Proposed PhD Titles and Details

Name of the Asia-wide Programme: **Asia-Link**

Contract Reference Number: **CN/ASIA-LINK/024 (109093)**

Project Title: A Framework Approach to Strengthening Asian Higher Education in Advanced Design and Manufacture (1st January 2006 – 31st December 2008)

Name of Partner:

GIK Institute of Engineering Sciences and Technology (GIKI), Topi, Pakistan, Asia;

Huazhong University of Science and Technology (HUST), Wuhan, China, Asia;

Islamic University of Technology (IUT), Dhaka, Bangladesh, Asia;

Northwestern Polytechnic University (NPU), Xi'an, China, Asia;

University of Strathclyde (SU), Glasgow, the United Kingdom, Europe;

University of Malta (UOM), Msida, Malta, Europe;

Troyes University of Technology (UTT), Troyes, France, Europe.

Potential Research Areas by SU

1. MULTI-CRITERIA DESIGN OPTIMISATION IN ENGINEERING DESIGN

Supervisor: Dr. X T Yan

Objective

- To produce a new visualization technique of the design optimization space, efficiency improvement of the constraint solver.
- To derive constraint expressions from complex design requirements and develop decision making support system using the derived solutions.
- To develop a generic framework solution to solve many complex design problems.
- You may also need to consider the challenge of modelling other aspects of a product in the global option of a product design. These could include life-cycle considerations, customer's requirements, etc.

The above will require a clear understanding of the design objectives and ultimate objective function you will be considering. It is therefore important to have an objective understanding of a design problem and the optimization technique you develop will assist designers to make informed and optimized solution based on their chosen criteria.

2. Constraint based design

Supervisor: Dr. X T Yan

This project will investigate the further advancement of constraint based computer support in engineering design. In particular, it will investigate the generation of constraints suitable for computational work from initial Product Design Specifications. A constraint solver will be enhanced to develop computational efficient tool. It is intended to use the constraint approach in product life-cycle design, covering a range of design parameters and considerations.

3. The magical number seven, plus or minus two

Supervisor: Prof. Alex Duffy

Cognitive studies show people generally can handle seven plus or minus two items of information at any one time (http://www.well.com/user/smalin/miller.html). This puts a strain on our cognitive ability to process and manipulate information and is considered to be the main factor in why we use models, paper sketches, notes, etc. and why things become too complex for us to handle. However, there doesn't seem to be any evidence of this within a design context. This project would investigate the relation between the magical number 7+-2 and design.

4. Measuring complexity

Supervisor: Prof. Alex Duffy

As mentioned in the outline project above, there seems to be a relation between the magical number seven and peoples' perception of complexity. Complexity is a major factor that needs to be managed within many aspects of design development and one this is little understood. This project will focus upon investigating the nature of complexity, how we can measure complexity, and/or its role in the design process.

5. Different types of intelligence and design

Supervisor: Prof. Alex Duffy

Seemingly there are nine different types of intelligence (http://www.macalester.edu/~psych/whathap/UBNRP/intelligence05/Mtypes.html). But how do these different types influence or impact on design? Which types are best suited to which design activities or traits? This project would look at conducting an experiment to give insights into the relations between the different types of intelligence in design.

6. Intelligent design media

Supervisor: Prof. Alex Duffy

Digital media is a rapidly developing area that is finding wider applications throughout our society. A main driving force is the developments in design media, ranging from a variety of applications such as animations, 3D modelling, video, film, World Wide Web and shared workspaces. This project would look at the identifying and evaluating the future needs of designers who might use digital media. Experiments would be defined in order to test the ideas.

7. Design Value

Supervisor: Prof. Alex Duffy

Value in design can mean many things to many people, organizations, users, customers, etc. But what is it truly and how to people determine value? What are the fundamental issues in determining value? Design adds value in some sense, either to the customer, society or the company. But how can we measure “value”. What is its nature and how do we perceive value? Value in what way? There are many intangibles when considering value and many different viewpoints. This project will look at providing answers to these questions through interviews and tests to determine the true nature of value and how it can be determined. It will focus on people centric value and will require an understanding of the different aspects of value including emotion, aesthetics and functionality.

8. Designing customer and user expectations for improved value

Supervisor: Prof. Alex Duffy

The determination of value is through human perception. A fundamental aspect of determining value is a person’s expectations. Designers on the other hand often design products for their functionality or aesthetic value and do not consider the customer or user’s expectations when attempting to create value to them. This project will look at investigating a designer’s potential impact on influencing the customer’s or user’s expectation of value and its impact on its determination.

9. Shared value

Supervisor: Prof. Alex Duffy

Value is a personal human perception. However, we have cultural and societal issues that influence our perception of value. Further, often design teams work closely to develop complex products that have to meet different customer and multiple user communities. This project would investigate and identify the fundamental issues in shared value in particularly contexts such as community perceptions of products or team working.

10. Sketch rendering

Supervisor: Prof. Alex Duffy

Sketching is a key element of concept design that helps formulate our ideas as well as present those ideas to others. Apart from the psychological influences of color, and basic technical drawing conventions, we know relatively little about the best way to convey the openness, or uncertainty/vagueness, of our ideas to others and the best way to present form, shape and aesthetics. We know relatively little of what information a sketch conveys, how we use sketches for communication or what are the key elements of a sketch and how to the different elements convey different information. This project would be to carry out an investigation into the best ways to convey our ideas from a sketch to human viewer.

11. Insect based design principles

Supervisor: Prof. Alex Duffy

Insects have remarkable power to strength and weight ratios. They can travel and enact speeds that in many cases far out perform animals. With ever-increasing importance being put on miniature and nano technologies the principles of medium sized products do not hold at small scale. This project would aim at analyzing the relationships between function, structure and behaviour within

the insect realm to determine and test design principles. The learned principles will need to be tested in some appropriate way.

12. Prevention of damage and fracture in severe plastic deformation of metals

Supervisor: Dr. Andrzej Rosochowski

Objective: Enable difficult to deform materials to be nanostructured by severe plastic deformation (SPD) without causing internal damage to the material.

Approach/Methodology: Ultra-fine grained (UFG) metals possess a range of unique properties, which make them attractive materials for a number of industrial sectors including automotive, aerospace, defense, sports equipment and medical industries. Alternatively to the nanopowder route, which is expensive, unreliable and hazardous, SPD is a new method of producing UFG structures in bulk metals. It is applicable to all metallic materials such as aluminum, magnesium, copper, titanium, iron, tungsten, nickel, etc. Since some of these materials are inherently brittle, they are prone to internal damage and fracture during SPD. In order to predict and prevent this damage, its mechanism and causes have to be understood and remedies prescribed. The methodology used will be based on experimental trials of SPD and relative density change measurements, tensile testing of UFG metals, documenting fracture by SEM micrographs, developing material models accounting for plastic flow localization and ductile damage, FEM simulations to predict material flow and damage and finally formulating guidelines for design of SPD processes.

Expected outcomes: Quantification of material damage in equal channel angular pressing (ECAP). Developing a ductile damage model appropriate for simple shear. FEM simulation of plastic flow localization and damage in ECAP. Establishing ECAP parameters in order to prevent/suppress material damage.

Candidate profile: A suitable candidate should be a high caliber graduate with sound knowledge of solid mechanics, FEM simulation and experimental techniques. The project can accommodate two students.

13. Shaping of ultra-fine grained metals

Supervisor: Dr. Andrzej Rosochowski

Objective: Assessing suitability of UFG metals for mechanical machining, EDM and metal forming. Formulating process design guidelines for shaping of UFG metals into high quality products.

Approach/Methodology: Ultra-fine grained (UFG) metals possess a range of unique properties, which make them attractive materials for a number of industrial sectors including automotive, aerospace, defense, sports equipment and medical industries. Alternatively to the nanopowder route, which is expensive, unreliable and hazardous, SPD is a new method of producing UFG structures in bulk metals. It is applicable to all metallic materials such as aluminum, magnesium, copper, titanium, iron, tungsten, nickel, etc. UFG billets produced by SPD have to shape into required components. Available technologies include mechanical machining, EDM and metal forming. Since UFG metals are very new, there is no knowledge regarding their behaviour during shaping by any of these methods or any information on recommended process parameters. In order to generate such knowledge, machining, spark erosion and metal forming trials will be conducted. Relationships between initial characteristics of UFG metals, shaping process parameters and product quality will be investigated. Providing theoretical explanation of the observed effects based on deep understanding of the underlying phenomena will be an important part of this project.

Expected outcomes: Characteristics of UFG metals produced by SPD. Experimentally established relationships between the initial state of UFG metals, process parameters and product quality in mechanical machining, EDM and metal forming. Models and mechanisms governing the behaviour of UFG metals in shaping processes. Guidelines for designing shaping processes for UFG metals.

Candidate profile: A suitable candidate should be a high caliber graduate with sound knowledge of manufacturing technology and experimental techniques. The project can accommodate two students.

14. Welding and Cutting Simulations

Supervisor: Dr. David Nash

Use of bolted flanged pipe joints is very common in petrochemical, nuclear and process industry. Welding of pipe to flange results in residual stress built up and distortions which provide negative effects on the structural integrity and sealing capability of the pipe-flange joint. The effects include stress corrosion cracking, brittle fracture, reduced fatigue and creep strengths, poor sealing performance and reduced buckling strength etc. The objective of this research is to investigate the extent and distribution of residual stress built up and distortions in the welded pipe-flange joints and to explore the most effective mode of mechanical stress relieving. This research involves studies for implementation of numerical technique for welding simulation and selection of appropriate models. In experimental work welding residual stresses will be investigated including their dependence on welding parameters and their mitigation technique and then the measurement of welding deformations.

Potential Research Areas by UTT

1. Structural Optimization based on mechanical analysis knowledge integration

Supervisor: Dr. Pascal Lafon

During the product development process, several tasks have to be carried out in order to progressively map a set of functions (requirements) to a technological structure. This structure is then designed taking into account some number of constraints related to the whole product life cycle (materials, structural analysis, recycling, etc.).

We have proposed a methodology to integrate the expert structural analysis constraints in the embodiment design phase, to constraint and to restrict, from a mechanical point of view, the geometrical and materials definition of the structures allowing the transmission of the loads between the mechanical connections of a given component. This methodology is based on three main steps: The first one consists in defining a model of behaviour, then secondly to analyze this model and to formulate analysis constraints and finally integrate these constraints in a view specific in the multi-view representation product model to the expert structural analysis.

These constraints are formulated as mathematical relations between a set of parameters. This set of parameter includes geometrical parameters, functional parameters and material parameter. The main goal of this PhD is to propose a methodology in order to support structural optimization of this component. Several aspects will be developed in this work:

- The formulation of the optimization problem, and specifically the reduction of the complexity of the problem using for example “constraints programming techniques”. The formulation of multiobjective and mutlicriteria problem will be study and specially the link between the criteria and functional requirements.

- The best well suited optimization method has to be defined, among several optimization algorithms available in our lab.

2. Synthesis of multiple geometric models as a support for collaborative activities in design process

Supervisor: Dr. Pascal Lafon & Dr. Lionel Roucoules

Since knowledge intensive design approach appeared, product modelling is not centred on form features any more but knowledge based as largely presented in the scientific community. We have proposed a methodology showing how the geometry of the product is emerging from design experts' knowledge integration, interpretation and translation to form features. Those translations therefore do not issue to a single geometric model but several ones which concurrently represent expert's product solution. The final common geometry has to be seen as the result of different compromises during the collaborative design process. The product is then defined by least commitment.

This PhD aims to develop a methodology to support the analysis and the comparison of several geometric description of the product. This methodology must be able to highlight differences between several geometric description in order to support the decision making process.

3. Functional and physical analysis of a hybrid manufacturing machine as initial stage for the design

Supervisor: Dr. Lionel Roucoules

Today, manufacturing machine is dedicated to a specific process (machining, laser sintering, laser cutting, water cutting, etc.) since a part is most often made of a unique process. In the recent scientific literature, new research presents original results toward hybrid prototype (i.e. several components) or DFM approach providing alternative manufacturing plans; it then seems interesting to investigate how those kinds of hybrid prototypes could be manufactured on a unique machine.

The PhD objectives are to apply original approach of functional analysis, physical principles analysis and technologies selection to the design of hybrid manufacturing system. A hybrid manufacturing system is therefore seen as a unique system able to process various manufacturing techniques. For example laser and water cutting plus machining. Such machines could be interesting for development cycle time reduction or for SMEs dedicated to rapid prototyping. The main benefits would be to faster the global process planning and to increase product quality manufacturing since the part is not moved. The hybrid concept will obviously concern the whole manufacturing system that can be generically seen as a tool (end mill, laser, etc.) and its respective energy, the part setting system, the clamping system, the machine environment (casing, etc.).

The functional approach aims at identifying the minimal functions and the physical principles related to the manufacturing processes requirements. Technologies selection can then be processed relating functional, physicals and technological attributes. Those relationships formalize the design decisions and can then be used to propagate any functional or technological changes. Each attribute is defined with its own range of values related to physical or technological limits; the conceptual design therefore provides a space of potential solutions that would be then constrained by a DFX approach in order to provide final alternatives detailed solution. The development of that case study via a global design environment supports the emergence of the CAD model of the machine.

4. Specification and development of dynamic database concepts for manufacturing information synthesis in a integrated design environment

Supervisor: Dr. Lionel Roucoules

Several approaches have been presented in the scientific community to take into account manufacturing information during the product development process. Those approaches can be identified under the generic term of DFM (Design for Manufacturing) and most of the time requires a manufacturing processes database that gathers a set of information related to quality, tolerances, costs, etc. The remaining problem is that each approach does not need the same inputs and outputs of the database respect to each specific activity process model. It is then difficult to use the same database in term of structure and even more in term of request.

The first approach is to develop ad-hoc database respect to every activity context but that goes en counter the unification of information. Moreover, some really good database (ex: CES4) already exists and it would not be interesting to develop new ones with the same information.

The PhD work would then, on the one hand, be to provide concepts and software solution to dynamically structure a set of information (ex: filter on the global information) and a set of requests that could then be treated by different DFM process.

On the second hand, the work will be to specify what could be a dynamic exchange format to extract from the global data base the specific data required by the DFM software solution. XML technology can obviously be used.

This PhD work could be led in collaboration between UTT, Univ. Strathclyde and Univ. Malta which all develop DFM approaches.

5. Specification and development of an interactive and intuitive Reverse Engineering tool

Supervisor: Dr. Sebastien Remy

Today, Reverse Engineering is too often considered as a set of tools and methodologies that enable to make a virtual copy of a physical object generally using a 3D digitising system that gives a point cloud. This copy is generally a non parameterised solid or surface based model. It can be used to make mechanical calculation by meshing it of it can be used to re-manufacture the associated part. In fact, the lack of information regarding to the definition of the different features that compose the model makes a real re-conception of the part a very time consuming and boring operation.

On the market, many powerful tools already exist in two categories. The firsts are friendly to use (paraform …). They enable to fit quickly and effortless complex surfaces (NURBS for example) on the digitized point cloud following a unique sequence of operations. As a result, the obtained solid model is, as said before, non parameterized but also without any type of primitive geometric features like plane, cylinder … This type of solid model is almost impossible to modify in a engineering context (modify a diameter, add a hole …). The second category is composed by CAD software (CATIA …). In Such software, everything is possible to do with the point cloud. They can be considered as some big tool boxes without any instructions. It is due to the user to invent his own sequence of operation. The main advantage is the possibility to adapt this sequence to every single digitized part but, as a drawback, rebuild a whole CAD model using this type of tools is really time consuming and needs very good skills.

In this PhD thesis, we will study the feasibility of using virtual reality equipments to improve the interface of the second category of tools in order to make Reverse Engineering intuitive keeping the possibility to produce solid models fully parameterized that enable reconception operation.

Potential Research Areas by UOM

1. Designing for Safety in Mechatronic Systems

Supervisors: Dr. Jonathan Borg and Dr. Conrad Pace

Mechatronic systems are by their own nature complex systems involving the integration of various technologies. It is therefore difficult to interpret the safety consequences of mechatronic design features unless an appropriate structured and systematic approach to safety is adopted when developing the mechatronic product. As mechatronic systems become evermore autonomous in their behaviour, safety becomes an even more critical component of the design process. Research in this field focuses on how to facilitate the development of safe mechatronic systems by understanding where and what safety analytical tools to apply and how to extract the appropriate safety features as a consequence of the analysis, with the scope of managing and reducing the underlying mechatronic system operational risk.

The objective of this project will be based on the identification and development of methodologies to be applied in the development of complex mechatronic products and systems in terms of safety. The work will initially focus on evaluating approaches that are currently adopted for safety assurance of complex mechatronic products that exhibit a high level of autonomous behaviour. This will then proceed towards the identification of the critical criteria for safe mechatronic product development as well as the identification of an approach to be adopted to enhance and facilitate the integration of safety within the product development.

2. Controlling Product Variety and Process Variability

Supervisors: Dr. Jonathan Borg and Dr. Conrad Pace

As product life-cycles drop and as demand for variety increases, flexible automated assembly is becoming an evermore desirable feature, particularly in terms of enhancing the agile response of a manufacturer to market demand. However flexible automated assembly does not occur in a vacuum and requires appropriate consideration of the desired and expected variability of the product and consequent effects on the process. Research in this field focuses on providing an insight into how product variability influences automated assembly, and additionally investigates approaches to the development of automated assembly which facilitates and accommodates the desired product variation whilst achieving the ubiquitous targets of time, cost and quality.

The objective of this project is to evaluate the effects on automated assembly process systems resulting from the shortening of product life-cycles, the increase in product variety demand and the drop in product quantities. This evaluation will initially have the scope of investigating how product variety influences automated assembly. Primarily, the scope will be that of understanding how design decisions influence the level of dedication of automated assembly systems. The work will then proceed towards exploring approaches in the development of automated assembly systems which provide the desired level of flexibility and the ability to accommodate the required product variety within the expected industrial constraints. The approaches will provide an insight both at a system level, as well as at a station level in terms of reconfigurable system requirements.