Information Transmission Through Human Informants: Simulation[1]

Gabriel C. Lawson[24] and Carter T. Butts[235]

[2] Institute for Mathematical Behavioral Sciences, University of California, Irvine
[3] Department of Sociology, University of California, Irvine
[4] glawson@uci.edu
[5] buttsc@uci.edu

Abstract

Although there is a large body of work concerned with information moving from person to person via "word of mouth" mechanisms, mathematical modeling of message content per se continues to be underdeveloped. Such models are of particular concern in the area of crisis response, wherein the need for accurate situation assessment based on informant reports motivates detailed modeling of information transmission among persons at an incident site. As a first step towards the modeling of information transmission in crisis contexts, we introduce a simple model based on prior findings from the literature on rumor propagation and informant accuracy. This model is calibrated using data from Allport and Postman's (1947) famous information transmission study, and various implications of the model for the fidelity of information transmission are explored.

1. Prior Findings

1.1 Information Transmission Within Social Networks

While the notion that information and influence diffuse across personal ties goes back at least to Moreno (1951), most formal models of such processes are of more recent vintage. While the population of models is diverse, one may (arguably) divide the majority on substantive grounds into models of interpersonal attitudinal influence (e.g., Friedkin and Johnsen, 1990; Friedkin and Cook, 1991; Friedkin 1998), behavioral adoption (e.g., Latane, 1996; Latane et al., 1994; Granovetter, 1978; Macy, 1991; Valente, 1995), and information propagation (e.g., Carley, 1991; Butts, 1998). The first of these categories includes models which are intended to capture the adjustment of attitudes based on interpersonal influences, the linear updating model of Friedkin and Johnson (1990) being the preeminent example. The second category consists of various models which seek to represent the adoption of a particular behavior (e.g., to employ a technology, contribute to a public good, etc.) based on the behaviors of other network members. While not complete formal models, the sideways-looking arguments of Burt (1987) and Coleman et al. (1957) are clearly of this type. Finally, the third category of models includes those which explicitly model the flow of information through a social network, as distinct from attitudes or adoption behaviors. It is this last category which is of most immediate significance, as we are here concerned with communication of factual information rather than attitudes or the like.

1.2 Rumor Studies

Allport and Postman (1947) provide what is perhaps the most comprehensive study of verbal messages moving from actor to actor ever implemented. In one of their more famous experiments, each subject was shown a picture depicting a complex scene, and was asked to describe this picture to another subject. This subject, in turn, would attempt to describe the picture to a third subject, and so forth. Like the so-called "telephone game," this design allowed for the detailed tracking of message content for chains of up to ten people. Allport and Postman recorded subjects' descriptions at each step of the chain, and examined how

[1]This material is based upon work supported by the National Science Foundation under award NSF ITR #0331707.

these changed as the chain progressed. Although a detailed quantitative analysis was not reported, Allport and Postman reported their experiments as showing that initially long lists of details quickly shortened to a few key concepts, which persist relatively unchanged. For the short chains which they studied, some original details were never completely obliterated.

A more recent study, tracing rumors regarding an explosion through the Canadian town of North Bay, Ontario (Dalyrmple, 1978), is closer to the crisis response context than the controlled laboratory work of Allport and Postman, and has a number of relevant findings. Dalyrmple's data, collected from 168 individuals randomly selected from a local phone book one day after the explosion, offers an example of reasonably systematic data acquisition following a crisis event which would be hard to reproduce in a laboratory setting (namely the explosion of a downtown office building). Her results match up interestingly with those of Allport and Postman, as all of the message passing chains which she was able to trace back to an original eyewitness were of length less than eight. The basic fact of the explosion itself did survive in a recognizable form through these chains, and so is consistent with their work. Also, she found that these short chains spread news very quickly when a relatively large percentage of the population actually witnesses the initial event.

Interestingly, conflicting results have been found, although often coming from less controlled studies; these studies have focused on the wildly inaccurate information that people often associate with the term "rumor". Buckner (1965) suggests a compromise position, advancing the notion that information transmission behavior changes depending on whether someone is an expert in the subject discussed in a rumor, whether the person is calm or not, and whether or not the person has been told to repeat the rumor word for word to the best of their ability. Only people who are calm and told to repeat what they are told will give results similar to Allport and Postman's study. Redundant networks, or groups of people, tend to strengthen the effects of the state of the individual actor just described, relative to simple chains of actors.

While the studies mentioned above, especially Dalyrmple, 1978, do touch directly on the situation which is to be modeled, no mathematically precise model seems to have been constructed for it. Here, we integrate the findings of these studies with a model of information diffusion through interpersonal networks.

2. Modeling of Communicative Behavior During Crisis Situations

We focus on models of communication which can be represented as discrete exponential families of distributions (Barndorff-Nielsen, 1978); i.e., families of the general form

$$p(x)=\delta_{\mathrm{X}}(x)\frac{\exp\left(\theta^T s(x)\right)}{\sum_{x'\in\mathrm{X}}\exp\left(\theta^T s(x')\right)}$$

where x is a finite, discrete vector, X is the discrete support of x (with indicator function δ^{X}), s is a vector of real-valued functions on X, and θ is real-valued parameter vector.

To form the simple communication model, we posit that the testimony of an actor regarding a crisis event is the result of a combination of evidentiary weights regarding incoming information (exposures) and baseline frequencies associated with particular assertions. In particular, a given assertion should be more likely to be included in testimony after an actor is exposed to it than otherwise, and assertions which have higher baseline frequencies are more likely to made than those with lower frequencies. A simple exponential family model incorporating both assumptions is as follows:

$$p(v|e,\beta,\gamma)=\prod_{i=1}^{N}\frac{\exp\left(\gamma_i v_i+\beta_i e_i v_i\right)}{1+\exp\left(\gamma_i+\beta_i e_i\right)}$$

where e is a binary exposure vector, β is a real-valued vector of evidentiary weights, and γ is a real-valued vector of base reporting parameters. We assume that the e vector for initial eyewitnesses is determined by the environment (i.e., the crisis event), with the testimony vector v for each such actor becoming the respective e for his or her alters. Consistent with reports of high levels of information transmission in the context of crisis events, we assume that all actors within the network communicate with all other actors at each (discrete) time step. It can be shown from the above that β can be interpreted as a vector of log odds multipliers associated with the incoming assertions, and that γ plays the role of a “prior" distribution on v. γ can likewise be interpreted as containing the logits of the baseline probabilities for the elements of v; more broadly, γ can be thought of as parameterizing the probability of all items in v, in the absence of an incoming exposure vector. This separation implies that inference may be conducted on γ directly by examining accounts which are produced in the absence of exposure (e.g., testimony elicited as a hypothetical scenario using think-aloud protocols (Connolly and Wantman, 1964)).

To gain insight into the behavior of the information diffusion model, we begin by exploring the minimal possible form, in which v is a single-bit signal. Simulations run under this constraint with groups of varying size show behavior which is highly dependent on the values of γ and β. Figure 1 is typical of the results. One can readily see that the fact will be more likely to be reported if more informants have witnessed the fact, but the difference is depressingly subtle, from the point of view of an emergency responder. Said responder, with her three informants, will be unable to tell whether the fact is signal or noise.

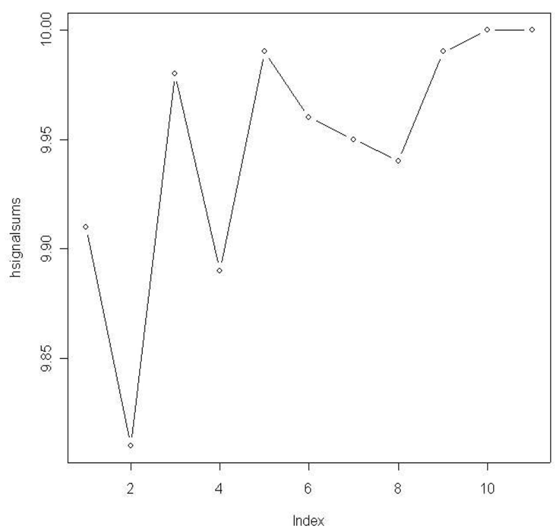

Figure 1: Number of informants reporting a fact as a function of increasing original witnesses to the same fact.

Variations of this simple-case model have also been explored. In particular, the published results of Allport and Postman, 1947 have been coded into vectors compatible with these models. This data has been used to calibrate the diffusion model for scenarios involving multiple simultaneous facts. Diffusion patterns then depend on the interaction of the initial stimulus with the base frequency and evidentiary weights; as a general rule, facts with low base rates are more likely to be lost, especially if they have low evidentiary weights as well. High base rates contribute to the generation of spurious reports, although accumulation of low-frequency errors across actors is another important factor. Network structure also affects information diffusion, suggesting that extensions of the Allport and Postman studies using more complex social structures would be useful in evaluating model behavior.

3. References

Allport, G.W. and Postman, L. 1947. The Psychology of Rumor. New York: Henry Holt.

Barndorff-Nielsen, O. 1978. Information and Exponential Families in Statistical Theory. New York: John

Wiley and Sons.
Batchelder, W.H. and Romney, A. K. 1988. "Test Theory Without an Answer Key." Psychometrika, 53 (1), 71-92.
Bernard, H.R.; Killworth, P.; Kronenfeld, D.; Sailer, L. 1984. "The Problem of Informant Accuracy: The Validity of Retrospective Data." Annual Review of Anthropology, 13, 495-517.
Buckner, H.T. 1965. "A Theory of Rumor Transmission." Public Opinion Quarterly 29:54-70
Burt, R.S. 1987. "Social Contagion and Innovation: Cohesion Versus Structural
Equivalence." American Journal of Sociology, 92, 1287-1335.
Butts, C. T. 2003. "Network Inference, Error, and Informant (In)Accuracy: A Bayesian Approach." Social Networks, 25(2), 103-140.
Caplow, T. 1947. "Rumors in War." Social Forces 25: 298-302.
Carley, K.M. 1991. "A Theory of Group Stability." American Sociological Review, 56(3), 331-354.
Coleman, J.S.; Katz, E.; and Menzel, H. 1957. "The Diffusion of an Innovation Among Physicians." Sociometry, 20, 253-270.
Connolly, J.A. and Wantman, M.J. 1964. "An Exploration of Oral Reasoning Processes in Responding to Objective Test Items." Journal of Educational Measurement, 1(1), 59-64.
Dalrymple, Christina Ford 1978. "The flow of crisis information as a probe of work relations." Cahiers Canadiens de Sociologie 3: 71-88
Freeman, L.C., Romney, A. K., Freeman, S.C. 1987. "Cognitive Structure and Informant Accuracy." American Anthropologist, 89(2), 310-325.
Friedkin, N.E. 1998. A Structural Theory of Social Influence. Cambridge: Cambridge University Press.
Friedkin, N.E. and Cook, K.S. 1991. "Peer Group Influence." Sociological Methods and Research, 19, 122-143.
Friedkin, N.E. and Johnsen, E.C. 1990. "Social Influence and Opinions." Journal of Mathematical Sociology, 15, 193-206.
Granovetter, M. 1978. "Threshold Models of Collective Behavior." American Journal of Sociology, 83, 1420-1443.
Latane, B. 1996. "Dynamic Social Impact: The Creation of Culture by Communication." Journal of Communication, 46(4), 13-25.
Latane, B.; Nowak, A.; and Liu, J.H. 1994. "Measuring Emergent Social Phenomena: Dynamism, Polarization, and Clustering as Order Parameters of Social Systems." Behavioral Science, 39, 1-24.
Macy, M. 1991. "Chains of Cooperation: Threshold Effects in Collective Action." American Sociological Review, 56, 730-747.
Moreno, J.L. 1951. Sociometry, Experimental Method and the Science of Society. An Approach to a New Political Orientation. Beacon, NY: Beacon House.
Sinha, D. 1952. "Behavior in a Catastrophic Situation: a Psychological Study of Reports and Rumors." British Journal of Psychology, 43, 200-209
Prasad, J 1935. "The psycholgy of rumor: a study relating to the great Indian earthquake of 1934." British Journal of Psychology, 16, 1-15.
Prince, Samuel H. 1920. Catastrophe and social change. New York: Columbia University Press.
Shibutani, T. 1966. Improvised News: A Sociological Study of Rumor. Indianapolis: Bobbs Merril.
Valente, T.W. 1995. Network Models of the Diffusion of Innovations. Cresskill, NJ: Hampton Press.