

Information Technology and the Topologies of Transmission: a Research Area for Historical Simulation

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Abstract—This paper surveys possibilities for applying the methods of agent-based simulation to the study of historical transitions in communication technology.

INTRODUCTION

HISTORY, in one sense, begins with the invention and adoption of a particular information technology: writing. Initially appearing in Mesopotamia some 5,000 years ago, it has spread (mainly by diffusion, but with some probable cases of independent invention) to cover effectively the whole world. Other key communication technologies have done the same. How does the adoption of such technologies alter social dynamics? How do they interact with economic and political structures, with other technologies, and with the human relationship with the non-human environment? Are there any general principles that can be extracted from the many historical examples available? How can simulation, and in particular agent-based modeling, contribute to advancing understanding in this area of research?

I. COMMUNICATION TECHNOLOGIES BEFORE WRITING

The earliest communication technologies, in the broadest sense, date from perhaps as much as 250,000 in the form of use of pigments and personal ornamentation [1] that may have been used to convey information about social status; or even as much as 700,000 years if the speculation in [2] that some Late Acheulean hand-axes were prestige objects rather than practical tools, is correct. If we regard the modification of natural objects to communicate status information as communication technology, of course, it is not unique to human beings – bower birds provide an obvious non-human example. There have been many agent-based models of the effects of reputation, often with intended practical application in on-line marketplaces [3], and some of the role of cultural markers in social interactions [4], but the role of prestige objects does not appear to have been explored. Abstract models of the dynamics of small-scale societies in which such objects play a role should be easy to design. Prestige objects must be comparatively rare, and easily recognized, so their effect on social contacts of the owner could be graded both by their

sensory qualities, and by how often similar objects have been seen. They can be acquired in three ways: by being found, perhaps with subsequent modification, traded (within or out-with the social group), or stolen; and all these methods could be included in a fairly simple model. Possession of such objects could increase the probability that other individuals will cooperate with the owner – but also the possibility that they will attack the owner to acquire the object. Outcomes of such models (the distribution of prestige objects, peaceful or violent transfers of possession, survival of their possessors, effects on trade between groups) could be compared with archaeological and anthropological findings.

Another very early form of communication technology may have been the use of waymarkers, allowing members of a social group to lay a trail for fellow-members to follow, although small-scale markers are unlikely to last long, while it is difficult to be certain whether more permanent environmental modifications, such as cairns and standing stones, were used in this way. In both these cases, agent-based models could be used to elucidate what effects the technologies could have had on social groups, and hence, possibly, to suggest what archaeologists and anthropologists should look for, or whether their interpretation of the function what has already been found is plausible. Many nonliterate cultures have produced maps and other navigational teaching aids [5], [6], although incorporating these into agent-based models would seem to demand agents of considerable cognitive sophistication.

II. WRITING

Writing is the first communication technology generally agreed to have had radical effects on social organization. Although some states of significant size, such as Great Zimbabwe [7] appear to have managed without writing, or even any record-keeping system able to fulfill some of the same purposes such as the knotted string records of the Incas (“quipu”) and other native American and Pacific societies [8], this is certainly unusual and may require special conditions (in the case of Great Zimbabwe, control of a rich source of gold). The oldest known writing system, in 4th millennium BCE Sumeria, seems to have arisen from the accounting and administrative needs produced by increasing socio-political complexity [8], [9].

Reference [10] argues that innovations in linguistic communication technologies, beginning with writing, and changes in the breadth of access to such technologies, are an important factor in determining how hierarchical and authoritarian societies are. When first invented, [10] suggests that writing greatly increased the power of rulers, along with a small scribal caste; but as forms of writing were developed that made literacy easier to achieve, culminating in alphabetic scripts, the result was the emergence of the first democracies, in classical Greece. One might question both the extent of ancient Greek democracy, which excluded women and rested on the extreme exploitation of a large slave class, and the importance of increasing literacy (the proportion of literate individuals is in any case difficult to determine) relative to changes in military technology which underpinned a “citizen army”, and indeed to the very presence of a slave class, which allowed citizens to gather in the city to pursue drama, philosophy and politics while the slaves tilled the land [11] and mined the silver which made Athens rich; and [12] (p.165) denies that there is any connection between alphabetic scripts and democracy, noting that while such scripts may aid the development of widespread literacy they are not essential to it, and that the latter is quite compatible with a lack of democracy.

This controversy might be illuminated by agent-based modeling, without requiring the detailed simulation of communication in different writing systems, by examining the effect of changing the costs of acquiring the ability to “read” and “write” messages on differences in inequalities in “wealth” and “influence”. However, such a project would require modeling societies of considerable complexity, probably involving thousands of agents, demographic processes, an agricultural economy (capable of generating a surplus sufficient to support non-agriculturalists), an elite exercising coercion (using specialist enforcer agents) to extract that surplus, craft-workers, trade in everyday and prestige goods, and conflict between neighbouring polities.

Assuming that such a model can be designed and implemented satisfactorily, we can list some requirements needed to incorporate the invention of writing and its possible effects. Even the attempt to do so raises interesting issues.

- Modeling writing requires specifying a set of messages – presumably recording which households or villages have and have not paid their taxes – and how much they are required to pay. This raises the question of how, without such a system, preliterate rulers organized tax collection, as opposed to simple looting, which risks missing some targets and taking so much from others that they starve and hence can produce no more. Possibly such rulers operated by giving each taxpayer (village or household) a “receipt” of some kind – so this could be modeled as a stage on the way to writing.
- Even once tax records of amounts paid were kept, rulers would need to associate each taxpayer with a

payment record. This would require some unique token to be associated both with the taxpayer and the payment record. Historically, this has been done with personal seals, or with a “split-tally”: a broad, flat stick, marked with notches to indicate an amount paid, then broken across the notches, with payer and receiver each keeping half; because of the irregular break, payers could identify themselves as such. The model would not, of course, need to specify the exact method used.

- A model of the effects of writing would also require a distinction between literate and illiterate individuals. In the simplest case, all those (or all males?) born into literate households would become literate.
- Initially, literacy would be restricted to members of the elite. However, if the size of the elite was limited (absolutely or in relation to total population), then the model would need to incorporate recruitment to the elite when there were spare places – and expulsion from the elite when too numerous.

If literate parents had some chance of passing on their literacy, there might emerge a significant non-elite but literate population. This still does not suggest any specific mechanism for increased literacy to reduce hierarchy as suggested by [10]. That might require a more general model of social change. But it seems feasible that the literate might be able to access additional sources of income – acting as scribes to send messages to contacts in other villages, or as traders, who also need to keep records once their activities grow beyond a certain scale. So this does suggest the possible growth of a “middle class”, which might then be able to wring concessions from the elite, perhaps in alliance with the masses.

III. PREINDUSTRIAL DISTANCE COMMUNICATION

In non-literate societies without some substitute for writing such as knotted string records [8], communication can only occur when communicator and receiver are in the same place at the same time, with the exception of waymarking and other forms of environmental modification, and of more limited forms of message-passing such as signal beacons, which can convey a simple message specified in advance. A partial exception is provided by the “talking drums” of west Africa [12], [13], which were used to convey messages of some complexity over distances of several kilometers, although requiring considerable redundancy, and being dependent on the tonal nature of local languages. Drums producing two distinct tones reproduced the tonal aspects of phonemes – and only those. To overcome the resulting ambiguity, both standardized phrases, and repetition and elaboration of the message in different words could be used. In effect, messages were sent by a whole village to all the surrounding villages; they could not be directed to a specific person or settlement. One can imagine that this system gave its users considerable advantages in summoning help, sending warnings, and arranging meetings, but whether sufficient detail of how

the drums were employed remains to inform a useful agent-based model is doubtful.

A more feasible target for modeling might be military and naval flag signaling, especially as there is a body of expertise in simulating battles as part of the computer gaming industry, and detailed records of, for example, the standard British and American naval flag signals at various times. A partial bibliography focused on the US Navy is available at [14].

It is puzzling that visual methods for conveying detailed messages rapidly across long distances, did not develop earlier than they did. Late 18th century Revolutionary France pioneered the development of the optical telegraph, a system of towers, each surmounted by two movable metal arms mounted on a rotating bar, which could be used to signal letters and numerals [15]. The idea spread to much of western Europe, but nothing about the technology should have been impossible to produce centuries or even millennia earlier, and could surely have been useful to the rulers of earlier states, which did put considerable resources into maintaining corps of royal messengers and their horses. Possibly a detailed agent-based model of the optical telegraph as it was finally developed and used would cast light on this question.

IV. PAPER, PRINTING AND PUBLIC OPINION

As [10] notes, profound changes in transmission topologies were produced by innovations building on the development of writing, including simpler writing systems (for example, alphabetic scripts), the introduction of different writing materials (notably parchment and paper) which brought down the cost of producing written materials, and movable type printing. Positive feedbacks operated between increases in the number of literate people, rising demand for texts for them to read, and reduced costs of producing them.

The movable type printing press in particular, invented by Gutenberg around 1440, has frequently been identified as a key innovation, making mass literacy possible, and setting Europe on the road to modern science and technology, and consequent global predominance. The European printing press spread rapidly - by the end of the fifteenth century there were printing presses in nearly 300 European cities [16], over a thousand in Germany alone [17].

The effects of this innovation look like an obvious target for agent-based modeling. With printing, it becomes possible for a large number of works to be accurately reproduced in large numbers, and many more individuals and groups can circulate their ideas - although they do need access to printing technology and distribution networks. Only those who are literate can be directly influenced - so they form an intermediating group between the producers of texts and the illiterate, and something reasonably described as "public opinion" can form. These changes in the topologies of transmission could be expected to have profound and widespread consequences.

However, two considerable caveats are necessary. First, Gutenberg's invention was only feasible and useful because

of a series of earlier European innovations, and imports from elsewhere: paper manufacture, from China via the Muslim world [18] and the application of water-power to reduce its cost, metallurgical discoveries that made Gutenberg's press workable, alphabetic script itself (movable type printing was first developed in 11th century China, but the techniques are different enough to make independent European invention probable [19], and the nature of Chinese script made it much more difficult to exploit), improvements in the readability of books due to the medieval schoolmen [20], and the development of universities which had already raised the demand for multiple copies of a range of texts [18]. Second, printing technology itself did not propel all societies with access to it toward modernity. Reference [21] notes that by some estimates, even by 1800 more material had been written and printed in Chinese than in all other languages together, while [22] notes that the Ottoman Empire's capital, Istanbul, acquired a printing press in 1726, but by 1815 only 63 titles had been printed there. The complex interactions between technological innovations and social processes, rather than the effects of a single "key" innovation, would therefore need to be the target of modeling.

V. ELECTRICAL NETWORKS: FROM TELEGRAPH TO INTERNET

The 1860s saw the most radical change in the speed of long-distance communication ever - and one that will never be surpassed, unless current physics is fundamentally wrong. In 1864 and 1865, the first successful intercontinental telegraph cables were laid, from Britain to India and to the USA [15]. The latter cut the time to send messages between the old and new centres of capitalist development from over a week to a few minutes. Those who made extensive use of telegraphs were always a small minority - primarily they were a tool of governments, and businesses large enough to need rapid long-distance communication. According to [10], this should have favoured an increase in hierarchy and authoritarianism, but in fact telegraphy's spread coincided with the growth of democratic and pluralist ideas and institutions in the industrializing countries building telegraph infrastructure - although also of European imperialism and militaristic nationalism, culminating in World War I. The agents in any agent-based model of the spread of the telegraph would probably need to be states or corporations, not individuals.

Between the spread of the telegraph and the advent of the Internet, there have been several waves of innovation in electrical or electromagnetic communication technologies, notably telephone, radio and television. The existing agent-based simulation work most relevant to these innovations is the extensive literature on simulations of opinion dynamics [23-25]; but this has almost all been highly abstract, dealing with a single, unspecified issue on which a population of cognitively very simple agents holds either one of two discrete opinions or a continuous range of opinions represented numerically, and often with a fixed network of contacts between agents. This abstraction has been criticized for its fail-

ure to relate to significant issues in social science [26]. A recent attempt to increase the realism of opinion dynamics simulations by modeling some features of argumentation is described in [27]; this approach is perhaps more likely than most opinion dynamics studies to be relevant to assessing the effects of historical changes in communications technology.

Reference [28] extends the usual paradigm of opinion dynamics agent-based simulations by adding either one or two “mass media” sources of opinion to the usual binary exchanges between agents, finding different regimes according to how willing the agents are to move closer to opinions different from their own, and whether there is one mass medium propagating a “central” opinion, or two propagating opposing “extreme” opinions.. There does not appear to have been significant subsequent work in this area.

Finally, the internet and social media have made many-to-many communication available to very numerous people. There is a large literature on internet social networks, but little simulation work on their broader effects: exceptions include [29], which introduces a distinction between agents who are and are not internet-connected but is otherwise a standard opinion dynamics abstract treatment; and [30], which examines the claim that the internet and related recent innovations in communications technology make organizing protest movements easier, finding that whether they do so depends on cultural and political factors.

VI. CONCLUSIONS

This extended abstract has covered a lot of ground in a rather superficial survey, the intent being to argue that there is an important set of related historical topics related to communication technologies, that form a suitable set of targets for agent-based modeling. These topics range from prehistoric small-scale societies to the twenty-first century, and together constitute a novel approach to the project of constructing a “re-unified historical social science” [31].

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