CIVL2330 (Introduction to Structural Design) to strengthen and stiffen application designs. Identify common crease arrangements between applications and thus potential multi-application TOMMbot designs.

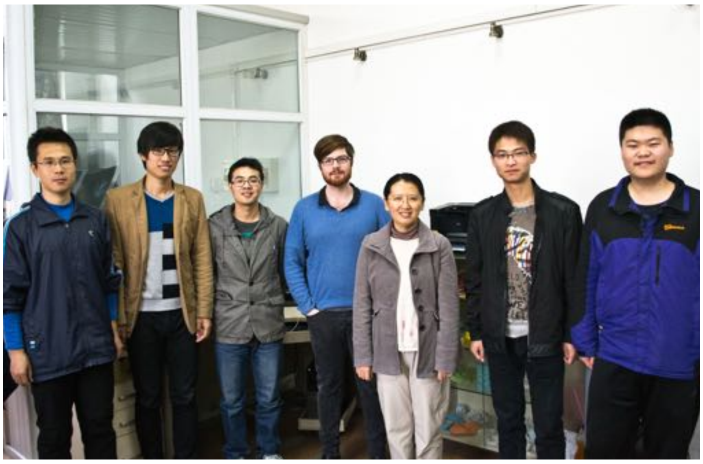
Weeks 13-16
No Icarus work during exam period.

Weeks 17-23: Travel
Travel to Tianjin University to prototype multi-application TOMMbots.

Project reading 1:
- Origami Engineering: A Primer
- Rapid Prototyping and the UQ Co-Lab
- Creative and User-Centred Design

Project reading 2:
- Programming: Matlab Introduction
- Origami Engineering: Matlab Tools
- CAD: Rhino Introduction

Optional reading:
- Visual Design: Basic Principles
- CAD: Rhino and Grasshopper
- Visual Design: Scientific Publications



08a MSL Origami Structures research team October 2014.

References

Delft Hyperbody. [izaslodka] (2013, July 14). *Pop Up Apartment: an interactive flexible house + ready prototype* [Video file]. Retrieved from https://www.youtube.com/watch?v=AFq15IHQ1Uc.

Hartl, D. [Reprogrammable Origami] (2013, August 12). *SMA-based Self-Folding Sheet Demonstration* [Video file]. Retrieved from https://www.youtube.com/watch?v=86eF5E7zbuU.

Hawkes, E., An, B., Benbernou, N. M., Tanaka, H., Kim, S., Demaine, E. D., ... & Wood, R. J. (2010). Programmable matter by folding. *Proceedings of the National Academy of Sciences*, 107(28), 12441-12445.

Kuribayashi-Shigetomi, K., Onoe, H., & Takeuchi, S. (2012). Cell Origami: Self-Folding of Three-Dimensional Cell-Laden Microstructures Driven by Cell Traction Force. *PloS one*, 7(12), e51085.

Lee, D. Y., Kim, J. S., Kim, S. R., Koh, J. S., & Cho, K. J. (2013, August). The deformable wheel robot using magic-ball origami structure. In ASME 2013 *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference IDETC/CIE.*

Peraza-Hernandez, E. A., Hartl, D. J., Malak Jr, R. J., & Lagoudas, D. C. (2014). Origami-inspired active structures: a synthesis and review. *Smart Materials and Structures*, 23(9), 094001.

Vergauwen, A., De Temmerman, N., & Brancart, S. (2014). The design and physical modelling of deployable structures based on curved-line folding. *Mobile and Rapidly Assembled Structures IV*, 136, 145.

Yanko Design. (2012) *Origami Shelter by Doowon Suh*. Retrieved from http://www.yankodesign.com/2012/08/02/origami-to-the-rescue/.

Information and Forms

For general information or queries about Icarus 2015, please email **icarus@civil.uq.edu.au.** Alternatively, email the following project mentors to obtain more information about their specific topics. Email addresses are on the following page.

Joe Gattas	General Information, TOMMbot, or Festi Flat Projects
Kevin Sevilla	General Information, Icarus Pedagogy Investigations
Alistair Grinham	Turbidity Challenge Project
Simon Albert	Turbidity Challenge Project
Sanghyung Ahn	Station Simulation Project

Prospective Students interested in joining a 2015 project should complete the form **Project Match for Students** and email to the above address.

Prospective Mentors interesting in developing a 2016 Project or following the progress of 2015 Projects should complete the form **Project Match for Mentors** and email to the above address.

Project Mentors 2015

Email the following staff to obtain more information on Icarus 2015.

Joe Gattas

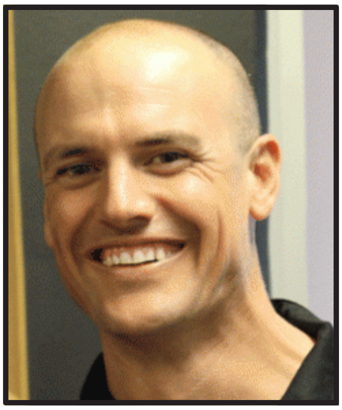
I completed a Bachelor of Engineering (Civil) at UQ in 2009 and a Doctor of Philosophy in Engineering Science at the University of Oxford in 2013. My research involves using origami design techniques to invent and improve thin-walled structures and devices. There are numerous applications of origami structures, including deployable housing; energy-absorbing barriers; and lightweight automobile and aircraft components. I am interested in all aspects of design, making, and coding, and incorporate much of this into my research.
Email: **j.gattas@uq.edu.au**

Kevin Sevilla

I completed a B. Sc. in Mechanical Engineering at the University of California, Irvine in 2007, a M.Eng. in Virginia Tech in 2011, and a Doctor of Philosophy in Engineering Education at Virginia Tech in 2014. My research focuses on studying student motivation and identity beliefs and how these influence student behavior. I am currently interested in applying my research findings to promote academic and social support programs on campus and online, and facilitating awareness of the technical specialties and range of careers available to engineering undergraduates and graduates.
Email: **k.sevilla@uq.edu.au**

Sanghyung Ahn

I received Bachelor's degree in civil engineering from Korea University in 2003 and Master of Business Administration degree from Hanyang University in 2007. From 2003 to 2007, I worked in industry as an assistant manager at Hyundai Engineering & Construction. I subsequently pursued PhD research at Purdue University. My PhD work is on sensor-based analysis and 3D-visualization of earthmoving construction operations.
Email: **sanghyung.ahn@uq.edu.au**



Alistair Grinham

My formal training was in biochemistry and marine biology focusing on Southern Ocean food webs. During my PhD I focused on the productivity of benthic microalgal communities in temperate and tropical lagoons. I joined the Centre for Water Studies in 2007 to work in the area of sediment nutrient dynamics of freshwater storages and coastal lagoons. In order to better understand these processes it is very important to monitor overlying water column processes as well as catchment storage interaction.

Email: **a.grinham@uq.edu.au**

Simon Albert

My broader research focus is a multidisciplinary approach to understanding the socio-ecological drivers of change to near shore ecosystems. I then use this knowledge to develop community based management mechanisms for ecosystem health. My PhD investigated interactions between water quality and herbivory on coral reefs in Fiji and the Solomon Islands. Subsequent research into environmental drivers of Lyngbya majuscula blooms led directly to altering catchment management in the Moreton Bay area to improve the water quality of runoff into areas prone to blooms.

Email: **s.albert@uq.edu.au**

José Torero

José L. Torero is Professor of Civil Engineering and Head of School. He is recognised for leading edge research in a broad arrange of subjects associated to fire safety and for the development of many innovative educational programmes in several countries. Professor Torero has developed novel educational programmes in integrated design, architectural engineering, fire safety engineering, structural behaviour in fire, energy management, heat transfer, combustion and fluid mechanics.

Email: **j.torero@uq.edu.au**

Project Match for Students

Students interested in joining Icarus 2015 should complete the following form and email to **icarus@civil.uq.edu.au** by Friday 6th March 2015.

1 Basic Information

Name ______________________________

Email ______________________ GPA (Optional) ________

Study Program ______________________ Semester of Study ________

2 Motivation

Please write a short description of why you would like to join an Icarus Project.

3 Comments / Questions

Please list any additional comments or questions you might have.

4 Areas of Interest

Below is a list of skill and interest areas. Select any you are interested in or would like to know more about.

Civil Skills	Civil Streams	Strategic Skills	Inter-Disciplinary
Technical	Structural	Code/Digital Literacy	Architecture
Theoretical	Enviro/Sustainability	Law/Policy	Mechanical/Aero.
Numerical	Transport	Outreach/Education	Geology/Science
Experimental	Geotechnical	Business/Entrep.	Material/Manufacture
Professional	Coastal	International Studies	Mining/Chemical
Written	Hydraulics	Commerce/Econ.	Software/Electrical/IT
Presentation	Fire	User/Graphic Design	Mechatronic/Biomed.
Documentation	Construction Mgmt.	Other ________	Other ________

Project Proposal for Mentors

Mentors interested in submitting or developing a proposal for Icarus 2016 should complete the following form and email to **icarus@civil.uq.edu.au**.

1 Basic Information

Name ______________________ Organisation ______________________
Email ______________________ Position ______________________

Interest
I have a project that I would like to offer.
I have a project idea but would like to discuss / develop it further.
I would like to assist / observe / co-supervise a project.
I don't have a project (yet) but am interested in the Icarus Program.

2 Information / Questions

Please tell us more about your project idea, areas of expertise, or areas / projects you are interested in knowing more about.

3 Areas of Interest

Below is a list of skill and interest areas. Select any that might be incorporated into the above project or you would like to know more about.

Civil Skills	Civil Streams	Strategic Skills	Inter-Disciplinary
Technical	Structural	Code/Digital Literacy	Architecture
Theoretical	Enviro/Sustainability	Law/Policy	Mechanical/Aero.
Numerical	Transport	Outreach/Education	Geology/Science
Experimental	Geotechnical	Business/Entrep.	Material/Manufacture
Professional	Coastal	International Studies	Mining/Chemical
Written	Hydraulics	Commerce/Econ.	Software/Electrical/IT
Presentation	Fire	User/Graphic Design	Mechatronic/Biomed.
Documentation	Construction Mgmt.	Other ______	Other ______

www.civil.uq.edu.au/icarus-2015

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA