TECHNOLOGICAL SECTOR RESEARCH: STRAND I

POST-GRADUATE R&D SKILLS PROGRAMME

2008 Application Form

Notes:

1. The General Guidelines and Conditions on the Post-Graduate R&D Skills Programme **must be read** prior to completing this application form. **Applications not adhering to the Guidelines will be returned to the Institute concerned.**

2. In particular, please note that completed applications must **not exceed 20 pages** in length (excluding appendices and Declaration sheet). **Applications over 20 pages in length will be returned to the Institute concerned.**

3. Appendices consist of appropriate **letters of support, details of resubmission (if applicable)** and **pro-forma supervisor profile** sheets **ONLY**.

4. Pro-forma supervisor profile sheets to extend to a **maximum of 2 pages**.

5. **Resubmitted projects** must attach an additional sheet, maximum 1 page, identifying **how the submission has been altered**. (Bullet pointed list will suffice).

6. Please have regard for the Marking Scheme prior to completing this Application Form.

7. Please ensure that you complete **all** sections of this form as fully as possible in typescript.

8. All Sections must be typed in at least **12pt font** and **1.5-line spacing**.

. 9. The Abstract on Page 2 of this form must be completed. The abstract should set out in **non-technical language** the nature of the proposed research project and what it is hoped will be achieved, i.e., the likely application of research outcomes. **Please note** that this does not obviate the need, where required, for appropriate technical description on the application form. The abstract **must not exceed 200 words**.

FOR OFFICE USE ONLY				
Project Code PRDSP/08/	**Institute**		**Category**	
Resubmission	**YES**		**NO**	

Institute:	Institute of Technology Blanchardstown		
Project Title:	Automatic assessment of painted road markings using computer vision techniques.		
Category[1]: (insert appropriate category code from list)	ET/IT		
Lead Supervisor:	Simon McLoughlin		
Has this project been submitted to Strand I before?	No	**Outcome of this submission?**	
No. of ongoing Strand I projects with lead supervisor	0	**No. of completed Strand I projects with lead supervisor**	2

Please summarise below the proposed project, the potential research outcomes and their likely application in <u>non-technical language</u>. This abstract should <u>not exceed 200 words</u>.

ABSTRACT

A vehicular mobile mapping system has been developed at the Institute of Technology Blanchardstown for the automated analysis of road signage and delineation. The system is composed of a number of navigation sensors for geo-referencing (positioning) and a multi-camera (stereo) system for automated feature extraction from imagery. In its current form the system is capable of automatically detecting road signs for inventory purposes and also for detecting faulty or defective road studs (i.e. 'cat eyes'). This project proposes to extend the systems capability by automating the analysis of painted road markings. This will be achieved by designing, implementing and testing novel computer vision algorithms for the automated detection of painted road markings in imagery acquired during low-light levels where illumination is provided by sources on the vehicle. Once image detection is complete the system should then be able to classify the marking in terms of its reflective efficiency or its ability to retro-reflect (return the incident light to the driver). This will be achieved by making a comparative analysis of the light intensity information in the imagery. Pass/fail statistics should then be made on segments of road examined. This facility will enable maintenance schedules to be produced without using handheld systems instruments that can be time consuming and disruptive.

Lead Project Supervisor/Department:	Dr. Simon McLoughlin, Department of Informatics, School of Informatics and Engineering.				
Institute:	Institute of Technology Blanchardstown				
Telephone:	01 8851343	**Fax:**	01 8851004	**Email:**	simon.mcloughlin@itb.ie

Second Project Supervisor/Department:	Dr. Catherine Deegan, Department of Engineering, School of Informatics and Engineering.				
Institute:	Institute of Technology Blanchardstown				
Telephone:	01 8851093	**Fax:**	01 8851004	**Email:**	Catherine.deegan@itb.ie

1. Costs in Respect of Project*

Trainee Grant (Total) **	€25,000	Materials[1]	€2600
Supervision Cost**	€5000	Travel[2]	€2000
Course / Examination Fees**	€7379	Training[3]	€1000
		Other (please specify)	€
Total Cost of Project**		**€ 42,979**	

[1] Materials include the following items:

Accurate GPS antenna	700
High intensity IR illuminator	900
Camera Lenses	500
Consumables	500
	2600

[2] Travel costs include those for flights, accommodation and subsistence whilst attending conferences and summer schools

[3] Training costs include those for conference and summer school registration fees.
All other costs are those set by the Institute.

2. General Outline of Project Proposal

Main Research Question(s):

1. To decide on the most appropriate camera/lens/illumination setup and configuration for this specific problem.
2. To develop and test effective feature extraction techniques for the detection of painted line markings in low light conditions under vehicle illumination (e.g. headlamps).
3. To determine classification thresholds for detected markings such that they can be classified based on their image light intensity characteristics into PASS or FAIL classes.

Objectives:

1. To carry out a literature and technology review into the areas of computer and machine vision applicable to the problem.
2. To develop a robust technique for the analysis of line markings which could improve upon current practices which are either unreliable, expensive or disruptive.
3. To train a graduate student to level 9 of the National Qualifications Framework such that he/she would be highly skilled in the areas of Computer Vision/Photommetry and be a prime candidate for employment in this area. The student will also improve other core skills such as software engineering.
4. To give a graduate student significant exposure and guidance in research and development such that they would be capable of conducting independent research in the future.
5. To maintain and enhance the R&D growth levels within the Institute of Technology Blanchardstown.
6. To maintain and strengthen the links between the School of Informatics and Engineering at ITB and industry/external organizations.
7. To improve the research curriculum vitae or résumé of the group and enable expansion through application of research grants.

Contribution to Knowledge of Discipline Area:

The following contributions will be made to the discipline area:

- A construction guide for a mobile vision system (optimum positioning of cameras, illuminators etc.) for the analysis of painted line markings.
- A robust techniques for extracting the painted road lines in imagery acquired under challenging conditions.
- A mapping function between observed image light intensity and line marking reflective efficiency or retro-reflection.

Relevance to Research Strategy of Institute:

The following are extracts from the Institute's strategic plan (2006-2011) and the Institutes Research Strategy which outline the Institutes research ethos and support for research such as that expressed in this proposal.

Strategic Plan:

- ITB's mission is to serve students and the community by achieving consistently high standards of relevance and quality in teaching, research, development and consultancy.
- ITB's mission is to serve students and the community by preparing high-quality graduates and by providing research and training relevant to employers' needs.
- We will ensure that a critical mass of staff is involved in research by stimulating the active involvement of at least 25% of lecturing staff in research, and achieving a commensurate increase in postgraduate student numbers.
- It is vital that ITB builds on its emerging strengths in research and the development of professional practice in the workplace. Strength in these areas will be essential to developing the teaching capability of academic staff and to the maintenance of relevant and stimulating curricula.
- Our aim is to stimulate research activity with strong links to industry and the public sector.
- We will achieve these objectives by supporting individual research activity, which focuses on specific technologies, application and know-how, which will enable the formation of at least two research centres.

Research Strategy

- The Institute is committed to providing opportunities to progress to the next level of academic learning. As such, the Institute has a strong commitment to providing relevant educational opportunities for NQAI level 8 graduates to progress to NQAI level 9 (Masters degree) and NQAI level 10 (PhD degree).

To support this research provision, the Institute is committed to:

1. Promoting and supporting research relating to the understanding and exploitation of technology.
2. Encouraging research into areas of new human knowledge and understanding.
3. Disseminating new knowledge and understanding, promoting public understanding and providing advice to the public across a range of academic disciplines.
4. Encouraging research which contributes to National development.
5. Encouraging development of intellectual property.

The proposed research is very much in keeping with both the strategic plan of the Institute and the research strategy. The Institute is focused on serving the community by developing high quality graduates. This project will see a high quality post-graduate emerge suitable for employment in a highly advanced and technical area. The knowledge gained throughout the project can be fed back into undergraduate degree modules to keep them fresh and exciting. Research links to external organizations is a priority of the Institute and this proposed project will help develop and maintain those links. Currently this area of research has strong links with the National Roads Authority as are outlined in the letter of support. The Institute is committed to promoting research into new and modern areas of technology, which is of particular relevance to this project. The Institute is committed to the dissemination of new knowledge which is an obvious goal of an research Masters degree through seminars, conferences, paper publications etc.

3. DETAILED PROJECT DESCRIPTION

DETAILED PROJECT DESCRIPTION
(To include justification of costs where necessary)

Research Motivation and Benefits

The motivations for this work are practical, humanitarian and academic. In 2004, a total of 7,867 people were injured in Irish road accidents and of this number, 374 were fatally injured. The Gardaí (Irish police force) identified the condition of the road and the environment as the contributing factor in 2.1% of these accidents [1]. A paper presented at the AUSTROADS Conference in Perth, Australia in 2004 [2] surmises a number of studies and surveys from around the globe that show the effectiveness of road markings in reducing traffic accidents. One such study from the US has shown that longitudinal pavement markings reduce accidents by 21% and edge lines on rural two-lane highways lead to reductions of 8% [3]. These reports and statistics underline two basic facts. The first is that the road environment poses a significant danger and threat to human life. The second is that the installation and maintenance of road delineation helps prevent road accidents by alerting drivers of the dangers that are intrinsic to the road.

The practical motivations behind the work stemmed from ongoing meetings and discussions with representatives from Tramore House Regional Design Office in Co. Waterford and the National Road Authority (NRA) of Ireland (see letter of support in appendix). These bodies have a direct requirement for efficient, robust and passive systems to address signage and delineation inventory and analysis so accurate maintenance schedules can be decided on. The maintenance of road markings is considered by such organisations as one of the most cost effective ways of improving road safety [4]. Automated systems to inspect road markings at traffic speeds are available but appear to be non-image based systems [5], which are costly and have been subject to some performance criticism. The current policy for markings analysis in Ireland sees trained personnel doing manual or hand held assessments [4]. The solution proposed here would allow a field engineer to collect large quantities of valuable data by simply driving the route himself/herself.

The problem discussed also has significant academic merit. Computer vision is a non-trivial multi-disciplinary area of research encompassing significant mathematical techniques, physics, computer science and engineering. This particular problem will require a candidate with aptitude in most of those areas to bring the project to successful completion.

Project Details

The system that is proposed provides a machine or computer vision based solution to the problem of painted road line inspection. The system will be passive and restrictions including precision driving will be reduced. The integrated mapping sensors in the system are synchronized with the camera capture for autonomous acquisition. After an initial configuration and calibration period, the system begins capturing the relevant data (position, attitude and images) for a specified time frame through the click of a button. The analysis of the data is done offline after acquisition, which is not an issue for this particular application. Once the cameras are configured correctly and the optimum images of the lines are obtained for analysis, the images will be processed automatically to detect the road lines (both center lines and edge lines). Initially only a single lane analysis will be done with the possibility of dual-lane analysis afterwards. After the line has been extracted, the mean intensity values of fixed segments will be recorded at regular intervals (e.g. every 20 metres). This will then be compared with a database table of quality measures that includes the light intensity range for conforming line segments. This information will be determined first in a controlled setting where proven handheld instruments can be used to estimate the reflective efficiency of the marking and the corresponding image intensities can be recorded. It will be important to replicate the operating scenario of the acquisition rig when doing these control/calibration experiments. Statistics will then be gathered and made available on segments of road examined. These can be presented using specific GIS software packages (e.g. ArcGIS) or applications like Google Earth or Microsoft Virtual Earth. The video sequences recorded and statistics gathered over time may also be used to allow a historic examination of the road infrastructure.

Originality

The proposed project will have a number of novel and original aspects to it which when completed will go some way toward filling the gap in knowledge in this area:

- Painted line marking extraction: while there is a significant body of work done on this problem in a daytime setting, there is little work done in a nighttime scenario when there is no ambient illumination. Not only will this present challenges in terms of image feature extraction, it will also require the student to become familiar with vision system configuration and setup.

- Defining a mapping between image intensities (luminance) and reflective efficiency of road markings. Whilst there has been some work done in this area in the laboratory [ref], little work has been done in more challenging environments such as that of a roadway.
- The presentation of the results data will also offer some originality. Previous work at ITB on the assessment of road signs and road studs used Google maps for presentation but other approaches will be investigated.

Research Methodology

- Literature Review: The student will be advised about the book chapters and research papers they should review. The student should summarise, critique and suggest improvements and developments on this work. At the outset of the project the student will perform an intensive literary review and continue reviewing relevant work for the duration of the project. Some of the books and journals the student shall review extracts from are:
    - Optical Engineering (SPIE)
    - Introduction to radiometry and photometry, McCluney, R.
    - Computer Vision: A modern approach, Forsyth, D. and Ponce, J.
    - Int. Journal of Computer Vision
    - IEEE Intelligent Vehicles
    - IEEE Intelligent Transportation Systems
    - IEEE Pattern Analysis Machine Intelligence
- Determine relationship between road marking retro-reflectance and observed image luminance: This task will involve the student doing a number of experiments in a controlled environment whilst trying to replicate real-world geometries. The student will investigate the relationship between measured retro-reflectivity (using hand held instruments) and observed image luminance whilst deriving a mapping function between the two. This will involve knowledge of radiometry, photometry, optics and projective geometry to estimate the required function parameters. The objective of this phase is not the development of an exact image based technique for retro-reflectivity measurement but to provide a reasonable estimate of road marking condition that may warrant further investigation. This objective was discussed with the

NRA.

- Vision System Configuration: This task will involve the selection of a number of parameters that will result in a near optimum image of the feature (road marking). The speed of the vehicle will be considered along with the possible camera frame rates. This will affect the choice of lens since smaller fields of view mean less road examined per image and thus require more images. The position and orientation of the cameras should also be optimally chosen to ensure a strong reflectance function. This will also depend on the light source used to illuminate the road markings. The light source will most probably be the vehicle headlights but infrared sources will also be investigated as was done in prior projects dealing with different features. Optimal camera exposure settings will also be determined to minimize motion blur whilst maximizing signal to noise ratio. The group already has in its possession high sensitivity cameras for such applications. The above parameters will be calculated analytically where possible, and tried and tested through trial and error based experiments.
- Painted line marking extraction: This task will involve the use of computer vision and image processing techniques to automatically extract the road marking from the image. The precise technique used will depend on the nature (e.g. clarity of the image, form taken by markings in the image etc.) of the image captured but it is envisaged that the following techniques will be used:
    - Edge Detection (probable use of Canny edge detector for increased performance) where image edges (significant changes in intensity) are determined. This will result in the two edges of a road marking.
    - Curve fitting: The image edges will be searched for parameterized curves where the parameters are determined from manual extractions of the road markings in the captured imagery. It is envisaged that the curve segments will be mostly linear but this will depend on the camera configuration. Techniques such as the Hough transform are available for such problems.
    - Region extraction: the region between two neighbouring parallel curves will be extracted.
    - Further road marking validation techniques will also be used such as image location tests, region geometric attributes etc.

- Marking classification: The intensity characteristics of the road marking will be mapped to a reflective efficiency rating which will determine its status as needing urgent maintenance, needing maintenance soon or no maintenance currently required.
- Results and statistics gathering: All images acquired by the vehicle are geo-referenced through GPS and Inertial technologies. Particular routes will be used as test routes where the markings are analysed. These routes will be incorporated into GIS management software and colour coded based on the road marking integrity, e.g. red, amber, green for the three categories mentioned above. Statistics on larger sections of road will also be available such as the percentage compliance between two waypoints.

Technical Feasability

Supervision

- The principal supervisor, Dr. Simon McLoughlin, has been an active researcher in the proposed area (imaging) for the last seven years and has published a number of papers in the area. He also played an active role in the supervision of two previous Master's students funded through the Strand I program and has seen these projects brought to a successful conclusion. More details on the principal supervisor can be found in the supervisor profile attached.
- In addition other group members (e.g. Dr. Catherine Deegan, ITB) and collaborators (e.g. Conor Fitzgerald, NRA) are at hand to advise on technical, administrative and practical aspects of the project.

Project Objectives

- The project has well defined requirements, milestones and deliverables. This will make it very clear to the student what has to be done and the timeframe in which to do it in.
- Previous projects with similar aspects (e.g. road stud assessment, road sign detection) have been successfully completed in the past (in collaboration with the Computer Vision group at NUI Maynooth) and a lot has been learned from these experiences. It is envisaged that the know-how and tools developed during these projects will ensure a quick start and a relatively smooth journey

through the proposed project.

Facilities and Equipment

- Laboratory/bench space is supplied within the Institute with a high-specification PC and access to all the required licenced software.
- A fully operational mobile mapping system which includes machine vision cameras, GPS receivers, inertial measurement units, light sources and housing has been developed by the group and will be used to test the techniques and tools developed as part of the proposed project. HEA funding has also been recently secured to purchase a high grade NovAtel SPAN navigation system which will improve the positioning accuracy and reliability of the mapping system. This item is awaiting delivery.
- Other funding applications are currently under consideration for an array of cameras/lenses/light sources that will add to the capabilities of the system. However, this project is not dependent on these items. Existing equipment will be perfectly adequate

References:

1. National Roads Authority (Ireland). Road collision facts, Ireland, 2004. Published 2005.

2. Carnaby, B., 'Road Marking - High Priority Road Safety, or Just Road Maintenance?', AUSTROADS Road Safety Researching, Policing and Education Conference, held in Perth, Australia in 2004.

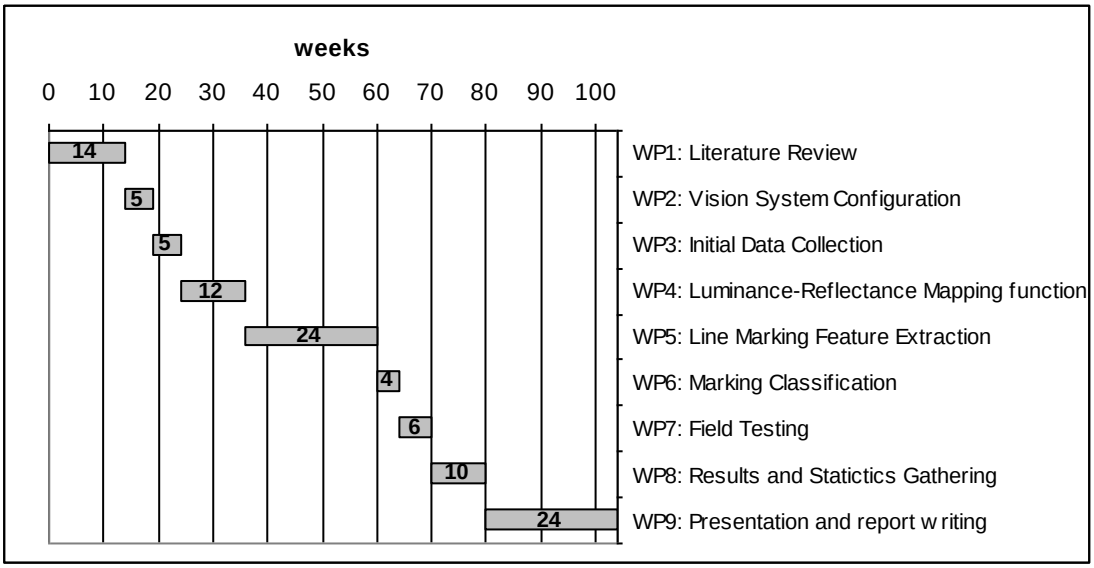
3. Miller, T.R., (1992a) Benefit-cost analysis of lane marking, Transportation Research Record, Issue: 1334, December 1992. pp 38-45.

4. National Roads Authority (Ireland). Personal Communication, 2002.

5. Tasman Data Systems Pty Ltd, www.tasmandata.com (last accessed in 2006).

Project Schedule / Timescale (indicate likely steps in project and timing in **graphical format**)

The project schedule is depicted below through an excel Gantt chart. Holidays are not displayed but factored in proportionately.



WP1: Literature Review

The student will spend the first 14 weeks reviewing the literature in the area and becoming learned with the skills and knowledge required to complete the subsequent work packages.

Deliverable produced*:* A technical report describing the fundamental principles in the area, the state of the art, limitations thereof and suggested improvements. This will form the bulk of thesis chapter 2 which discusses related work.

WP2: Vision System Configuration

This task will involve the selection of a number of parameters through analytic analysis and experiments that will result in a near optimum image of the feature (road marking).

Deliverable produced: A vision system with near optimum parameter values such as camera position and orientation, lens selection, aperture and exposure settings, frame rates, light source selection.

WP3: Initial Data Collection

During this work package a number of surveys will be performed on various stretches of road where data will be collected and analysed. There may be some overlap between this work package and WP2 where the data collected provides insights into

optimal configuration settings. In addition controlled data collection will be performed where the data sets are of known reference values that may be determined from handheld instruments.

Deliverable produced: Optimal test data for the subsequent work packages.

WP4: Luminance-Reflectance Mapping function

The student will investigate the relationship between measured retro-reflectivity (using hand held instruments) and observed image luminance whilst deriving a mapping function between the two.

Deliverable produced: A computational algorithm (documented, implemented and tested) that is capable of outputting a reflectance value based on the input parameters such as image light intensity and position of features with respect to the illumination source. A research paper will be produced based on this and submitted to a domestic conference for publication consideration. Prospective conferences include IMVIP and the Irish Graduate Symposium on Vision Graphics and Visualisation.

WP5: Line Marking Feature Extraction

This task will involve the use of computer vision and image processing techniques to automatically extract the road marking from the image (see research methodology above for more information).

Deliverable produced: A machine vision technique and software implementation for the extraction of painted line markings in low light conditions.

WP6: Marking Classification

In this relatively short work package the student will determine the luminance characteristics from the extracted road markings and map these to a corresponding reflective efficiency value using the mapping function developed in WP3. The marking will then be categorized based on its reflectance into one of three categories, i.e. needs urgent maintenance, needs maintenance soon or no maintenance currently required.

Deliverable produced: A tested software interface between WP3 and WP4 that consumes the output of these packages and determines the category for the extracted road marking.

WP7: Field Testing and Evaluation

During this work package the group will identify the most appropriate test routes (markings in good working order, markings in poor order etc.) to test the road marking analysis system. The system will then be operated on these routes for performance evaluation purposes.

Deliverable produced: Captured final test data (geo-referenced imagery). Raw system outputs from test data processing.

WP8: Results and Statistics Gathering

During this stage the raw results from the previous work package will be compiled in a GIS management system where net results and statistics on road sections examined can be summarized and presented in a graphical and interpretable manner.

Deliverable produced: Tabulated and graphed result data highlighting the state of the painted line markings on sections of road examined. Graphs will take the form of the road segment geometry and colour coded based on the road marking category. An international conference paper will be generated based on the work done up to this point and submitted for publication.

WP9: Presentation and report writing

The main activity in this task will be the generation of the M.Sc. thesis. Presentations will be given to the interested parties involved in the project.

Deliverable produced: Student M.Sc. thesis and presentations/seminars. The student will also be encouraged to write a journal paper based on their thesis and research done, which will be submitted for publication towards the end of the project.

Research and Development Training (indicate steps to be taken/mechanisms to be used to train graduate in R&D skills, list learning objectives/outcomes)

Steps to be taken to train graduate:

1. A literature and technology review will be carried out by the student under the direction of the supervisor. The student will be shown how to source the relevant material through the library, inter-library loans, online journals etc. The student will also be shown how to review and prioritise bodies of work based on relevance, importance (i.e. fundamental theory) and performance.
2. The student will attend ITB research training seminars, which are held regularly in the Institute. Statistical methods and technical writing skills/tools are amongst the subjects delivered.
3. The student will attend an international summer school on computer vision in 2009. This allows the student to establish links with their peers and get some practical training from leading researchers in the area.
4. The student will give regular seminars on their research within the Institute. These seminars provide a means for the student to prepare for conference

presentations through public speaking and also contribute to the general research awareness within the Institute.

5. The student will attend conferences where they will gain exposure to the state of the art in the area and develop an appreciation for the level of knowledge required. The student will present their work at the conferences and learn to deal with criticism/suggestions/appraisal. Workshops and tutorials that are normally held at conferences will again give the student the opportunity to acquire hands on training from leading researchers.
6. There will be regular meetings held between the student and the research group to monitor and guide the student's progress.
7. The student will develop an appreciation for the research project plan through initial discussions with the supervisor where the project schedule will be presented to the student.
8. The student will be exposed to the R&D life cycle so that they will be able to employ the models in future projects they may be involved in.
9. The student will be involved in meetings with external organizations to enable them to develop their own external links and also to facilitate their learning in terms of project organisation.

Learning Outcomes

1. Competency in Vision Systems design, computer vision and radiometry.
2. Core skills enhancement in areas such as mathematics and software development.
3. Proficiency in a number of (possibly new) technologies including Matlab, MS Visual Studio and .NET framework, Open CV.
4. An ability to perform self directed research.
5. An ability to work as part of a multi-disciplinary team.
6. An ability to generate high quality research reports/papers and disseminate the work through the right channels.
7. An ability to give insightful presentations on research work.

Institute Facilities (provide details of any Institute facilities that are relevant to the operation of this project)

This question not to be completed in the case of Business and Humanities Applications.

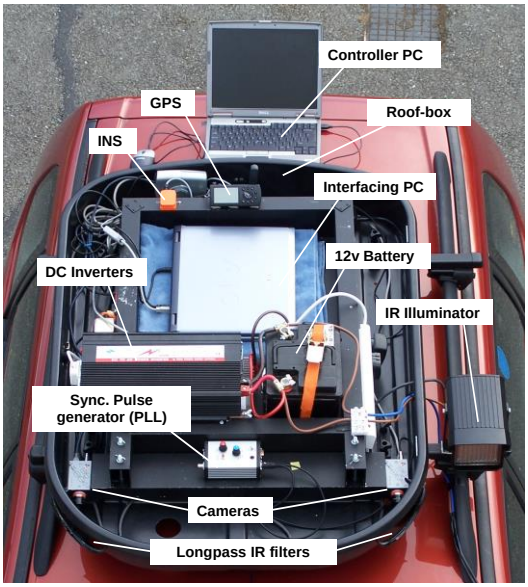
LINC center: The learning and innovation center at the Institute hosts most of the research and commercial projects. Within the building there is open plan lab space for conducting experiments and desk/office space for software development, reading and administrative duties.

Computers and software: All postgraduate students in the Institute are supplied with a desk/phone/PC with Internet access and email facilities. In addition, the Institute also has a number of research licences for the relevant software packages such as MatLab and MicroSoft Visual Studio.

Technical Support: The Institute has a number of technical support staff in both computing and engineering. This staff group help with software/hardware installations, technical trouble shooting and IT supplies.

Test Track: The environs of the LINC center are relatively large with a seldom used tarmacadam driveway around its back (approximately 100 metres in length). While this is not a purpose built test track it has served extremely well in previous projects due to its surface properties and size.

Mobile mapping system: The mobile mapping system for data capture has been developed over the last 5 years. This system can be seen in the figures below. The student will be brought up to speed on this system quickly which will enable them to configure it and capture data early on in the project.



Library: There is an excellent library facility within the Institute that hosts a number of core texts in the area. Also available are electronic books through Safari books online, electronic subscriptions to ScienceDirect (Elsevier) journals and an efficient inter-library loan facility. There is also a free equipment hire facility (e.g. laptops, video cameras etc.) should the student need it. The research group also has high spec. laptops for data acquisition should the student need one.

Seminars/Training: As mentioned earlier, the Institute run regular postgrad/staff training workshops and seminars in topics such as technical writing and statistics.

Departmental website: There has recently been a research dedicated departmental web-server set up at ITB, which will allow the dissemination of knowledge and skills across the Internet. The groups is currently working on their website which should be operational by June 2008.

Institute / Industry Links (How will the project enhance links with industry or other relevant external organisations. Where relevant indicate details of any support from industry including company name, contact person and contribution).

The research group has established links with the National Roads Authority and Tramore House Regional Design Office over the last number of years. These organisations have provided and will continue to provide materials, samples, equipment and expertise in practical road management (see attached letter of support). The NRA also conducts business with a number of contractor companies in the area of road/highway surveying e.g. Pavement Management Services. It is also a longer term goal of the research to communicate with such companies with a view to real world deployment of the techniques developed. This will be achieved through demonstrations of the software technologies with the possibility of subsequent licensing agreements. Other infrastructure surveying companies and organisations (both in Ireland and abroad) would also have a direct need for the software techniques and skills developed. The passive vision based techniques for infrastructure analysis have thus far proved to robust and accurate and capable of rivalling existing methods that have been subject to constraints like road closure, precision driving and performance criticisms. The point of contact at the NRA is Mr. Conor Fitzgerald, B.Eng., Engineering Inspector, NRA, Kildress House, Pembroke Row, Dublin 2.

Plans to Disseminate Outcomes

As indicated in the Project Schedule / Timescale at least two conference submissions will be prepared on the results of the research carried out in the project. The student will have the facility to publish technical reports in the ITB Journal, currently in its 10th year of publication. This is valuable experience for a student to engage in technical writing. It also allows a stage-by-stage record of the project that will facilitate efficient completion of the final thesis. The student will be expected to give several oral presentations to the School of Informatics and Engineering at ITB. The student will present at two internationally recognized conferences. Potential conferences include:

- Irish Graduate Symposium on Vision Graphics and Visualisation (VGV)
- Irish Machine Vision and Image Processing conference (IMVIP)
- IEEE Intelligent Vehicles Symposium,
- IEEE Intelligent Transportation Systems,
- Mobile Mapping Symposium,
- British Machine Vision Conference.

In addition, the student will be encouraged to write a journal article on completion of the project. Potential journals include:

- IEEE Intelligent Transportation Systems,
- IET Intelligent Transportation Systems,
- IEEE Intelligent Vehicles,
- Computer Vision and Image Understanding.

As indicated in the facilities section, project details and results will also be hosted on the departmental research website.

Profile of Student to be Recruited

The recruited graduate should be from an Electronic Engineering/Computer Science degree course. Their degree should have been awarded with a minimum of a 2.1, or they should have a minimum award of a 2.2 and also have demonstrated at least one year related work experience in technical software development or machine vision. The recruited graduate should also have demonstrated an interest in computer interfacing, physics, robotics or computer vision, through the appropriate choice of under-graduate degree project and course options. The student should be self-motivated and enthusiastic about research.