Institution: University of Reading

Unit of Assessment: 10 Mathematical Sciences

Title: of case study: Applying the mathematics of evolving networks for more effective social media marketing

1. Summary of the impact: Researchers in the Centre for the Mathematics of Human Behaviour at the University of Reading have developed a novel approach for the real-time monitoring of evolving social networks. These networks, in which connections between individuals change over time, are an important opportunity for online advertising. The research has been used in collaboration with Bloom Media Ltd to develop a new tool that gives their clients a better understanding of the impacts of social media campaigns. As a result Bloom are leading the field in this area, allowing them to attract major new clients and leading to significant growth of the business. The company now directly employs highly skilled mathematics graduates specifically to work in this area.

2. Underpinning research

Research background

Digital communications between individuals have resulted in large, multi-layered social networks that evolve from moment to moment. Although methods exist for analysing and modelling static networks, recent trends in communications, transport and energy have highlighted the need for methods that are appropriate for dynamic, evolving networks. Therefore, funded by an EPSRC Digital Economy programme through the Horizon hub, Professor Peter Grindrod collaborated with Prof Desmond Higham (University of Strathclyde) to develop a simple mathematical model of evolving networks [1], defined here as a fixed set of vertices (e.g. a group of people) with edges (e.g. peer-to-peer communication) that appear and disappear over time. The approach uses a temporal series of snapshot graphs instead of collapsing different time points on to one (denser) graph, thereby retaining both information about time-flow and the benefits of more sparse graphs.

Main contribution

The core of this work involved exploring centrality measures in evolving networks. Centrality is the relative importance of an individual (a vertex) and determines its involvement in a network. Prior to this work, centrality measures had been developed for static networks, but had not been successfully translated to evolving networks. The full technical details are given in [2] although the discussions leading to the impact were prompted by a SIAM news article [3], which was written for a wider audience.

Katz centrality computes the relative influence of a node within a static network by measuring its number of immediate neighbours and other nodes that connect to it through those immediate neighbours. An attenuation factor lessens the influence of longer pathways. The researchers built an extension of Katz centrality for evolving networks that gives communicability across time steps. When peer-to-peer communications can be observed, this allows the identification of individual strong broadcasters and listeners [4]. It can also be scaled up to very large data sets as it involves handling large but sparse matrices.

Fast algorithmic computations of centrality ranking can be achieved using sparsity and series approximation. Although for some real applications the choice of the attenuation factor can be challenging, the researchers showed that this can be solved simply by normalisation and probabilistic interpretation of the attenuation factor as a proxy for radius of centrality [5].

Further developments

The researchers are now working on a continuous version in which edges are created and destroyed continuously rather than being simply snapshots in time. Additionally, ‘memory’ is being incorporated into the centrality ranking, so that recently appearing edges are given more weight than older ones [6].

Key researchers
Peter Grindrod (Professor, 2008-Sept 2103)
Mark Parsons (PhD student 2010-July 2013; PDRA July-Oct 2013)
Danica Greetham (PDRA Nov 2010-Oct 2011; Lecturer Oct 2011-present)

3. References to the research
All references are peer-reviewed. [1],[2] and [6] are published in highly regarded international journals, [2] has since been cited in several reviews and research articles on temporal networks. [6] appeared in SIAM review with 5-year impact factor of 8. [3] is in *SIAM news*, which addresses a wide audience and is a news-journal for world-wide applied mathematics community.

[1] Grindrod, P., & Higham, D. (2010). Dynamical models, inverse problems and propagation. *Proceedings of the Royal Society, Series A*, vol. 466 no. 2115, 753-770. doi:10.1098/rspa.2009.0456
Citations on Web of Science: 12 as of 18 Sep 2013
[2] Grindrod, P., Parsons, M. C., Higham, D. & Estrada, E. (2011). Communicability across evolving networks. *Physical Review E*, 83, Issue 4 pp 046120. doi: 0.1103/PhysRevE.83.046120
Citations on Google Scholar: 41 as of 18 Sep 2013
[3] Desmond J. Higham, Peter Grindrod, and Ernesto Estrada (2011) People who read this article also read… Part I and II(SIAM) Newsletter article*, SIAM News*, Volume 44 , Numbers 1 and 2
[4] Grindrod, P., & Higham, D. (2011). Models for evolving networks: with applications in telecommunication and online activities. IMA Journal of Management Mathematics doi: 10.1093/imaman/dpr001
[5] Vukadinovic-Greetham, D., Stoyanov, Z., & Grindrod, P. (2013). Centrality and spectral radius in dynamic networks. *Computing and Combinatorics, Lecture Notes in Computer Science.* 7936, pp. 791-800. Hangzhou, China: Springer. DOI 10.1007/978-3-642-38768-5_72
[6] Grindrod, P., & Higham, D. (2013). A matrix iteration for summarizing dynamic networks. *SIAM review*, 55, 118-128. http://dx.doi.org/10.1137/110855715
1 citation on 18 Sep 2013

Relevant grant funding:

EPSRC grant EP/G065802/1 (as part of 'The Horizon Hub' led by the University of Nottingham)
PI (Reading): Peter Grindrod
Value to Reading £886,658. Period: 01/10/2009 to 31/05/2015.

EPSRC MOLTEN EP/I016031/1
PIs: Peter Grindrod and Desmond Higham (University of Strathclyde)
Title: Mathematics Of Large Technological Evolving Networks.
Value: £171,474. Period: 01/03/2011 to 28/02/2013

TSB #710104 (Awarded to Bloom Media)
PI: Peter Grindrod
Title: Digital Business Analytics for decision makers
Value: £94,000 Period: 01/12/2011 to 30/11/2012

Centre for Defence Enterprise (a part of Defence Science and Technology) DSTLX-1000059966 (Awarded to CountingLab Ltd – spin out company of the University of Reading)
PI: Peter Grindrod
Title: Applying New Thinking To Counter-Terrorism: Communicability across an Evolving Social Network – Determining the biggest influencers, risers and fallers
Value: £40,500 + VAT Period: 01/09/2011 to 12/03/2012

4. Details of the impact: The research was used in collaboration with digital media agency Bloom Media Ltd. to develop Whisper, a new data analytics tool capable of analysing social network data in real time as a framework for return on investment (RoI) measurement.

Applying the research

In 2011Bloom were looking to speed up the market research cycle and measure return on investment (RoI) for their clients, something not then possible for social media campaigns. Bloom's Head of Data Insight, Mr Peter Laflin, approached Prof Grindrod to discuss a collaborative approach for commercial development of the research [6] (which he had read about in [3], Section 3).

Initially, the researchers assisted Bloom to secure funding through the Technology Strategy Board to develop a proof of concept that communicability could be used to effectively measure social media marketing campaigns. Ultimately this led to the creation of Whisper [1], described as a world class platform for analysing Twitter and other social media data feeds and which incorporates algorithms generated by the research within its engine.

Whisper is marketed by Bloom [2] as an entirely new planning tool that allows their clients to monitor the opinions, stories, emotions and affinities of social media communities discussing topics that resonate with their clients' products or values. This is achieved using algorithms developed by the researchers that enable visualisation of the structures of these communities as they adapt in real time. This enables Bloom to assess huge data sets and identify the key influencers within these communities and allows Bloom's clients to engage efficiently with these communities in real time, giving them insight into their customers' brand affinity, mood, device use and location.

In a letter to Prof Grindrod [5], Mr Laflin describes the key role of the research: "Whisper is the world's first data analytics tool that can accurately measure the impact and RoI from social media. At the heart of Whisper is a specific implementation of your work and the measure of 'influence' is a proxy for your communicability ideas". Mr Laflin highlighted that by the end of 2013, Bloom will have invested over £200k in this work, and intend to continue investment and development in order to stay "at the cutting edge of the scientific measurement of marketing".

Impacts within Bloom

The unique insight provided by Whisper has enabled Bloom to alter their brand direction. As a result of exhibiting the technology, they have developed substantial new business opportunities, including significant growth and a range of new clients such as Anglian Home Improvements, ADT and LA Fitness[9]. Income has doubled to £2.4m and staff numbers have doubled to 60 during the financial year 2012-2013[8]. Additionally, Bloom now employs highly skilled mathematics graduates and postgraduates to develop and grow this increasingly important area. The company have also developed additional market opportunities by providing analytics services to other marketing agencies for use under their own names.

This work has significantly raised the profile of the company within the industry. For example, they have been nominated for the 2013 DADI awards and the Innovation category of the 2012 Some Comms Awards for their use of Whisper with Anglian Home Improvements [9].

Impacts on Bloom's clients

A key aim for Bloom was to provide their clients with clear evidence of RoI for social marketing activities. The tool and framework have enabled Bloom to identify the true influencers within a social network, and then use this information to plan viral content for their clients. This has enabled Bloom's clients to gain greater value from their marketing activities and an improved understanding of their customers, leading to better targeting and changes in their digital marketing approach.[11]

Raising public awareness

Graphics produced by Whisper, which show the evolving networks in a clear and simple format and demonstrate how network members interact and the relative influence of individuals, have contributed to the public understanding of social network interactions. An example was on show at the Royal Society 2013 Summer Science Exhibition and was runner up in the Infographics category of the Exhibition's image competition [7]. The exhibition attracted over 10,000 members of the public including 2,000 school students[10], with many more reached through coverage on TV, in the media and online.

Wider impacts

The benefits of the research within social media were immediately recognised, as the methods work efficiently and for large matrices. However, applications for other sectors are also being developed by the researchers, and early work with the defence sector has led to a 2011 TSB grant to develop a proof of concept.

5. Sources to corroborate the impact

1. Whisper: http://www.bloomagency.co.uk/whisper/
2. The collaboration between the researchers and Bloom Media was highlighted in an online article: http://www.thedrum.co.uk/news/2012/03/27/centre-mathematics-human-behaviour-university-reading-appoints-bloom-develop-next
3. The impact of the collaboration with Bloom has been highlighted on their website: http://www.bloomagency.co.uk/measuring-influence-at-digital-futures-2012/
4. The collaborative work has also been presented as a conference paper at SocInfo2012, 5-7 Dec 2012, Lausanne. Laflin P, *et al*. Dynamic targeting in an online social medium.
5. Letter from Head of Data Insight, Bloom Agency – available upon request.
6. http://www.bloomagency.co.uk/whisper/history/
7. Royal Society Picturing Science 2013 image competition (http://royalsociety.org/grants/picturing-science/). Runner-up: Infographics category. Image title "Twitter activity: a snapshot of tweeter-follower interactions as a conversation grows" (http://www.bloomagency.co.uk/from-data-to-art-bloom-at-the-royal-society/; image at http://www.flickr.com/photos/royalsociety/8691325239/in/set-72157633103539082/lightbox/). Competition to select outstanding images of science provided by Research Fellows. The judging criteria are visual impact of the image; public appeal of the image; and scientific story behind the image.
8. http://www.thedrum.com/news/2013/04/02/digital-agency-bloom-sees-income-grow-24m-it-doubles-staff-numbers
9. Press releases from Bloom
   http://www.bloomagency.co.uk/adt-helps-keep-home-safe-while-youre-away/
   http://www.bloomagency.co.uk/anglian-team-up-with-bloom-to-offer-one-lucky-winner-a-different-type-of-glass/
   http://www.bloomagency.co.uk/time-waits-for-no-man-as-new-new-la-fitness-begins-roll-out/
10. Figures found at the top of this page http://royalsociety.org/summer-science/proposals/
11. Press release from Very – http://www.bloomagency.co.uk/very-and-bloom-team-up-to-push-second-screening-boundaries/