Institution: The University of Edinburgh

Unit of Assessment: B11 — Computer Science and Informatics

Title of case study: Actual Analytics Ltd: automated processing of video data to reduce the use of laboratory animals in scientific research

1. Summary of the impact

Series of images from animal behaviour studies contain vast quantities of complex and highly valuable data. Extracting the value from this scientific data often requires expert annotation. This is frequently an intuitive process based on experience gained through years of training to make important decisions. Experts are rare, expensive and hard to train so the iBehave project at the University of Edinburgh (2006–2009) sought to reverse this model and deliver systems that learned to mimic expert annotation of video data. This effort resulted in a new spinout from the School of Informatics, a software company called Actual Analytics Ltd (Actual). Founded in 2010, Actual delivers innovative software solutions for behaviour analytics which use machine learning algorithms to process video data of laboratory animals to improve the accuracy of the experimental process and reduce the need to use animals in scientific research.

2. Underpinning research

The research underpinning the spinout of the new business stemmed from a long-term interest into the relationship between genes and behaviour explored by the Armstrong research group. Professor Armstrong has worked for the University of Edinburgh since his appointment in 2003. The key members of his group working with him on this research were James Heward (Research Associate, Sept 2006–Jan 2010) and Dean Baker (Research Associate, July 2003–July 2006).

In [6], Armstrong and collaborators analysed the behavioural influence of over 1000 genes in 150,000 flies in a matter of months through an innovative combination of the behavioural assays and use of informatics data handling and analysis. The first funding for work at Edinburgh in this area was a BBSRC grant “Gravitactic behaviour in *Drosophila melanogaster*” S18944 awarded to Armstrong in 2003.

Armstrong, Heward and Baker then looked at courtship behaviour, a complex social ritual normally manually assessed by experts. Rather than constructing an expert system to score the behaviour they built a system that could track the insects accurately using computer vision techniques. To this they added datasets manually annotated and through methods borrowed from machine learning inferred rules-sets that could be used to mimic expert annotation of the interacting animals. While designed originally for flies [1,2] this was identified as a generic problem in neuroscience and in drug discovery. This breakthrough was submitted for patent protection: Armstrong JD, Baker DA, Heward JA: *flyTracker*. University of Edinburgh – Patent Applications (UK and US) PCT/GB06/001113 (2006).

A market study indicated that there was considerable market need for rodent studies and collaborators and advisers were sought from industry and key neuroscience groups. These experts included Prof Seth Grant, Wellcome Trust Sanger Institute; Dr Chris Larminie, GSK; Dr Tony Hawcock, Pfizer; and Prof Ed Kravitz, Harvard University. The school appointed the services of a business development executive (BDE) to help with the development and commercialisation of the research. The research then focused on proof-of-concept studies extending the concepts from the initial breakthroughs in Drosophila to other animals (especially rodents). Systematic analyses on a genomic level required the development of new methods for studying the behaviour of laboratory animals such as rodents that is simple, low cost and statistically robust [3,4].

Research during this period, funded by Scottish Enterprise by Heward (RA), Lukins (RA) and Dewar (RA) showed that innovative application of computer vision and machine-learning technologies could be used to solve behavioural analysis problems that previously had to be scored by hand. A suite of tracking algorithms for handling a variety of animals was developed and tested in real-life applications [4,5].

3. References to the research

3.1. Publications

1. J.D. Armstrong, D.A. Baker, J.A. Heward, and T.C. Lukins. *Sex, flies and no videotape*. In Proceedings of the 5th Measuring Behavior Conference, Wageningen, NL, 2005. *http://bit.ly/14kWPZr*
2. J.A. Heward, D.A. Baker, T.C. Lukins, and J.D. Armstrong. *flyTracker: real-time analysis of insect courtship*. In Proceedings of the 5th Measuring Behavior Conference, Wageningen, NL, 2005. *http://bit.ly/1350YdD*
3. P.A. Crook, T. C. Lukins, J.A. Heward, and J.D. Armstrong. *Identifying semi-invariant features on mouse contours*. In Proceedings of the British Machine Vision Conference, Leeds, UK, 2008. *doi:10.5244/C.22.84*
4. T.C. Lukins, M.A. Dewar, P.A. Crook, J.A. Heward, A.B. Hawcock, and J.D. Armstrong. *Automatically determining active investigation in rodents using contour analysis*. In Proceedings of the 6th Measuring Behaviour Conference, Wageningen, NL, 2008. *http://bit.ly/17VFof3*
5. Sheward WJ, Naylor E, Knowles-Barley S, Armstrong JD, Brooker GA, Seckl JR, Turek FW, Holmes MC, Zee PC, Harmar AJ. (2010) Circadian control of mouse heart rate and blood pressure by the suprachiasmatic nuclei: behavioral effects are more significant than direct outputs. PLOS One Mar 22;5(3):e9783 *doi:10.1371/journal.pone.0009783*
6. Armstrong JD, Texada MJ, Munjal R, Baker DA and Beckingham KM. (2006) Gravitaxis in Drosophila melanogaster: A forward genetic screen. Genes, Brain and Behavior. 5: 222. DOI: *10.1111/j.1601-183X.2005.00154.x*

Publications [3], [5] and [6] are most indicative of the quality of the underpinning research.

3.2. Related grants and funding

- Scottish Enterprise Proof of Concept Award. *iBehave – intelligent software for behaviour analysis*. 01/06-12/09 £330k
- EPSRC Research Grant (with B. Webb). *Context dependent and multimodal learning: from insect brains to robot controllers*. Grant number *EP/F030673/1*. 04/08-03/11 £717k
- Wellcome Trust Functional Genomics Grant. *Genes 2 Cognition*. 01/03-12/09 £6.9M *http://www.genes2cognition.org*
- BBSRC Project Grant. *Gravitactic behaviour in Drosophila melanogaster*. Grant number *S18944*, 05/03–07/06 £153k

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

4.1. Automating interpretation of behavioural events in experimental studies

Modern molecular science can study entire genomes in a single experiment (tens of thousands of genes) yet behavioural research is still largely rooted in a human observer watching the animals behave, especially within social or interactive environments. The studies conducted by Professor Armstrong's group into individual annotators and experts showed that individual interpretation of behavioural events have a huge impact in experimental studies. Building on this knowledge, the researchers developed a range of tools that automate behavioural analysis and data capture [H]. These tools bridge the gap between the levels of analysis we can perform on large protein complexes to their phenotypes in integrated studies.

Furthermore, the use of computer vision and tracking algorithms can capture information that is extremely hard to obtain using any other method. These techniques are also providing new insights into behaviour. Using techniques from machine learning the research team developed a new approach to these problems where the system learns directly from experts how to recognise the behaviour under investigation. Studies in a range of animal behaviours demonstrated that the system could effectively mimic a human expert.

4.2. Commercialisation of the research

During the period funded by Scottish Enterprise, the management team took the decision to directly commercialise the research. Achieving this commercialisation required the alignment of the academic research activity with crucial business and staff development processes. Supported by the University of Edinburgh and the School of Informatics, the founding team sought the advice of directors from major pharmaceutical companies [B] and recruited business development advisers [C] for guidance. A strategic decision was taken early on to build towards a company with Armstrong focusing on the science and Heward taking the business lead. The School invested significantly in the training and development of Heward over the four years sending him on the best business training programmes available (e.g. MIT's Entrepreneurship Development Programme).

Actual Analytics Ltd. (Actual) spun out from the University in 2010. Actual obtained a license to the iBehave technology to form the basis of its first software solutions. It has raised just under £1.5 M from some of Europe's leading early-stage private investors to support initial product development and marketing activities [E,F]. The company now develops and sells software for supporting behaviour analysis and first products were distributed via a combination of Software-as-a-Service (Cloud) model, Server products and bespoke consultancy contract work [G]. In 2011, Actual negotiated a contract with the market-leading reseller (TSE-Systems) to develop a new suite of server products (PhenoTracker, figure 1) now resold by them internationally [I].

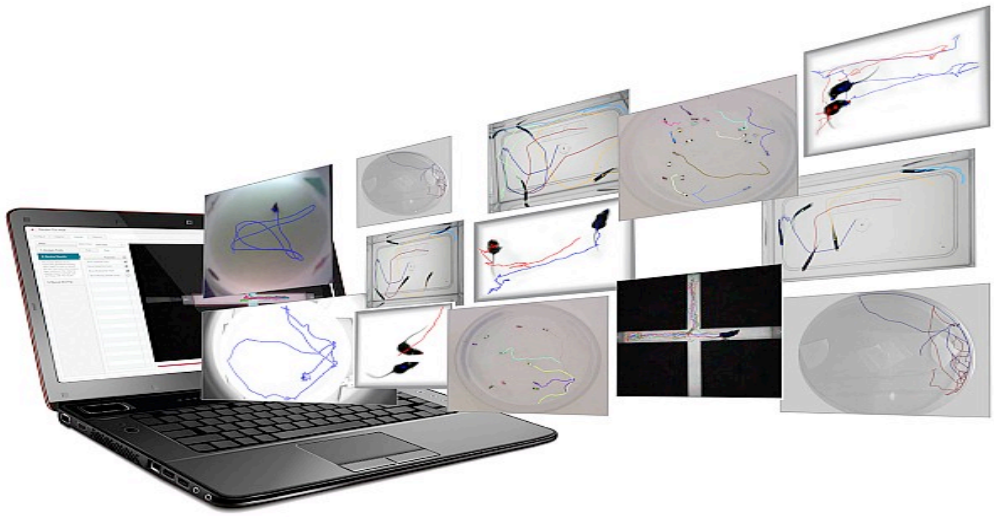

Figure 1: The PhenoTracker software developed by Actual Analytics Ltd

Within the University the original inventors recruited highly experienced commercial development staff as well as the best technical minds to translate the ideas into a viable business proposition. Actual Analytics now has ten employees in the UK (as of January 2013), providing stimulating careers for highly-skilled individuals.

4.3. Reducing the use of animals in laboratory research and the Crack-IT challenges

The UK's National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs, *http://www.nc3rs.org.uk*) funds innovative research into methods to reduce reliance on the use of animals in science across a range of animal species to accelerate the discovery of treatments across several therapeutic areas. In 2011, NC3Rs proposed the Crack-IT challenges to tackle the "scientific and business challenges that involve the use of animals" [A].

In 2012, in partnership with AstraZeneca (UK), TSE Systems (Germany) and the University of Strathclyde, Professor Armstrong and Actual Analytics won a major NC3Rs award under the Small Business Research Initiative (SBRI) framework (Crack-IT) for £500k to develop a new monitoring system for safety pharmacology in rats [D]. This project developed a highly disruptive new technology that automatically monitors animals for weeks or months in their home environment

rather than just during short artificially-controlled laboratory experiments. The benefits for both animal welfare and increased quality and quantity of experimental data are very high. The funding awarded was NC3Rs UK, SBRI, *Rodent Big Brother: The Trurat Show*, 04/12–0314, value £500k.

In late 2012, Professor Armstrong and Actual Analytics won a second award (£100k) in this area to expand its development in this area to include mice in collaboration with the largest animal facility in the UK (MRC Harwell). This programme expanded rapidly because of expressions of interest to join from other leading pharmaceutical companies. This research was funded by NC3Rs UK, SBRI, *Rodent Little Brother: A Brave New Homecage*, 12/12–06/13, value £100k.

In July 2013, Professor Armstrong and Actual Analytics won a third award (£500k) to deliver the second phase of this programme. Actual Analytics Ltd received funding to develop a mouse cage with an integrated 'big brother'-style video monitoring system, to record specific types of behaviour and allow for social interaction in mice being studied for nervous system disorders. The automated, non-surgical system improves animal welfare for this type of research since animal handling and other interventions are greatly reduced. It allows monitoring of individual mice when housed together in their natural grouping, rather than individually, producing more reliable results compared with current observational methods. This research was funded by NC3Rs UK, SBRI, *Rodent Little Brother: Measurement of mouse activity, behaviour and interaction in the home cage*, 07/13–date, value £500k.

4.4. Summary of the impact

In summary the impact is best measured by the new company, which has achieved the following:

- Raised £1.5M in investment for product development.
- Grown to employ 10 people spanning business development and research
- Successfully negotiated a contract with a world-wide sales and marketing company (largest in the sector)
- Successfully secured three major SBRI contracts totalling £1.1M to develop new products to improve animal welfare in pharmaceutical research and development.

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

A. CRACK IT, the first open innovation platform designed to support research and development which will replace, reduce and refine the use of animals (*the 3Rs*), *http://www.crackit.org.uk*
B. Director, Computational Biology, GlaxoSmithKline — acted as an independent scientific advisor on the programme prior to the spinout of Actual Analytics from the School of Informatics.
C. A serial entrepreneur, founder of six start-up companies and a former Director of the MIT Entrepreneurship Centre — acted as an independent business advisor on the programme prior to the spinout of Actual Analytics from the School of Informatics.
D. Crack-IT 2011 Challenge Competition winners *http://www.crackit.org.uk/crack/2011/challengewinners*
E. Actual Analytics Case Study | SMART/SCOTLAND | Scottish Enterprise *http://www.scottish-enterprise.com/resources/case-studies/abc/actual-analytics.aspx*
F. Actual Analytics Secures £900,000 Investment *http://www.tricapital.co.uk/content/news/TRICAP-TweedRenaissanceInvestorsCapital-News-ActualAnalytics.php*
G. Actual Analytics Launch World's First Web-Based Behavior Analysis System, *http://www.edinburghsciencetriangle.net/news.asp?id=N-10091*
H. FlyTracker video *http://www.tissue-atlas.org/dbaker2/index/flytracker.mov*
I. PhenoTracker – Modular video tracking software, *http://www.tse-systems.com/products/behavior/video-tracking-software/phenotracker/index.htm*

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