Institution: University of Strathclyde

Unit of Assessment: 11

Title of case study: Improved video surveillance and customer relations management through efficient data representation.

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

Research on data compression produced novel algorithms that optimise the use of bandwidth and processing power. This research has led to the establishment of a product line that applies these algorithms to video surveillance software, marketed by Digital Barriers plc. Since 2008 this compression technology has allowed the company to grow from 8 to 41 staff and increase revenue from £800K to £6M in 2013. The novelty and usefulness of the data compression research was also appreciated by ThinkAnalytics plc. This led the company to the optimal design for data compression in their recommender system, which is currently being supplied to 130M cable TV customers making the product the most deployed content recommendation system in the market.

2. Underpinning research (indicative maximum 500 words)

Context: Between 1994 and 1996, Wilson was engaged in research on novel data compression algorithms with Cockshott, McGregor and Fryer, funded by EPSRC [5]. They proposed a new approach to data systems architecture that focused on optimising bit representation of real-world entities [1,3]. Using this approach, a compressed data representation can be tailored to data manipulation requirements in different domains. The architecture was implemented in the context of database and video compression, and measurements of performance were compared to those of other high-performance systems. Speed of retrieval was increased (by one to five orders of magnitude), and the same or slightly faster performance during insertion and compression of data was achieved for database systems. At the same time, about a 10-fold compression in data volume was also recorded. To address the domain of video compression, a codebook approach was developed to minimise data transfer. This provides significantly higher quality images than JPEG at the same compression ratio [2]. The resultant architecture was thus more cost effectiveness than conventional approaches and suitable for data intensive tasks such as transmitting video over mobile networks.

Key findings*:* The fundamental finding of the research focused on the advantage to be gained by minimising the bit representation in data-intensive systems, whilst at the same time preserving sufficient organisation in the data to enable it to be processed in its compressed form without having to first decompress the entire structure.

In the context of database systems, this design principle is translated into the representation of data in minimal bit dictionaries. Each entry in the dictionary consists of a lexeme (the text to be stored in the database) and a token (an integer with the minimum number of bits needed to identify the lexeme). Thereafter the token is stored in the database in place of every occurrence of the lexeme. This exploits the redundant occurrence of text and makes the database searchable on the tokens, with only the results being translated back into lexemes. Both European (1997) and US patents (2001) were secured to protect this technology [6,7].

The same principle of minimal bit representation in the context of video compression is realised in the use of codebooks to represent an image. This approach divides an image into a pattern of smaller blocks. The blocks are then represented by a minimal bit token and it is the token that is transmitted when the image changes, rather than the complete codebook. In video images where there is little change, this process results in faster transmission since although the codebook needs to be transmitted once, subsequent movement can be displayed based on the transmission of minimal bit tokens [4]. The work was developed into a US patent in 2000 [8].

Key Researchers*:* The research was carried out in the Department of Computer Science, University of Strathclyde by: Douglas McGregor (Professor 01/03/82 – 30/04/09), Richard Fryer (Senior Lecturer 01/03/86 – 31/03/09), Paul Cockshott (Lecturer 01/04/93 – 13/02/98) and John Wilson (Lecturer 01/02/1986 - present).

3. References to the research (indicative maximum of six references)

References 1-3 best indicate the quality of this work.

[1] W.P. Cockshott, D.R.M. McGregor and J.N. Wilson (1998). High performance architectures using a compressed database architecture. Computer Journal. 41(5): 283-296. doi 10.1.1.107.4726

[2] W. P. Cockshott and R. Lambert (1999). Algorithm for hierarchical vector quantisation of video data. IEE Proceedings - Vision, Image and Signal Processing, 146(4): 222-228. doi 10.1049/ip-vis:19990443

[3] W.P.Cockshott, D.R.McGregor, N. Kotsis and J.N.Wilson, (1998). Data compression in database systems, Proc. IDEAS'98. pp.111-120, doi: 10.1109/IDEAS.1998.694365

[4] R.Lambert, R.J.Fryer, W.P.Cockshott and D.R.McGregor. (1996). Low bandwidth video compression with variable dimension vector quantisation. In Proc. ADVICE 96 doi 10.1.1.56.4560

Other evidence for quality of research

[1] Computer Journal is graded A* in the ERA journal evaluation. It ranks in the top 8% (rating 70) of Computer Science journals in Microsoft Academic Search. [2] This paper is published in a fully refereed journal with a rating of 33 in Microsoft Academic Search. [3] IDEAS is a fully refereed, B rated conference on the ERA conference ranking and is in the top 13% of database conferences as ranked by Microsoft Academic Search. [4] This is a fully refereed conference. The paper was submitted in RAE 1996.

Research funding and patents:

5. D.R.McGregor, W.P.Cockshott and J.N.Wilson. Implementation of RAM/RAID for high performance databases relational data. EPSRC GRANT GR/J92170 1994-1996, value £150,694.

6. D.R.McGregor, W.P.Cockshott, J.N.Wilson. (1997). Databases. International Patent Number WO 1997/032263.

7. D. R. McGregor, W.P. Cockshott, J.N. Wilson (2001). Databases, US Patent Number 6169990.

8. W.P.Cockshott, D.R.McGregor, R.J. Fryer, and R.B. Lambert. (2000). Data Compression. U.S. Patent 6049632.

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

Process/events from research to impact*:*

The underpinning research on data compression has been commercially adopted in two areas

1. Customer relations analysis and product recommender support (ThinkAnalytics)
2. Video surveillance (Digital Barriers)

The idea of entropy coding in which data is represented by minimal bit collections emerged from research at Strathclyde. During the process of patenting the database aspects of this work, contact was made between McGregor and Mr Tim Jones of Planning Sciences plc. and this led to the licensing of the patent by Planning Sciences. Between 1993 and 2000, Planning Sciences' technical products and know-how were successively transferred to Gentia Software plc., K.wiz Solutions and then to ThinkAnalytics Corporation. The patent was used in K.wiz (the commercial name of K.wiz Solution's main product) as the basis for internal data storage (1998). In this way, the output from research on database compression was transferred to the K.wiz product. In 2002, the K.wiz software was reorganised by ThinkAnalytics to expand its functionality. The reorganised software was influenced by implementation experience gained from the patent. The design preserved the dependence of the system on an internal data store using techniques informed by the Strathclyde data compression research programme. K.wiz was reused by ThinkAnalytics as the basis of recommender software (Think RE, Source A). This suite of programs is currently (2013) in use by ThinkAnalytics for providing consumer-directed recommendations based on patterns found within TV viewing data. The experience of implementing the compressed data store provided direction during implementation of data handling in Think RE (Source A).

In parallel with the exploitation of database research, the novel entropy coded video compression research led to the construction of a University Spin-off company, Essential Viewing Systems Ltd

in 1999. The aim of this company was to commercialise the principle that video compression can be achieved by the use of a codebook of image primitives that resides with both the encoder and decoder. Essential Viewing Systems Ltd was a successful operator in the area of video surveillance until it was taken over in 2011 by Digital Barriers plc. The video compression research at Strathclyde was used to design Essential Viewing's product and subsequently Digital Barrier's remote surveillance system called Tactical Visual Intelligence (TVI) (Source C).

1. Adoption of technology for customer relations analysis and product recommender support:
The Think RE software suite developed by ThinkAnalytics is used particularly for providing customer relations analysis and product recommender support to cable TV networks and broadcasters. In this context, it monitors usage patterns and can provide the basis for advice to consumers on optimising their experience of televised entertainment. ThinkAnalytics' recommender engine is currently (2013) the basis of the software that is offered by the company. ThinkAnalytics' Recommendation Engine is marketed directly to broadcasters and cable TV operators and has more than 50 such customers worldwide including Liberty Global, Cox Communications, BSkyB and Virgin Media. Through these intermediaries, Think RE provides a service to more than 130 million end users in over 16 countries, making ThinkAnalytics the world leader in this area and Think RE the most deployed Content Recommendations Engine in the market. (Source A confirms all claims relating to the company.)

Benefits to Customers: Customer relations analysis benefits consumers by ensuring that services that are offered to them can be closely tailored to their personal taste. Personalisation benefits such as these are not available without the software to support the analysis of large data collections. Service providers supported by Think RE report a significant increase in Video on Demand and live TV usage as a consequence of deploying the system. The software helps end-users to discover material that they would be unlikely to find on their own.

Benefits to the company: ThinkAnalytics has the largest market share for customer relations management software that supports cable TV customers (Source A). The company was nominated as provider of the Best TV Experience Enhancement in 2013 by the TV Connect Industry Awards. The ThinkAnalytics Recommendations Engine won the 2013 Best Video Discovery Service award at the Streaming Media European Readers' Choice Awards. Typical competitors include Viaccess-Orca (16 million subscribers) and TiVo (3 million subscribers) both with significantly smaller user communities than ThinkAnalytics. The Think RE engine makes possible the combination of data sources such as Video on Demand, broadcast TV, the Web, and social media to provide an improved end-user experience in the context of recommending entertainment material. Multilingual support is provided in 17 different languages. Successful deployment of Think RE enabled ThinkAnalytics to double its revenue and profit in 2012 (Source B).

2. Adoption of the technology for video surveillance: Video surveillance is an important means of observing industrial and medical processes as well as having impact on the monitoring of human behaviour. Increase in the usage of such systems presents a challenge for data transmission. The video compression developed by the University of Strathclyde spin out company Essential Viewing facilitates the sending of video images over IP networks. This makes transmission easier since such networks are widely available, and this provides the key advantage of Digital Barrier's TVI product (Source D). The compression approach is particularly suited to transmission over Wi-Fi or 3G connections in real time, providing higher quality video than would otherwise be possible. In the context of surveillance systems, the video compression approach is essential to prevent streaming from exceeding bandwidth limitations, which can result in the loss of potentially important frames. Digital Barriers has expanded its range to include new products with new capabilities and to extend their overseas sales reach.

Since 2009 Digital Barriers' has been providing hardware and software solutions into the UK, and increasingly into global markets under the brand name of TVI. The video compression concepts developed during research at Strathclyde are currently used in Digital Barrier's TVI product to support transmission of high quality video images over low-bandwidth networks.

Benefits to Customers: In marketing their data compression-based video surveillance product, Digital Barriers concentrate their commercial effort on 20 major customers including governments and big international companies. Within the UK, every police force uses the TVI products for operations including mobile traffic enforcement, community safety, driver training and dashboard cameras in patrol cars (Source C). In addition to national law enforcement agencies, the MoD are also customers and the equipment capability is viewed as world class when compared to offerings by other suppliers (Source C). There are more than 3000 end-users of TVI. This product has now been deployed in more than 40 countries across the globe, providing world class technology for law enforcement, government and military customers by supplying protective surveillance capabilities (Source C).

Benefits to the company: Essential Viewing Systems Ltd was acquired by Digital Barriers plc. for £3.4M in March 2011. Digital Barriers are a UK business created in 2009 and listed on the London Stock Exchange (Aim market) in 2010. Since 2008 the number of staff employed in this company has grown to 41. Revenues from Digital Barriers have continued to expand, growing from £1.3M in 2010, when the company first reached profitability through to £6M in the year to March 2013. The future for the business looks bright, as the reach of Digital Barriers has allowed sales to increase into an increasing number of countries with revenues set to grow further in 2013 and beyond (Source E). This growth has also been facilitated by incorporation of the video compression technology into the wider Digital Barriers' product architecture

Benefits to the local economy: In addition to the growth in the engineering aspects of Digital Barriers' enterprise, many of the back office functions for the company such as Finance, Operations and Manufacturing are being co-located within the Glasgow office, building on the capabilities already provided by the Essential Viewing Systems team and leveraging the manufacturing expertise in Scotland (Source C). All of the products are manufactured in the UK with many of these being manufactured in Scotland and utilising the expertise within the UK manufacturing base in electronics (Source C).

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

A. Statement provided by Director and Chief Technology Officer at ThinkAnalytics supports the claim that the patented database compression technology developed at Strathclyde was used as the basis of KWiz and that this experience directly informed the development of customer relations analysis software. The statement further confirms that the CRA suite forms the basis of the Recommendation Engine product, the extent of usage of this product and the consequent global dominance of ThinkAnalytics in entertainment recommendations.

B. The news release available at http://www.thinkanalytics.com/newsAndEvents/pr210813.html supports the claims that Think RE contributed to a doubling of profits at ThinkAnalytics in the year 2011-2012; the system has the largest market share in the field and that usage of entertainment material increases as a consequence of deploying the system.

C. Statement provided by Director, Advanced Technologies at Digital Barrier's supports the claims that Essential Viewing exploited the compression research programme at Strathclyde; Essential viewing was taken over by Digital Barriers; Digital Barriers are using the compression process in their current product range; the size of the customer base for Digital Barrier's products that use compression; the technical importance of video compression in Digital Barrier's product range.

D. http://www.digitalbarriers.com/tvi/ - Digital Barriers TVI products

E. http://www.digitalbarriers.com/news/company/digital-barriers-issues-trading-update/ Digital Barriers revenues and sales