Institution: Glyndŵr University

Unit of Assessment: 11
Computer Science and Informatics

Title of case study:
Software Integration and Visualisation for Complex Electrical Motor Design Programming, Simulation and Modelling
[11/2]

1. Summary of the impact (indicative maximum 100 words)

Research was undertaken into practical methodologies for integrating disparate engineering design software packages, including techniques for managing data in different formats and package functionality available through varying programming models. There was an emphasis on usability for end users allowing a complex solution to be built without advanced programming experience or technical understanding of the underlying packages. The results were made available through a commercial software package marketed by an SME, successfully contributing to a significant increase in company profile, modified internal working procedures and an expanded portfolio of services available to customers. The final product has only recently appeared on the market, but to good review, promising early sales and projections of significant sales and increased turnover.

2. Underpinning research (indicative maximum 500 words)

The Computing Department at Glyndŵr University has been conducting specialist research into the implementation of algorithmic principles in connected and restricted environments for around a decade **[references 1-5]**. These specialist areas include applications where processing power or storage are severely limited **[1-3]** and where requirements are complex and/or software interoperability is a particular problem **[4, 5]**. The work is led by Professor Grout, a specialist algorithmic designer.

The Computing department was awarded TSB Knowledge Transfer Partnership funding for a project (KTP 6756, 2008-2010) in collaboration with a software company, Motor Design Ltd (MDL). MDL supply software solutions across the world. The initial brief of the project was to produce a software design package for the design and analysis of electric motors. Initial research established a number of weaknesses in existing approaches to electric motor design and in the software available at the time, summarised as the following:

1. Most existing techniques for modelling, analysing and designing electric motors were highly specialised and focused on a small number of particular aspects of electric motor design, leading to sub-optimal overall performance.
2. Different aspects of electric motor design (heat distribution, magnetic field density, for example) usually required modelling in precise, and generally different, forms, with an approach to one aspect rarely being applicable to another.
3. There appeared to be no universal model for electric motor design, thought to be an unusual and highly-constrained form of multi-objective optimisation.
4. Most existing software packages (SPEED, Flux, Motor-CAD, Portunus, etc.) for electric motor design required users to have specialist technical knowledge and programming skills.
5. Even with the necessary technical skills, an experienced user would find it difficult to move from one design package to another because the different operating principles of each package.

Research focussed on identifying a unified model for electric motor design that was broad enough and flexible enough to deal with most, preferably all, aspects of the design process. (This would then be followed by the development of an appropriate software package, exploiting this "universal model", which is described in section 4 of this case study.). The research process was as follows:

i. The key packages in widespread use in motor design were identified and their methods of operation (i.e. interfaces, processes, data structures, variable conventions, scripting, etc.)

analysed,
ii. Various methods for presenting/modelling programming/script were identified and analysed, including their relative interoperability, including existing 'off-the-shelf' solutions,
iii. Recognised experts in interface design, along with potential and existing customers, were consulted,
iv. A 'core set' of shared (interoperable) functions was identified,
v. A mechanism for sharing information between these functions in different systems was developed using a common scripting tool, including transfer of data/variables,
vi. A framework was agreed to represent the composite system, and
vii. The framework was tested in prototype form

The key components of the model were:

a. The model, regarded as a framework, would be capable of drawing together the disparate requirements of individual design principles applied to different aspects of electric motor design,
b. The model, regarded as a tool, should be compatible with all commonly used existing packages for different aspects of motor design, and
c. The model, regarded as a tool, should be able to be used, so far as possible, by a user with limited technical skills and a minimal knowledge of programming.

Such a modelling technique was developed in 2008 and 2009. The model was based on a highly configurable and intuitive form of flowchart design. Although, in effect, the methodology was based on conventional structured program design, this would not be immediately apparent to someone implementing the model and indeed a knowledge of formal structured program design was not necessary in order to build working models from the tool designed **[4,5]**.

The work was supported by two KTP programmes, one 'classic' and one 'shorter':

- Motor Design Ltd. 'Software package for motor design and analysis', £99,044; Principal Investigator: Professor V Grout, 2007
- Motor Design Ltd. 'Motor Design Efficiency Map Software', £17,000; Principal Investigator: Professor V Grout, 2011

Glyndwr Computing Individuals involved:

- Lyndon Evans, KTP Associate/Research Student, Glyndŵr University
- Professor Vic Grout, Head of Computing, Glyndŵr University

Professor Peter Excell, Dean of Arts, Science & Technology, Glyndŵr University

3. References to the research (indicative maximum of six references)
Available on request if not in the public domain.

[1] Grout, V. "Principles of Cost Minimisation in Wireless Networks", *Journal of Heuristics*, Volume 11, Issue 2, April 2005, pp115-133. DOI 10.1007/s10732-005-0433-y
[2] Grout, V, Davies, J. & McGinn, J., "An Argument for Simple Embedded ACL Optimisation", *Computer Communications*, Vol. 30, No. 2, January 2007, pp280-287. DOI 10.1016/j.comcom.2006.08.024
[3] Grout, V., McGinn, J. & Davies, J.N. "Real-Time Optimisation of Access Control Lists for Efficient Internet Packet Filtering", *Journal of Heuristics*, Vol. 13, No. 5, October 2007, pp435-454. DOI 10.1007/s10732-007-9019-1
[4] Evans, L., Grout, V., Staton, D. & Hawkins, D., "Integration Methodologies for Disparate Software Packages with an Emphasis on Usability", *3rd International Conference on Internet Technologies and Applications* (*ITA 09*), Glyndwr University, Wrexham, Wales, UK, 8-11 September 2009, In: Cunningham, S., Grout, V., Houlden, N., Oram, D. & Picking, R. (eds.), Proceedings of the 3rd International Conference on Internet Technologies and Applications (ITA 09), Glyndwr University, 2009, (ISBN: 978-0-946881-65-9) (Available from http://www.glyndwr.ac.uk/computing/cards/pubs/SEIN_EGSH.pdf)
[5] Dorrell, D., Hsieh, M.., Popescu, M., Evans, L., Staton, D. & Grout, V., "A Review of the Design Issues and Techniques for Radial-Flux Brushless Surface and Internal Rare-Earth Permanent Magnet Motors", *IEEE Transactions on Industrial Electronics* (special issue on *Innovation in Electric Machines*), Vol. 58, No. 9, September 2011, pp3741-3757. (Submitted in REF2) Doi: 10.1109/TIE.2010.2089940

4. Details of the impact (indicative maximum 750 words)

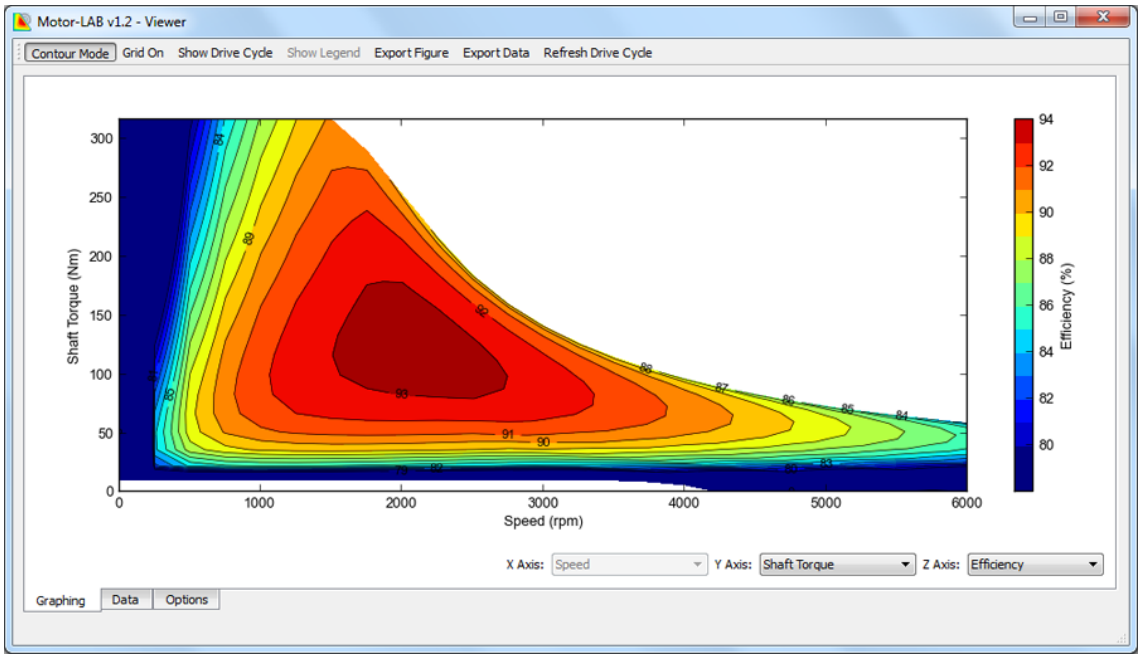
The impact arising from the research was enabled through the KTP projects referred to above. The results of the research enabled the development of a software package which could:

A. tie together a number of existing electric motor design packages within one framework, allowing each to be used to its full potential but together rather than separately.
B. so far as possible, not require detailed technical understanding (from the user) of each of the individual packages.
C. so far as possible, be intuitive in its use and not require highly developed programming skills.

A number of key features were introduced in the design of the system as an impact of the initial research. A modified flow chart structure was used at the top level, since this was known to be accessible and understood by users. When more detail was required, and number of options were provided, depending on the level of the user's technical understanding. For those with limited technical ability, a revised/expanded form of flowchart was used; for those with limited algorithmic/programming skills, common scripting was used across all integrated packages; for those technically experienced in any or all of the integrated packages, the actual syntax and operational methodologies of those packages could be embedded. The initial research showed that such an approach should be successful and indeed it was when the various prototype versions came to be tested. These principles were extended and updated through the various alpha and beta versions of the developed software.

The end product, known as "Motor-Lab", was produced in 2012 and refined for final release in 2013. The following is taken from the company's literature:

"MDL's unique combined electromagnetic and thermal modelling tool is the first of its kind in the marketplace; no other modelling tool offers equivalent functionality. Motor-LAB was developed to enable rapid and accurate modelling of any permanent magnet AC motor over the entire operational envelope. It is specifically designed to aid the design of motors for traction applications. With Motor-LAB, engineers can create efficiency maps, plot torque/speed characteristics, study the continuous and peak thermally constrained operational envelope and analyse performance over driving cycles. It is fast, easy to use and the techniques have been experimentally verified. Motor-LAB has an intuitive user interface: data is produced in a simple format that can easily be exported to Matlab, Microsoft Excel and other applications. A wide variety of graphs can be generated and a number of publication-quality output formats are supported."



Marketing and selling of Motor-LAB has only just begun but early sales are promising and the company has very high hopes for this product and has invested heavily in its marketing. Initial

reviews are excellent and significant sales, and subsequent increase in company turnover, are expected.

Alongside the financial returns from Motor-LAB has been a fundamental shift in the company's business approach. It is no longer necessary to write individual, somewhat fine-tuned, software solutions for each customer. Instead, Motor-LAB can be shipped to all customers with features relevant to them enabled/disabled as appropriate. The charging model is then applied consistently on the basis of what services are offered. This leads to a more transparent portfolio of services and better customer perception of the MDL 'catalogue'. Feedback in response to this new strategy has been excellent and the customer base is expanding rapidly. Finally, in-house training for both customers and MDL staff is also simplified and made more efficient.

In the course of the design of the universal package, a separate, specialist package was developed with a particular focus on building and analysing an efficiency map for electric motor design. The package known as "Eff-Map" was produced and marketed in 2011.

A final spin-off from the research collaboration has been the development to market of the 'FE-Therm' module within the existing Motor-CAD package. FE-Therm provides increased detail on conduction heat transfer in various components; it can be used to analyse conduction heat transfer for complex geometries such as multi-layer interior magnet motor rotors and to calibrate analytical lumped circuit models, thus improving accuracy.

These developments are significant since MDL have a number of customers and collaborative partners all over the world. They are recognised as the world-leaders in their (this) particular field of specialism. Other companies offer small parts of the MDL service in isolation but none of them can match the integrated approach to motor design that MDL can now offer. Their global influence continues to grow.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Managing Director, Motor Design Ltd

Motor Design Ltd. Website, http://www.motor-design.com/index.php

'Motor-CAD', 'Eff-Map', 'Motor-Lab' and FE_Therm software; customer reviews and other detail:

http://www.motor-design.com/motorcad.php http://www.motor-design.com/motorlab.php

http://www.motor-design.com/fetherm.php http://www.motor-design.com/testimonials.php

http://www.motor-design.com/latest.php http://www.motor-design.com/contacts.php