Manuel Cebrian, Ph.D.

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Employment

UCSD, Dept. of Computer Science & Engineering, Assistant Research Scientist, 2011—present.

Facebook, Data Science Team, Visiting Scientist, 2011—present.

MIT, Media Laboratory, Postdoctoral Associate, 2009—2011.

Telefonica Research, Postdoctoral Associate, 2008—2009.

Brown University, Department of Computer Science, Postdoctoral Associate, 2007—2008.

Education

Ph.D. Computer Science, Autonomous University of Madrid, Spain, 2007.

B.S. Computer Science, Autonomous University of Madrid, Spain, 2003.

Honors

DARPA Shredder Challenge, Honorable Mention, Team Leader, 2009.

DARPA Network Challenge, Winner, Team Leader, 2009.

Fulbright Fellow, 2009 (Declined).

Award to the Best Doctoral Dissertation, Autonomous University of Madrid, Spain, 2007.

Papers highlighted in recent conferences:

2010 ACM International Conference on Ubiquitous Computing (nominated for best paper award).
2010 AAAI Conference on Artificial Intelligence (outstanding paper).

Selected publications

For a complete list of publications see: http://cseweb.ucsd.edu/~mcebrian

1. "Stealing reality: when criminals become data scientists (or vice versa)," Y. Altshuler, N. Aharony, Y. Elovici, A. Pentland, and M. Cebrian, *IEEE Transactions on Intelligent Systems* 26(6):22-30 (2011).
2. "Time-critical social mobilization," G. Pickard, W. Pan, I. Rahwan, M. Cebrian, R. Crane, A. Madan, and A. Pentland, *Science* 334(6055):509-512 (2011).
3. "Reflecting on the DARPA Red Balloon Challenge," J. Tang, M. Cebrian, N. Giacobe, H-W. Kim, T. Kim, and D. Wickert, , *Communications of the ACM* 54(4):78-85 (2011).

4. "Sensing the health state of a community," A. Madan, M. Cebrian, S. Moturu, K. Farrahi, and A. Pentland, *IEEE Pervasive Computing Magazine* (forthcoming).
5. "Modeling dynamical influence in human interaction," W. Pan, M. Cebrian, W. Dong, T. Kim, J. Fowler, and A. Pentland, *IEEE Signal Processing Magazine* (forthcoming).
6. "On lattice protein structure prediction revisited," I. Dotu, M. Cebrian, P. Van Hentenryck, and P. Clote, *IEEE/ACM Transactions on Computational Biology and Bioinformatics* 8(6):1620-1632 (2011).
7. "Social sensing for epidemiological behavior change," A. Madan, M. Cebrian, D. Lazer, and A. Pentland, *Proceedings of the ACM International Conference on Ubiquitous Computing*, Copenhagen, Denmark (2010).
8. "Measuring the collective potential of populations from dynamic social interaction data," M. Cebrian, M. Lahiri, N. Oliver, and A. Pentland, *IEEE Journal of Selected Topics in Signal Processing* 4(4):677-686 (2009).
9. "Detecting translations of the same text and data with common source," K. Koroutchev and M. Cebrian, *Journal of Statistical Mechanics: Theory and Experiments* P10009 (2006).
10. "Redundant modeling for the quasigroup completion problem," I. Dotu, A. del Val, and M. Cebrian, *Proceedings of the International Conference of Principles and Practice of Constraint Programming*, Kinsale, Ireland (2003).

Synergistic activities

Principal Investigator, DARPA, Grant: "Social Scientific Studies," 2011—present.

Co-Principal Investigator, US Army Research Office, Grant: "Algorithmic Modeling of Social Interactions Over Networks." 2011—present.

Software

"Crowdsourcing the DARPA Shredder Challenge," K. Benson, M. Cebrian, W. Lian, D. Ricketts, and A. Vattani, available online at http://shredder-challenge.ucsd.edu/.

"AC: An anti-plagiarism system for programming assignments,". M. Freire, N. Cebrian and E. del Rosal, available online at http://tangow.ii.uam.es/ac/.

Patents

"A Method for the Automatic Characterization of Telephone Users Interests," Enrique Frías-Martínez, Manuel Cebrian, and Moisés Pascual, registered December 2009.

Reviewer

Journals: IEEE Transactions on Pattern Analysis and Machine Intelligence, Journal of Computational Intelligence (Wiley-Blackwell), IEEE Selected Topics in Signal Processing, IEEE Multimedia.

Conferences: Ubicomp 2011, IEEE SocialCom 2011, ACM Conference on Recommender Systems 2011 and 2010, Extended Semantic Web Conference 2010, ACM Advanced Visual Interfaces 2008.

Funding agencies: Swiss National Science Foundation.

Collaborators

Collaborators and co-editors: Pentland, A. (MIT), Barabasi, L. (Northeastern U.), Lazer, D. (Harvard U.), Van Hentenryck, P. (Brown University), Clote, P. (Boston College), Lesovec, J. (Stanford University), Kirkpatrik, S. (Hebrew University of Jerusalem), Eagle, N. (MIT), Paturi, M. (UCSD), Franceschetti, M. (UCSD), Fowler, J. (UCSD), Huerta, R. (UCSD), Procaccia, A. (CMU), Moro, E. (UC3M), Rahwan, I. (Masdar Institute), Marlow, C. (Facebook), Krammer, A. (Facebook), Jennings N. (Southampton U.), Naroditskiy V. (Southampton U.), Vaquero L (HP Labs).

Graduate and Postdoctoral advisees: Lahiri, M. (University of Illinois), Krumme, K. (MIT), Pan, W. (MIT), Ricketts, D. (UCSD), Benson, K. (UCSD), Rutherford, A. (Masdar Institute).

References

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Prof. James H. Fowler
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Dr. Nuria Oliver
Telefonica Research
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Statement of Research Interests

Mobile Phone Society: Studying the Dynamics of Human Relations in the 21st Century

We are on the verge of a *computational social science*, based on massive archives of digital trace data on human behavior, combined with the power of 21st century computers. I propose a multidisciplinary, multimethod roadmap to study one of the most important of these emerging digital trace archives, call log and locational data from mobile phones. I would argue that data from mobile phones have the potential to transform my understanding of the underlying dynamics of society. This research weaves together methods from network science, which emerged from physics in the late 1990s with a focus on an analytic understanding of large scale networks, and social network analysis, a field that dates to the 1930s, where social scientists have developed powerful methods to measure, analyze, and understand the dynamics of groups, organizations, and communities.

Mobile phones have become one of the primary instruments of communication in the 21st century - with over 4 billion active subscribers today, the mobile phone represents the fastest technology adoption in human history. In mobile operator databases distributed throughout the world, there are over 5 trillion location and communication events logged annually. These data are part of a broader trend of accumulation of "digital traces" left in the wake of human activity and interpersonal communication. These digital traces have the potential to revolutionize the study of human behavior. I believe that we are in the midst of a sea change in the empirical basis of the study of human behavior comparable, for example, to the adoption of scientific sampling in the social sciences approximately sixty years ago. It is my goal to foster, encourage, and lead computer science and the social and allied sciences in this new direction. My view builds on an existing successful interdisciplinary collaboration among computer scientists, physicists, engineers, and a social scientist that has already yielded several papers in journal ranging from *Science* to *Communications of the ACM*.

I have three inter-related scientific ambitions from this type of behavioral data. The first is aimed at building a bridge between traditional social network constructs and mobile phone data through a variety of supplementary data collection efforts in which both self-report and behavioral data are captured. It is critical to build a Rosetta stone between these two sets of measures to interpret digital trace data that, after all, were not collected for research purposes. It is almost certain, for example, that mobile phone data sets offer a biased picture of interaction patterns in these respective societies, because phone use varies with age and subculture. I plan to develop a thorough survey of the relationship between mobile phone use and various socioeconomic and cultural factors. I hope that these data will provide a powerful baseline with which to adjust existing behavioral data, and to allow comparisons of behavioral data across years. I also believe that this approach provides a model for the validation of the many massive databases that are emerging around the world for scientific analysis. In short, I am seeking to build a bridge from data to meaning.

My next two goals seek to move from meaning to insight. The first will use the call log data to help unravel a striking but as yet unexplained empirical regularity—the fact that the output and creativity of cities tends to increase more than linearly with population. Analytic models previously developed suggest this may be the result of a more efficient structure emergent within social network topologies of ever-larger populations. My proposed research will allow me to examine, in detail, whether the network topologies of larger cities qualitatively differ from those of smaller cities.

An ultimate understanding of the role of human dynamics into collective creativity needs to examine the characteristics of human mobility in human agglomerations. It is important to understand human mobility not only in terms of transportation infrastructure and the movement of things that people carry with them (such as infections)—but to move from logistic and epidemiological models to empirical work on how ideas are propagated face-to-face in the real world. Mobile phone datasets offer the most comprehensive views of human movement ever assembled. While my proposed research will build on preliminary analysis suggesting there are profound regularities in human mobility, I will particularly focus on the heterogeneity in individuals' movements across multiple human agglomerations (from the small village town to the megalopolis), and try to understand how they differ to make some places more productive than others.

The implications of my research will extend across multiple disciplines and topics. I hope to provide sociologists, epidemiologists, organizational theorists, social psychologists, anthropologists, political scientists, economists and other social scientists validated tools for investigating such fundamental and varied issues as the structure of communication within communities, the flow of infectious disease through populations, and patterns of collaboration within organizations.

THE DATA

The pillars of my research are the massive data sets generated my mobile phones, and I want to give a sense of concreteness by the describing two of them obtained from phone companies in Europe and Central America. The first is from British Telecom, involving virtually every landline call as well as the majority of mobile phone calls made in the UK. The second is from a mobile phone carrier from a Central-American nation. These datasets are exemplars of the type of data that I believe should fuel the emergence of a computational social science in the 21st century. As addressed in the previous section there are challenges in going from these data, not collected for scientific purposes, to insight. It is appropriate to illustrate the scope of my vision with a summary of these data (plus some supplementary data) because these datasets are my point of departure, and because their collection preceded my conceptualization of what insights they might provide.

The UK Dataset

In collaboration with British Telecom (BT), I have a complete, anonymized record of calls going through any BT switch in the UK during a period of four weeks, in August, 2005. Because of the massive infrastructure investment due to BT's former role as the monopoly national telecommunications company, this dataset contains over 90% of the mobile phones and nearly all residential and business landlines in the UK. The full communication dataset consists of approximately 12 billion communication events involving 220 million unique phone numbers (including mobile, landline and international).

The UK data are notable for their comprehensive coverage of the population and the fact that the UK has perhaps the most extensive array of community level data (demographics, health, crime, social capital, etc.), of any country in the world (see http://www.data-archive.ac.uk/). Recent analyses, for example, have revealed a striking relationship between diversity in network structure and an aggregate measure of economic deprivation—where a network characterized by triadic closure and insularity has a powerful tendency to suffer from higher levels of deprivation ($r = 0.88$, $p<.0001$, N. Eagle, et al. (2010), "Network Diversity and Economic Development," Science 328(5981), pp. 1029-1031; and Figure 1).

Fig 1. The London area depicting the UK census Index of Multiple Deprivation overlaid with regional communication behavior. I find that communities with diverse communication patterns tend to have lower deprivation (represented from red to yellow) than the regions with more insular communication (Eagle et al.).

The Central-American dataset

Over the past three years I have been collaborating with an International mobile communication company, which has provided me access to the anonymized billing dataset of their consumer base. This dataset has some advantages and disadvantages relative to the UK dataset. The obvious disadvantage is that it is smaller (21 million customers), and, more importantly, with only approximately a 25% market penetration. This dataset has some significant advantages, however. First, it covers a much longer period—almost 2 years, to date. Second, the dataset contains the time and coordinates of the phone tower routing the communication for each phone

call and text message sent or received by over 21 million customers, summarizing over two years of activity. These data allow me to reconstruct the daily trajectory of each mobile phone user for the observed period. The dataset has two notable limitations: (a) the user location is known only with the resolution of the mobile phone towers, resulting in approximately a 0.5 km uncertainty in cities, and 1-3 km uncertainty elsewhere. (b) The location is recorded only when the customer uses the phone, so I have no knowledge of the user's whereabouts between these active sessions. Despite these limitations, these data offer one of the most extensive empirical records of human mobility in existence. For example, in Fig. 2, I show the trajectories of two users in my database across the H1N1 pandemic alerts, illustrating the nature of the mobility patterns that can be extracted from the dataset. Note that the trajectories are time resolved, i.e. we know the time when the user can be found in the vicinity of a specific tower.

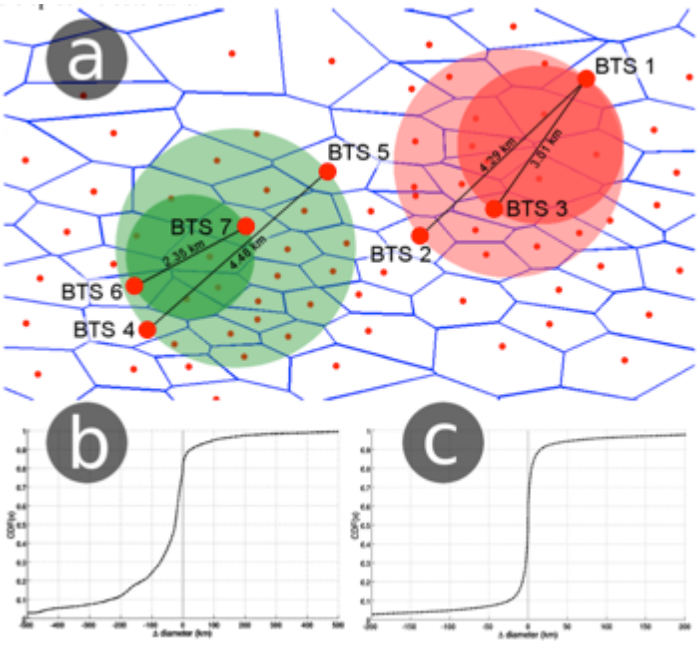

Fig. 2: **User Trajectories:** (a) Example of the change in diameter of two individuals. Red dots represent BTSs and their coverage is approximated using Voronoi diagrams. The diameter baselines of the two individuals are 4.29km (defined by BTS1-BTS2) and 4.48km (BTS4-BTS5). During one of the H1N1 epidemic alert periods, their diameters are reduced to 3.01km (BTS1- BTS3) and 2.35km (BTS6-BTS7); (b) CDF of the change in diameter of individual mobility on April 27th, where 80% of the population reduces its diameter, 50% by more than 20 km, and only 10% increases its diameter by more that 20km; (c) CDF of the change in diameter of individual mobility on May 1st, where less than 10% of the population increases its diameter by more that 20km.

As with the UK dataset, I have detailed data at the community level on demographics and basic economic indicators (although not quite as comprehensive).

For the mobility analyses I supplement the Central-American dataset with a second dataset (SmallScale) from this carrier, from 1000 users, who subscribe to a location-based service that assisted with commuting that required the company to record their detailed location at every two hours during a two week period. The SmallScale dataset will allow me to evaluate whether my analyses on the Central-American data are robust to a different (and superior) sampling scheme.

MIT datasets

I will also complement my analysis with two other datasets, tiny by comparison, but with far deeper information on each person. In the first, I examine data collected by Eagle and Pentland, in which 100 users were given free Nokia 6600 smart phones that captured their physical location and proximity to other users. In addition, standard self-report network data were collected on friendship. These data yielded the Eagle, Pentland, Lazer paper ("Inferring Social Network Structure using Mobile Phone Data," Proceedings of the National Academy of Sciences (PNAS) 106(36), pp. 15274-15278) that examined the relationship between friendship and behavior.

In the second, about 80 students in a closed community (a dormitory) were given free smartphones. These smartphones also collected locational and proximity data, as in the first MIT data set. Further, participants received a far more extensive array of surveys on their relationships with other participants, physical and mental health, and a variety of health related behaviors (diet, smoking, exercise).

These data sets will allow me to explore some of the findings from the larger data sets (the focus of this proposal), with far less statistical power, but in a much more homogeneous population with far deeper information about each person.

Other potential datasets

Finally, I expect to gain access to other datasets relevant to the proposed work. For example, I am currently negotiating access to a dataset capturing the mobility of approximately 50,000 users in a major European city, recorded every five seconds for several months. I am also collaborating with researchers who have access to data similar to my Central-American data in seven countries, which would allow me to eventually uncover truly robust patterns of human behavior.

INTELECTUAL MERITS AND BROADER IMPACT

Generally, the streams of digital breadcrumbs about human behavior must have enormous potential to improve my understanding of individuals and societies. However, these massive data sets were not designed for research, and thus capture confounding bits of information in those data streams. I propose a series of analyses that should allow us to discern the signals in the cacophony of the mobile phone data. I hope to understand, at the community level, the network antecedents to human creativity. I will use these data to build a fundamental understanding of how human mobility affects innovation. In short, this research moves me, first, from data to meaning, and then from meaning to understanding.

These digital traces have significant potential for positive impacts on society. I will investigate the foundations of collective human creativity. An improved understanding may point the way to interventions in my cities and societies to foster economic development. I will also investigate the dynamics of human movement. A better understanding of human movement may elucidate the spread of innovations and suggest strategies for designing smarter cities.

Statement of Teaching Interests

More than anything else, a desire to teach at the collegiate level motivated my pursuit of a PhD. This passion ignited in only my second term on a college campus, when I was offered a position as a recitation instructor for Scientific Computing, at Autonomous University of Madrid. That initial experience was so addictive that I continued to serve as a recitation instructor or teaching assistant each term for the remainder of my four years at the University, including five different classes over the course of eleven academic terms. My years as a graduate student have been tightly focused on research activities, yet I taught two additional courses, one as a recitation instructor and the last as a full-fledged instructor, along side several professors. In total, these seven different courses span the entire range from freshman-year introductory courses to the advanced graduate level.

Regardless of the level or subject matter, my teaching is driven by a quest to impart intuition and inspire curiosity. Facts and methods learned by rote are likely soon forgotten, but the seeds of interest, once planted, often sprout anew. During my four years of teaching at Autonomous University of Madrid, I had the opportunity to teach several students multiple times as they proceeded through the curriculum. I found a great sense of satisfaction in watching students who I taught in the first introductory course succeed at progressively higher and higher levels. Just recently, I chanced upon a student whom I recalled having considerable difficulty in my Computer Simulation class as he searched for direction in his studies. Now seven years later, he informed me that he had not only successfully graduated with a degree in Computer Science, but was employed as a software engineer at Google. The joy the news brought me reaffirmed my belief that I have chosen the right vocation.

My broad academic background equips me to teach a range of undergraduate courses, from my core expertise in statistics and scientific computing to more distant topics such as computer simulation, evolutionary dynamics, or behavioral game-theory. I take pride in my ability to make complex material accessible at many levels. I strive to frame lectures around intuitive explanations backed by concrete examples. Examples, whenever possible, are reinforced with illustrative problems. I try to craft exam and homework problems that not only reinforce material covered in lecture, but also are learning experiences in themselves.

At the graduate level, I look forward to teaching topics directly related to my research, such as computational social science and network theory. It is my firm belief that graduate courses in computer systems should be project-based. Carefully crafted class projects frequently produce publishable results, and, more importantly, motivated researchers. To that end, I would be particularly excited to develop a seminar course on Data Science or Computational Social Science as a vehicle for introducing students to my areas of research.

Classroom learning is only part of the educational process. Once a student has been motivated to move beyond the classroom and into the research laboratory, the professor's role takes on an additional dimension. A student's advisor can greatly influence the success of student's graduate career, not only through straightforward means such as exposing students to interesting and topical problems, but in far more subtle, yet likely more critical ways like thoughtful selection of office-mates and project teams. My most rewarding experiences as a researcher have come from deep, collaborative immersion in a focused problem area. I believe such experiences are critical for developing a taste for promising research areas and defining crisp problems to address. I have watched as my postdoctoral advisors, Alex (Sandy) Pentland and Albert-Laszlo Barabasi, have constructed productive and thriving research groups. While the flavor and personality of the two groups differ, in my view, the groups share a similar cohesive spirit of collaborative exploration and critical self-examination fostered by careful mentoring. I look forward to continuing this tradition of collegial collaboration as I form my own research group.

The Media Laboratory

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Dear Search Committee,

I recommend Manuel Cebrian for your position in the highest possible terms. Manuel may well be the best network scientist of his generation, and he is certainly among the top few in the world.

I came to know of Manuel through my former student Nuria Oliver, who now directs network research for Telefonica. She recommended Manuel to me in the highest possible terms, and this convinced me to accept him as a post-doctoral fellow in my Laboratory.

He has been spectacular. Not only was he key in our winning the DARPA 40th Anniversary of the Internet Grand Challenge, in the one year he was in my Laboratory he has also lead fundamental research into explaining the scaling properties of cities, understanding the phenomenon of `idea cascades' in society, the role of `learning by example' in explaining the fitness of society, and has been centrally involved in research that discovered that personal financial patterns are closely related to personal mobility patterns, that social influence plays an unexpectedly small role in on-line markets, and research that has uncovered a new and extremely dangerous class of network `worm' attacks.

To give an idea of the importance of these contributions, each and every one of these research papers is being being reviewed or prepared for submission to Science, PNAS, or IEEE Themes. This is an incredible record for one year.

While I am sorry to lose Manuel, it is the nature of academic training that people move on. I look forward to having Manuel as a link between my lab and yours.

Best,
Alex `Sandy' Pentland
Toshiba Professor, MIT Media Laboratory
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December 22, 2011

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RE: Letter of Recommendation for Dr. Manuel Cebrian

Dear Search Committee,

It is my pleasure to recommend Dr. Manuel Cebrian for a faculty position at New York University. I have first met in Manuel in 2008, during a trip to Madrid, and at that time he was leading the social network research team at Telefonica Research. His position was already remarkable back then—he had quite a number of interesting results on call and mobility logs from millions of customers, working in an environment that initially was not particularly supportive for the research he was doing. The very fact that he managed to convince the management that this was of both scientific and business interest was quite remarkable. In addition to his visibility in the scientific community, his work led to patents with immediate commercial and engineering applications. His experience with large-scale telecommunication datasets, and his successful struggle to get a huge organization like Telefonica appreciate the work he did sets him apart in the field.

In the following year Dr. Cebrian applied for a postdoctoral associate position at my group. After interviewing many candidates, our panel in charge of the hiring process unanimously ranked him first. At the end Dr. Cebrian decided to join my colleague, Professor Alex Pentland at MIT, which I think was a fantastic choice for him. Yet, I have had a chance to follow closely his research since he moved to Boston. On top of this he has been collaborating closely with one of my group members, Dr. Gourab Ghoshal, on modeling collective behavior, once again giving me a window into his thinking.

One of the most impressive works Manuel was recently involved in concerns search on social networks. Dr. Cebrian led the team that solved the DARPA Network Challenge, and with them he and his colleague became media stars overnight. The Challenge explored how the Internet and social networking could be used to solve a distributed, time-critical, geo-location problem. More than 4,000 teams competed to find ten red weather balloons deployed at undisclosed locations across the continental United States. It was designed to identify how recent developments in social media and crowd-sourcing, can be used to quickly solve a challenging, distributed geo-location problem. The MIT team led by Dr. Cebrian has used his deep understanding of social networks to develop a

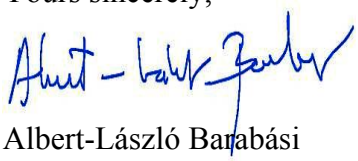
(continued)

very clever strategy to correctly identify the locations of all ten balloons in less than nine hours, with the help of an extensive group of volunteers they recruited using social networks and motivated using economic incentives. Another objective of the challenge was to compare the relative role of mass media with social media. Both the diffusion of how individuals and teams heard about the Challenge, and the solution itself provided new measures for the relative effectiveness of mass media and social media. I was so impressed by how they applied their theoretical knowledge to solve a practical problem of such magnitude that we invited them to give an invited talk about their strategy at the NetSci meeting, the most prestigious conference in network science.

Manuel is a highly creative investigator in a new research field that is increasingly called Computational Social Science. He has delivered talks at the leading computer science conferences, namely AAAI, UbiComp, WIN, IEEE SocialCom, and his work occupied four different slots in the prestigious 2010 International Network Science Conference. The diversity of his work and collaborators is truly unique.

I believe he has the potential to lead Computer Science in new and exciting directions. As a founding member of Computational Social Science community, I regard Dr. Cebrian as one of the best and most promising scientists of his generation. On the personal side, he has the best personality for an independent career--- inquisitive, curious, pragmatic, nice, cheerful, and someone everyone from students to colleagues would love. I whole-heartedly recommend Dr. Cebrian for this faculty position.

Yours sincerely,



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December 16, 2011

Dear Colleagues:

I am very happy to recommend **Manuel Cebrian** for employment at your institution. Manuel is currently a research scientist in the Computer Science Department here at the University of California, San Diego.

Manuel recently started working with me on several collaborations to use massive/passive sources of data to make inferences about human behavior and social processes. In one of these we developed a new method for detecting influence in high frequency dynamic data. In another, we are using data from extremist forums that produce terrorists to infer the strategies these groups use to avoid detection and server attacks (and, as a result, the implications for their ability to produce terrorists and support terrorism).

Manuel is probably most well known for leading the team that won the DARPA balloon contest. He also recently nearly won the DARPA shredder challenge, and would have if his servers had not been persistently attacked by the team that ended up winning. He has realized that the best solutions to these large scale problems rely on a combination of technological platforms, economic incentives, and crowdsourcing.

Manuel is creative, energetic, highly intelligent, hypersocial, and a natural leader. It has been a real pleasure to work with him. He is also one of the rising stars in the field of computational social science. His commitment to interdisciplinary work is perhaps even more extreme than mine, and I am constantly amazed at the range of new projects he is always taking on.

In sum, I offer Manuel to you with my highest recommendation.

Sincerely,

James H. Fowler
Professor of Medical Genetics and Political Science
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