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Social networks and collective intelligence: A return to the Agora

Manuel Mazzara, Luca Biselli, Pier Paolo Greco, Antonio Marraffa,
Nafees Qamar and Simona De Nicola

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Bibliographical details

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Scalable and Responsive Event Processing in the Cloud

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About the authors

Manuel Mazzara achieved his Masters in 2002 and his PhD in 2006 at the University of Bologna. His thesis was based on Formal Methods for Web Services Composition. During 2000 he was a Technical Assistant at Computer Science Laboratories (Bologna, Italy). In 2003 he worked as Software Engineer at Microsoft (Redmond, USA). In 2004 and 2005 he worked as a freelance consultant and teacher in Italy. In 2006 he was an assistant professor at the University of Bolzano (Italy) and in 2007 a researcher and project manager at the Technical University of Vienna (Austria). Currently he is a Research Associate at the Newcastle University (UK) working on the DEPLOY project.

Luca Biselli obtained his MSc in Architectural Engineering from Turin Polytechnic, Italy. He is a registered engineer at "Ordine degli Ingegneri della Provincia di Torino", Italy as well as a freelance designer for several architectural practices in Italy. He is currently working as architectural engineer/senior designer at Sadler Brown Architecture, Newcastle upon Tyne, UK and is a Visiting tutor at Newcastle University School of Architecture, Planning and Landscape. He was involved in a number of architectural events in London and Newcastle-upon-Tyne in 2007/8. His areas of research include advanced technologies, parametric architecture, robotics, industrial design and electronics.

Pier Paolo Greco graduated as a chemical engineer in 1999 and worked in a Corporation for two years in detergents' technology. He later moved to the UK to get his Master's degree in Clean Technology/Sustainable Development. His next professional role was as Product Manager for Water Technology Chemicals, operating in Europe, Middle and Far East for 6 years before going back to Academia. Pier Paolo is currently in his 3rd year's Ph.D. at Newcastle University focusing on Micro Porous Materials.

Antonio Marraffa achieved his Masters in Linguistics and German studies in 1998 at the University of Bari (Italy). In 2007 he has obtained a Master in Computational linguistics at the University of Munich LMU. Since 2004, he works in the field of search engines: ranking algorithms, configuration and implementation for enterprise search solutions and SEO. In this area he has been working for Lycos, Fast Search & Transfer, Scout24 Holding (a Deutsche Telekom company). He also has great expertise in location based services and mobile applications. Currently he is working as a freelance consultant for online business.

Nafees Qamar has a doctorate in computing science (2011) from INRIA/LIG Grenoble, France. He now holds a Postdoctoral Fellow position at the United Nations University (UNU-IIST), Macau SAR China. His current research addresses the challenges of the security and privacy issues arising in software systems by employing innovative software engineering and formal methods concepts.

Simona de Nicola, class 1983, achieved a degree in Communication and Semiotics at Alma Mater Studiorum University of Bologna. Simona worked as a researcher in the Web, Communication and Technology Department, Bologna University on a study investigating the 'Use of Social Media in Academic Field'. At the moment she is working as a freelancer on communication, new technologies and web 2.0.

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Social networks and collective intelligence: A return to the Agora

Manuel Mazzara, UNU-IIST, Macau
and Newcastle University, UK

Luca Biselli, Independent Researcher

Pier Paolo Greco, Newcastle University, UK

Antonio Marraffa, Polidoxa.com, Germany

Nafees Qamar, UNU-IIST, Macau

Simona De Nicola, University of Bologna, Italy

Abstract

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Introduction

In the democratic city state of ancient Greece, the “agora” (from Greek: *ἄγορά*, “gathering place” or “assembly”) was the place where citizens used to meet, discuss, exchange information and make important decisions about the future of society. This was a political system based on the equality of knowledge, exchanging of information and fairness of decision making. Nowadays, the mechanism with which information is spread and communicated (and consequently how decisions are taken) has had a significant change in nature. In fact, most of the people retrieve their information from major TV stations, radio and newspapers. The weakness of this mechanism is that it is a one way information and a not equal flow; this means that citizens have lost their ability to interact with the decision making process. Consequently, the concept of “agora” is lost in favour of a different mechanism. Let us look into these aspects more in detail.

These days the average citizen gets access to information mainly by watching TV, especially the main national channels. Radio, newspapers and magazines represent a secondary source of information but they are hardly comparable to the power of TV. In particular, reading takes time and it does not well suit the frenetic life style of big cities. As a consequence, information obtained by reading books can be considered quite negligible for an adult citizen with an average level of education. Another major problem comes from the fact that the majority of the world population speaks just its native language while some information is not always accessible in that language. Furthermore, to have a complete unbiased (or at least, multi-biased) source of information, it would be quite useful to access documents coming from sources in different languages. According to the A.C. Nielsen Co., the average American

watches more than 4 hours of TV each day (or 28 hours/week, or 2 months of nonstop TV-watching per year). In a 65-year life, that person will have spent 9 years glued to TV. The percentage of Americans that regularly watch TV while eating dinner is 66%, while 49% say they simply watch too much of it (*Television Statistic*, in “The Source book for teaching science”, www.csun.edu/science/health). These numbers are very alarming and raise health concern, but we believe there is an even bigger problem behind them. Accessing information mainly or exclusively from TV, as the common experience (plus statistics) shows, is obscuring the potential of other sources of information like radio, newspapers, magazines, books, the Internet or our community of trusted contacts. These other sources are generally able to provide a much wider range of viewpoints. Indeed, we are not really able to access unbiased sources (they simply do not exist) but we could get what we call a multi-biased source, at least: a more heterogeneous set of different viewpoints which then needs human critical thinking and cognitive interpolation.

The fundamental problem with TV news is that the information streaming is simply unidirectional, i.e. there is no possibility for the audience to control the process in any way. This is clearly an opposite principle to “agora” functioning. The final result obtained from a mass media passes through many levels of organizational processing on its way to the audience and, at each step of the process, the original data is filtered – reduced in length, edited and so on. Each step in the process could be thought as a gate, through which the data must pass to reach the consumer. Consequently, this situation is known as *gatekeeping* (M. McCombs and D.Shaw, 1972. See figure 1). Gatekeeping is generally a very good and safe mechanism to ensure that an irrelevant or misleading piece of information will not be consumed by the general public. It determines a quality ensuring process and an expert evaluation similar to what happens in conferences/journals peer review system. However, there is also a potential drawback: with TV and its gatekeeping, audience is not able to give a real time feedback, and this may cause misunderstandings and lack of active interaction. Furthermore, people are not able to decide their information source or the type of content and neither to express the will to expand some topics. This means that mass media tend to set the “agenda”, i.e. the list of items that people will be discussing. This theory is known as *agenda-setting theory* (McCombs, Shaw, 1972 and McCombs, 2004) and asserts that mass media have a large influence on audiences, choosing which stories have to be considered newsworthy and how much prominence and space give them. Agenda-setting theory’s main postulate is *salience transfer (ibidem)*. Salience transfer is the ability of a mass media to transfer relevant issues from their news media agendas to public agendas. Thus, the power of the media may lie not in its ability to determine people’s opinions, but rather in its role of determining what issues will be considered important enough to discuss. Whatever is not appearing on the main media simply does not exist. This has a quite subtle consequence. The German political scientist Elisabeth Noelle-Neumann has defined an important theory called *the spiral of silence theory* (Noelle-Neumann, 1974). This theory asserts that a person is less likely to voice an opinion on a topic if he/she feels that idea belongs to a minority. This is for fear of reprisal or isolation from the majority. Thus, TV news can easily transfer this feeling to the watcher who is following the news from his home, maybe at a time of the day when the attention is not at its peak: remember that 66% of Americans regularly watch television while eating dinner and this is the time when news are usually broadcasted (McCombs, Shaw, 1972).

In some cases, the fact that information goes through gatekeeping (i.e. every journalist has to go through several levels of approval like director, editor, company shareholders before the information is released to the public) could lead to situations that are unfavourable to the final “consumer”. Consider, for example, the case in which news agencies are purchased and they

become part of a larger business, where providing information may not be the main core business or in addition they could be affected by the company's position on the Stock Market. Example of this has been the concern that Reuters' objective reporting may be affected by recent merging with Thomson Corporation, owning the 53% of the company, in contrast with the 15% limitation to share ownership historically imposed by its constitution to preserve freedom and integrity of the agency¹.

Once the gatekeeping process has been understood, its risk and limitations have to be accepted together with its advantages. Now, if we consider how the main channels and news agency are more and more centralized (like every other business), it is not difficult to realize how the whole mass media communication process has the potential to be set under control in the future, especially in some countries where the democratic process is considered weaker (Maurer and Kolbitsch, 2006).

Outline and Contributions

This paper contributes with several principles and technicalities to build a social platform to achieve collective intelligence via information sharing among trusted contacts. It also presents a Twitter-based implementation of a subset of these principles. Trust modelling, social networks, collective intelligence, algorithms and the relative motivations supported by literature in communication sciences are a quite inedited interdisciplinary blend which has not been really investigated so far. We intend to pursue our investigation and move the human knowledge further on this topic.

The paper is structured as follows: after an introduction on the problems and motivations which led to this research, an overview on traditional media, search engines and social networks is presented and a synopsis is offered. What Polidoxa is and its trust model is then detailed. Specifically, the aspect of trust is investigated under different aspects and as a function of several parameters. Privacy and security, among others, are also considered. The relevant concept of "immunity" is also investigated. Finally, a simple Twitter-based implementation is presented.

Traditional Media

The mechanisms on which traditional media (like TV, radio and newspapers) intrinsically operate, is to allow only passive actions, i.e. reading, watching and listening to specific content, according to the opinion of some expert or authority which should guarantee the quality of information. The audience here does not control the medium content, the agenda setting, and the choice of experts and commentators in charge of presenting the facts. This means that the media owner (the publisher) indirectly chooses who are the experts and controls who say what. Indeed, in a globalized world, media from different cultural, political or religious background, present quite different interpretations of facts coming from different "experts". With so many sources of information and no shared and agreed evaluation parameters to decide who is an expert and on what, citizens are left in confusion. Even when, for fairness (or in Latin "par condicio"), experts from different parts are involved in the discussion, the user has still no chance to intervene in the process. The only freedom and choice given to the audience is switching the media, or that specific channel, off. The Communication model is consequently unidirectional and it relies on three rigid rules: Gatekeeper, Speaker and audience as shown in Fig.1.

¹ <http://news.bbc.co.uk/2/hi/business/6656525.stm>

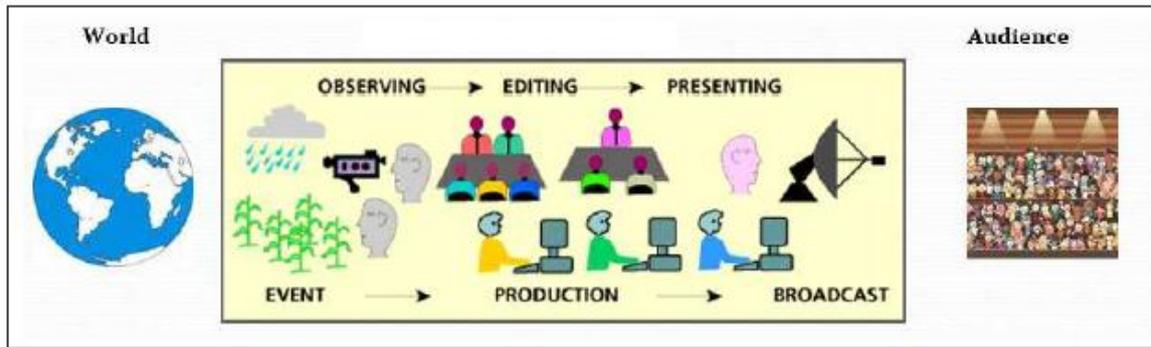


Figure 1: Gatekeeping process

Internet and Search Engines

Given the limitations of the traditional media, it is necessary a look into new media, to identify how the gap could be filled. Since Internet offers an open platform to exchange information and can be considered a paradigm shift similar to the one that was brought by the Gutenberg's invention of mechanized press, it seems to be an obvious target for this research.

With the arrival of Internet, the limitations of traditional media (i.e. offering only the passive actions, of reading, watching and listening) can be surpassed. It is indeed possible for users to control the information they achieved, to choose the content to read and how interact with other users or bloggers. It is also possible to choose the timing for accessing the information. As said, people tend to watch the news while dining and this is certainly one of the weakest times for a critical thinking. Internet has the full potential to invert (or at least minimize) the process, avoiding the agenda-setting theory issues or the spiral of silence condition. However, to exploit this potential, users need some know-how: given the limited control on the information on the Web, it is possible to find very good pieces of so-called "alternative journalisms" as well as any kind of hoax.

Internet is not a passive media like TV: users are expected to be active and critical thinking is stimulated. However, users have to be educated to use the media. The potential of Internet could be seriously reduced in the future, if focal nodes will be set under control with the same gatekeeping process discussed for the traditional media. Again, also in this case gatekeeping is good to ensure quality but it limits feedback process and critical thinking. We always find pros and cons. At the best of our empirical knowledge, search engines like Google or social networks like Facebook are, for most users, the starting point of the majority of their research. So the important question is: how can we be sure that these nodes are trustworthy? Let us briefly analyse the main characteristics of these two powerful instruments in the hands of Internet users.

Search Engines

Today the most popular and used search engines on the market allow users to search over nothing less than trillions of different documents. Such a possibility was totally unthinkable only 20 years ago. However, results coming from these engines are mainly commerce-oriented and purely based on a quantitative algorithm that, although being at the state-of-the-art, has significant margins of improvements in terms of results quality. For example, simply

typing in Google bar “economic crisis in Europe” we are offered hundreds of millions links and their order is purely decided on the basis of the most linked pages, which tells nothing about the specific user needs, which are different from one person to another. There are two critical aspects of Google ranking: first, pages coming from popular newspapers are clearly top ranked apart from their content; second, privileged ads slots can be bought, again independently from their content. Consequently, gatekeeping process is still an open issue and Google could be influenced as easily as TV channels. Furthermore, the communication model is still unidirectional. Given the enormous amount of information available on the Web and the typical user profile and effort put in the search, vast amount of information remains, in fact, inaccessible for users. Therefore, this communication model remains not very different from the one offered by traditional media, i.e. the Gatekeeper (databases and ranking algorithm), Speaker (result page), Audience (users). The major lack in this model is the fact that the audience has no chance to self-configure the ranking algorithm and therefore being able to influence the content and the order of the search results (apart from minor flexibility given by the use of advanced search features). The way in which the search engine presents the results still remains a black box for the average user. Overall, we could say that “what is not found on the first page of Google results does not exist”. Considering how powerful a medium like Internet is, we would expect users to be somehow able to interact with it in a much more proactive way.

Social Networks

Social networks service like Facebook have a focus on collection and sharing users data (family, friends, pictures etc..) and personal interests/information and, these days, they have massive numbers of users accounting worldwide for an incredible amount of hours of usage. If we disregard all the private information posted on Facebook, which are irrelevant for people outside your closest group, the platform can be proactively used to share quality information. Indeed, social networks are very different from search engines, because of the way the source of information can be controlled by users. A generic user, for example, can follow a specific trusted friend or hide information coming from untrusted users, who seem to post information considered irrelevant. Unfortunately, even with Facebook, users are not able to rank information since all posts are only shown chronologically. Users are not able to set content alerts to be informed only about specific topics. Another problem is that users cannot enrich their posts linking information which is not on the Internet, although this is becoming less and less relevant in the moment in which all the other media are also posting their contents on the Web.

Being Facebook supported by advertising, this information is more critical in term of quantity, rather than quality. The way Facebook is structured does not consequently promote or improve critical thinking, learning, comprehension and discussion among its users. Mechanisms such as ”like”, for example, are structured for giving just a quick evaluation, which, as a consequence, may be simply an accelerated feeling, not moderated by critical thinking. According to a Nielsen’s Company research, people are spending more and more time on social networks: global average time spent is in fact about five and half hours per month and this number is increasing, with Facebook currently dominating its position as a destination.²

Social networking is globally expanding and it is likely to deeply influence the way people will interact with other people in the future, promoting connections able to go beyond the

² <http://mashable.com/2010/03/19/global-social-media-usage/>

classical geographical limits (Mazzara, Marraffa, Biselli, Chiarabini, 2011). Contemporarily, social networks have some other interlinked privacy and security issues that are discussed hereunder.

Privacy and Security in Social Networking

Massive growth of social networks such as Facebook, LinkedIn, and MySpace -- with millions of users everyday -- have become an indispensable part of our daily-life. Such an expansion of social networks has also paved the way to share our crucial personal and professional data over the Internet that eventually leads to data security and privacy challenges. Albeit social networks proclaim several benefits and competitive features, they are not exempt from subtle data leakages. They also lack in specifying and implementing appropriate security and privacy procedures to protect users' data. For example, our whole Facebook album is exposed to a stranger after a comment from a friend in our network. Also, how our stored information can be manipulated is one of the unknown aspects. Several famous personalities across the globe have been the victims of intruders and attackers on such social networks. Ordinary users are generally unaware of such intricacies unless they encounter certain inconveniences against which they report loss of data and misuse of their accounts. Such victims are large in numbers and they need coordinated efforts to deal with their issues.

Users' data may as well be sold by a social network to a third party. An outcome can also be compromising data integrity and confidentiality (irrespective of the intentional or unintentional move) due to flexibly implemented security mechanisms or inadequate security policies. These real-life issues are encouraging to underpin the state-of-the-art security and privacy support for such social networks. The alluded problems already have been approached in various ways such as Safebook (Cutillo, Molva, Önen, 2011), which offers a so-called replacement to Facebook using P2P network in a more decentralized way. Safebook puts a special emphasis on the privacy of its users with regards to the application provider and shields against malicious users or intruders. Ding et al (Ding, Cruz, Li, 2011) attempt to model a feature social network called friend suggestion. Their approach is based on high level Petri nets, but extended with channels to formally model social networks. Another recent added challenge of security and privacy is in mobile social networks, which require user's location and preferences. Issues reported in mobile social networks can be found in (Beach, Gartrell, Han, 2009) such as direct anonymity issues and eavesdropping, spoofing, replay and wormhole attacks. This lack of security and privacy does not surprise in a way, since social network applications do not take into account security and privacy by design.

The right choice of security mechanism and security policy are vital to understand and enhance social networks' security and privacy. To this end, use of formal methods in terms of analyzing and reasoning security and privacy properties makes sense as they allow a systematic and compact description of the desired properties. For example, using formal methods one can unambiguously specify pattern of social relationships and then reason about it. For instance, Fong et al (Fong, Anwar, Zhao, 2009) have given a formalized model of Facebook access control mechanism and reported it as a discretionary access control (DAC). The construction of formal models for privacy and security in social networks requires a rigorous treatment by the use of novel concepts and then to allow formal reasoning over the constructed models. For example, access control mechanism and a security policy play the role of backbone in such systems which can be taken into account to construct formal models. For instance, DAC can only be used where the user of a computer system is fully aware of the consequences of a granted permission and revoking it, which is just not the case in Facebook.

It is pertinent to note that although Facebook offers DAC but eventually fails to handover all the control to its users. Thus, a greater portion of the information is beyond the control of users, and actually the information is centrally administered -- just as in Role Based Access Control (RBAC). Centrally administered security policies result in exposing a user's photo album or a wall post, and appearance to a stranger as a suggested friend outside the work with basic information.

The notion of trust is equally applicable to social networks. For example, the research appeared in (Bonneau, Anderson, Church, 2009) suggests to have privacy suites for the users, choosable from privacy settings. These suites would either be specified by friends or trusted experts, with a possibility to be modified by its user if necessary. One of the reasons to opt such an options roots back to the problem that users lack in understanding privacy settings, for example, Facebook presents 61 settings on 7 different configuration pages, and LinkedIn has 52 settings on 18 Pages (source: Bonneau, Anderson, Church, 2009). Thus, given a trust model between a user's friends and other experts, one can reduce the security and privacy threats in social networks.

State of the art

In synthesis, our research identified the following:

- Traditional media: the content is controlled by the gatekeeper.
- Web and search engines: the content is controlled by the gatekeeper, but users can decide the topic. However, the requested content has to be stored in the corporation databases and, practically speaking, this content has to appear reasonably high in the engine ranking to be accessible to the average user.
- Social networks: the content is not controlled by any central authority or gatekeeper, but it is controlled by the specific user belonging to a contacts' network. The major feature of a user's network is trustworthiness of the content.

Polidoxa and trust

The advent of social networks may give rise to a paradigm shift in communication provided that a number of issues are solved. Our objective is combining the potential of search engines to quickly retrieve information and the ability of controlling its source which is typical of social platforms. Polidoxa (from Greek poly, (πολύ), meaning many or several and doxa (δόξα), meaning "common belief" or "popular opinion") is a platform which aims at introducing the notion of "trust" in social networks to improve information quality and general knowledge. In social sciences "trust" is defined as a situation where one party is willing to rely on the actions of another party.

More formally, let us define a set U of users; the function *trust* is defined as follows:

$$\text{Trust: } (A \in U, B \in U) \rightarrow [0,99]$$

That means, the trust of a user A for user B is expressed by a natural number between 0 and 99. For example, $\text{Trust}(\text{Alice}, \text{Bob}) = 99$ means that Alice consider Bob a very trustable individual. It is worth noting that this function is not transitive, i.e. it can be that $\text{Trust}(\text{Bob}, \text{Alice}) = 0$.

At the moment, social networks like FaceBook or LinkedIn allows only information to be shown chronologically or being filtered in some very basic way. There is no notion of “trust” between users and different contacts have similar relevance. Polidoxa is instead based on the principle that immediate contacts have more influence, while the others see a reduction of their influence which is proportional to their distance. Even direct contacts are not all at the same level, but users can decide a “trust” score and this score will change over time according to their activities. Polidoxa is based on the principle of collective/swarm intelligence which is the normal way of operating between colonies of insects living in collaborative communities (Maurer and Kolbitsch, 2006; Joslyn, Rocha, Smith, Johnson, Rasmussen and Kantor, 1998). Trust is the key to information and Internet has an enormous potential to fix the problem of information trustworthiness.

Multi-dimensional trust

In the previous section we considered trust to be a mono-dimensional entity. In reality, trust between individuals is not a mono-dimensional entity, but a multi-dimensional one. Multi-dimensional trust can be formally defined as follows (U is a set of users and T is a set of topics):

$$MTrust: (A \in U, B \in U, t \in T) \rightarrow [0,99]$$

That means, the trust of a user A for user B regarding a topic t is again expressed by a natural number between 0 and 99. For example, $Trust(Alice, Bob, football) = 99$ means that Alice consider Bob a very trustable individual. It is worth noting that this function is not transitive, i.e. it can be that $Trust(Bob, Alice, football) = 0$ while, at the same time, it can be $Trust(Bob, Alice, fashion): 99$.

A given topic t directly defines a *projection* of trust over a user’s contacts.

$$Experts: (A \in U, t \in T) \rightarrow P(U).$$

For example, for Alice Bob, Ken and John are football experts and their opinion is highly valuable:

$$Experts(Alice, football) = \{Bob, Ken, John\}$$

Once a subjective set of experts for a given user and topic has been individuated, a number of analyses can be performed on these experts, for example opinion mining.

Opinion mining and collective intelligence

Although other researchers have used swarm intelligence techniques to get high quality data from web communities, applying swarm intelligence algorithms to social networks to achieve collective intelligence is an open research domain. One of the most promising investigations is described in the paper “Swarm Intelligence for Analysing Opinions in Online Communities” (reference) by the University of Erlangen-Nuremberg in Germany. In this work text mining techniques are combined to ant colony metaheuristic algorithm to do opinion mining. This research can be divided in two major parts: opinion mining and use of ant colony for swarm opinion forecast. The main goal of this work is to distinguish between “positive”, “negative” and “no opinion”. The method consists in separating the words in each

sentence and calculates the relative frequencies. At that point, polarity of each post is calculated. In Fig.2 the results of this work are presented.

| Class | Precision | Recall |
|------------|-----------|--------|
| Positive | 62.96% | 62.52% |
| Negative | 86.35% | 86.05 |
| No Opinion | 81.65% | 81.07% |

Once opinion mining has been performed, an algorithm inspired by the ant colony metaheuristic can be used. The actual implementation of the algorithm consists in using posts polarity as ant pheromones. In this way, ants can predict next post polarity. More details about ant algorithm will be given in the following sections.

Quarantine and trust as a function of distance

Trust is not only a multi-dimensional, but also a multi-level concept. Google+³, for example, evaluates only the first degree of separation between contacts. Polidoxa, instead, aims at evaluating the whole network of contacts, assuming knowledge sharing as being important even when coming from indirect sources. The assumption is that immediate contacts have more influence, while other contacts from different levels see a reduction of their influence which is somehow proportional to their distance. Every user of Polidoxa has a basket of first contact users which he/she likes to follow and are considered information sources and generators. Whoever is not in this immediate set of informers belongs to “the rest of the world”, a grey mass of users about whom he/she does not have any information. Polidoxa aims at offering a second list of users, i.e. a “selection” of people from “the rest of the world” which has the potential to become relevant and trustable by the user. This list of people will be kept initially in a “quarantined mode”, i.e. under observation and the user will be able to pick up some (or all) of those and bring them into the set of direct contacts. These features will be detailed in the next paragraphs. How do these candidates are selected from the system among the (potentially) millions of users? It is well-known that every person in the world is separated on average by anybody else by six steps; at least in western urban world. This fact is well known as the “Six degrees of separation theory” or “Small-world experiment” (J. Travers, S. Milgram, J. Travers, S. Milgram, 1969). Thus, how can the “most trustable” persons in the system be suggested to the users? A mathematical model of “trust transitivity” needs to be developed. How does trust decrease when we pass from one level of separation to the next one? This issue is not entirely solved at the moment and several possible solutions are under consideration. The most obvious, simple, but imprecise solution is defining the inferred trust as decreasing in a linear way.

Let us define a function expressing the distance between two users:

$$Dist: (A \in U, B \in U) = \rightarrow N$$

Now, let us suppose we have (with k=99 in this case):

$$Dist(A,B) = x$$

³ <https://plus.google.com/>

then

$$\text{Trust}(A, B) = k \text{ for } x=1$$

$$\text{Trust}(A, B) = 1/x * k \text{ for } x>1$$

This means that first level contacts have here a value trust of 99 and the indirect contacts see their trust decreasing in a linear way. Of course, this is a simplification since the direct contact trust can be in fact set by the user (in practice this k is changing over time, see the following sections to understand how further parameters are implied in this change).

However, this solution is imprecise because we know that trust is not a linear relationship, i.e. the contacts a person has at the third or even fourth level have a value which is generally close to zero while direct contacts or contacts of contacts are very valuable. Other better possibilities are expressed in Fig.3.

We are currently also evaluating another ranking system based on a trust relationship inspired to a Kepler-Newton modelling system. During our life time we in fact trust our parents, relatives, friends, or even people we do not know, creating our solar system, adding new planets which we critically found compatible to our beliefs of our mental galaxy and our contact links are based on a non-linear relationship, where the quality of trust increases when it gets closer to our beliefs, knowledge, commitment etc. Research in this area has been already developed at McGill University, Canada (M. Maheswaran, Hon Cheong Tang, and A. Ghunaim, 2007). The Inverse Square Law on which the idea is based is shown in Figure 4. We can make a simpler analogy between this idea and how forces distribute over a sphere. By defining the intensity i of the Trust as: $i = T/A$ where T is Trust and A the area of the sphere, i.e. our social network, we get $i = T/A = k*T/(4\pi x^2)$ with x the radius. Thus, if $x_2 > x_1$ then $i_2 < i_1$ which means the more the contact is distant, the less powerful is the Trust.

| TRUST(u, v) = $\alpha(d(u, v))$ | |
|-------------------------------------|----------------------------------|
| Linear | $\alpha(x) = \frac{1}{x}$ |
| Quadratic | $\alpha(x) = \frac{1}{x^2}$ |
| Gravitational | $\alpha(x) = \frac{1}{4\pi x^2}$ |
| Exponential | $\alpha(x) = e^x$ |

Figure 3: Trust Definition

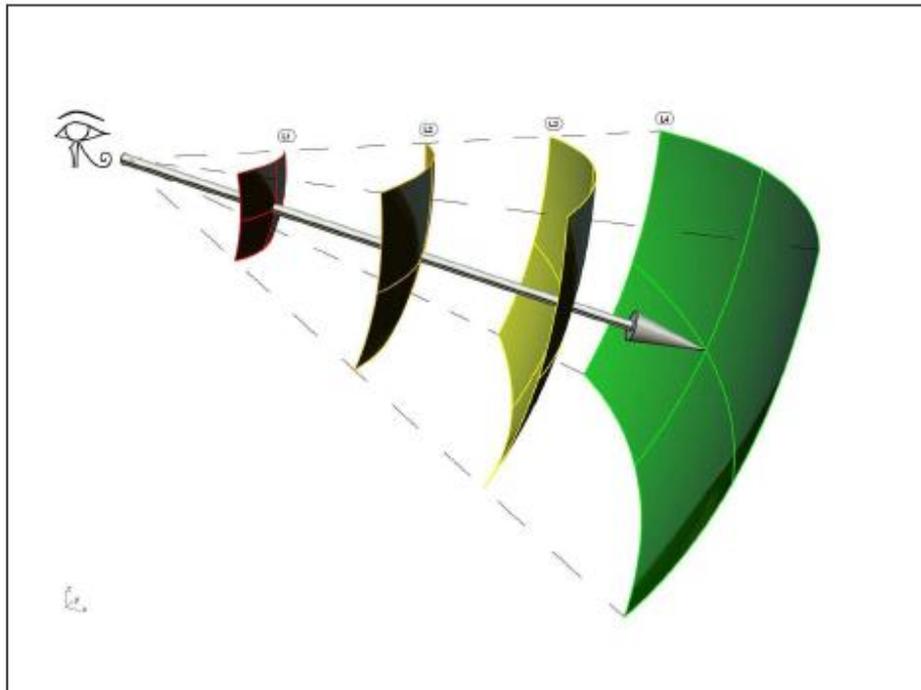


Figure 4: Inverse Square Law

Social networks as swarms

Nature has always been and still is an inspiration for humanity. Ant, bees, fireflies and termites are not the only source of inspiration. Swarm intelligence in many cases is based on other natural systems, like solar systems or the mammal's immune systems. All of them have some common principles:

- They are composed by many individuals.
- The agents of the system are identical, or in some cases they have some small variations
- The agent has only local knowledge of the system
- The overall result of the system is the interaction between the independent agents
- The System implements protective measures and actions

Therefore, social networks are swarms where the agents are users of the network. Swarm intelligence has goals like, for example, finding optimal paths to food and it has been used to solve optimization problems like travelling salesman (I. Kuo et al., 2010). Polidoxa's goal is about improving information quality and general knowledge and discussion and although this cannot be formulated as an optimization problem (there is simply no optimum), swarm intelligence can be still exploited as it will be presented in the following.

A stigmergic behavioural system as in swarms

Insect colonies are huge communities. To communicate they use a "face to face" communication without the intervention of a centralized artificial medium. This system guarantees that information will be never centralized by a small subset of the colony. The

knowledge sharing process works bottom up, following the principles of democracy as it was in the Agorà. This principle seems to work perfectly in insects communities. Every time the information is passed, the receiver checks who the sender is. If some information is ambiguous, the receiver stops the information flow and sends other insects to control which information is actually the correct one. The human way to transfer and share information is different and it is normally influenced at best, or filtered at worst, by mass media (TV, radio, newspaper, books, education system...). Humans communicate in an unreliable way because they almost entirely rely upon mass media, bypassing every democratic principle and accepting a top down sharing of information. A very strict group of people have the potential to control the information, while this is impossible with the insects' communication model which does not permit a centralized control. This is why Polidoxa model is inspired by insect colonies behaviour.

Polidoxa is designed to work as a stigmergic system, a strategy based on what can be found in biological systems. Social interaction and networking is enhanced by the collective intelligence, which is superior to the sum of knowledge of individuals and opinion trends can be predicted via swarm intelligent algorithms. Polidoxa can offer a platform for discussion which aims at elevating the users to a higher level of knowledge, criticism and consciousness.

An example of a stigmergic system is Wikipedia. (assuming there are no administrators). Let us consider, for example, how social insect colonies build up a complex system to tell each other where to locate sources of food or picking up materials. This happens in a collaborative way, without any external instruction, guidance or hierarchy. In the same way, Polidoxa users, as a colony of brains, can share information, interact with it, generate discussion, enhancing the service itself, redefining how it will work, etc. This happens like in a self-organizing system which facilitates cooperative team work. This evolution from chaotic groups to self-organized users groups without any central guidance, will help in the re-definition of how information can be delivered, offering a real alternative to traditional media top-down approach. The limitations imposed by the lack of users' guidance and hierarchy to meet the community goals, are possibly overcome by a Holonic System

How Polidoxa as a Holonic System addresses the lack of hierarchy.

The concept of a holonic systems, firstly coined by Kostler (Koestler, A. 1968) can be expressed in engineering terms as that of a system that is made up of autonomous units who are themselves (sub)systems, all acting in a cooperative way (Brennan, R. W. 2001). Although subject to the system's supra-hierarchy called holarchy, self-reliant units are characterised by a degree of independence, that aims at self-sustaining, stability and efficient use of resources (Calabrese, M. 2011). The intrinsic duality of a Holonic system, being simultaneously a "whole" and a "part" brings in a potentially new approach in how to implement the aims of the Polidoxa Platform.

An example of a holonic system and its duality is the human body; being it a whole system whose physical boundaries could be set as the skin that "senses" many, although not all the external "signals", it transfers these signals to the brain which interprets them and instructs the specialised sub-systems (such as organs, muscles, etc.) to perform the required action(s).

The Holon, seen as a self-contained autonomous and cooperative entity, can be described also as a dissipative system in thermodynamics. A dissipative system (an Open System) is capable of exchanging energy and matter and interacts with the outer environment by means of its surroundings; any exchange of energy and/or matter results in the modification of its internal energy. These exchanges can be considered stimulus and they will produce a response that is

managed by higher-level components “super-holons” and is transferred to lower-level components “sub-holons”. A Holonic system is represented in Fig. 5.

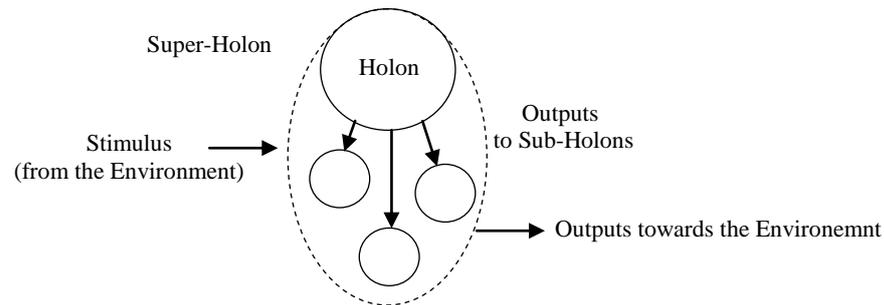


Fig. 5: a Holonic System composed by a Super-Holon, a lower level Holon and a further lower-level sub-holons. When stimulated by the outer environment the holon produces responses to sub-holons and then to the outer environment.

If the stimulus that the Super-Holon detects from the external environment through suitable sensors can be of different nature, and not all may be beneficial, it is of primary interest to understand and implement how it is possible to prevent malicious stimulus to affect the holon. This challenging task requires that stimulus, or Users from now on, are recognised as genuine ones after being quarantined before gaining access. Any recognised malicious user will then be expelled by the system and prevented from re-entry even if it changes “identity”. The following paragraphs provide a methodological approach towards the holonic quarantine.

Invited Users or Self-Candidacy Users

Polidoxa aims at redefining the Trust and Trust defines acceptance among users. Polidoxa is based on a holonic system which acts as a whole system and, simultaneously, as a cooperating set of sub-systems. Users’ attempts to gain entry to the Polidoxa Platform need to be recognised not only as non-malicious, but they have to comply with the goals of being self-sustaining, increase system’s stability and make efficient use of available resources (of the Polidoxa users’ community). Quarantine is believed to be an effective way for any user to be accepted by the Polidoxa community; quarantine is performed by peers (other Polidoxa users) who are fully specialised and so capable of recognising a similar pair.

A very interesting example of such peer-review activity is offered once again by nature. Studies on ants’ communities demonstrated that once a colony member has been infected, its nest-mates perform a grooming activity toward the affected pair with the ultimate goal of guaranteeing the survival of the whole colony (Konrad, M., Vyleta, M. L. et al. 2012). The tasks can be broken down in few steps and the ants behave in such a way that they 1) share part of the fungal infection in order lower its concentration from the severely affected individual to non-lethal values, 2) transfer (sharing) of low infection levels triggers the immune system of the grooming group and speeds up the healing process of the affected individual 3) the immunizing agent acts as a marker for the recognition of future occurrences of the infection. By doing so the community is preserved from identical future infections because the immunization information has become part of common knowledge.

Social contact to pathogen-exposed individuals, or malicious users, enables immunisation of the entire colony, the Polidoxa Community, and this is applied to Polidoxa. A sequence of steps would be as follows: a) each user intervenes in quarantining a new user and is (or should be) capable of recognising any potential threat, b) acts to remove the malicious pathogen, c)

keep memory of it and shares the information for social immunisation and d) the malicious user is marked and permanently banned from any future re-entry attempt.

Trust as a function of network activity

It has been demonstrated that trust changes as a function of distance. Furthermore, trust changes over time as a function of network activity. The following parameters have been individuated as being relevant to update trust:

- For each user, the number of likes related to his posts: user popularity
- For each user, the ratio #Likes/#Dislike (with #A cardinality of set A) for that user
- Rate of activities (share, comments, like, dislike...) on a posted item within a temporal interval
- Number of private messages between the user and another user
- For each post of the user, the number of comments coming from another user
- Number of user comments to posts coming from another user
- Followers list
- Users that belong to subscribed groups
- each group to which the user belong, number of the published posts on that group
- List of configurable keywords
- Favourites sites/blogs list
- Post labels
- Post frequencies
- RSS feed's list of the user and of all the first grade user's contacts –i.e. people directly connected with him – (configurable in case of extension to more than one level)

The following table synthetize how trust has to be calculated at given time intervals.

| Dynamic Parameters depending on activities and degree of separation |
|--|
| 1: Evaluate <i>like</i> and <i>dislike</i> : the more 'like' an article gets the more important it is |
| 2: Evaluate comments in like thread |
| 3: Evaluate amount and frequency of share function within a temporal interval : a high frequency within a temporal interval is an indicator of a hot and important news |
| 4: Evaluate the number of comments of the post |
| 5: Evaluate the number of private messages exchanged with the poster. |
| 6: Evaluate keywords, labels match |
| 7: Evaluate if the poster belongs to a shared group and the activities on that group |
| 8: Evaluate the freshness of a document/article/post |

All these parameters can be used to identify malicious users and non-trustworthy information in the style of Immune Network Systems (reference), but this goes beyond the scope of this work.

Polidoxa@twitter

Twitter⁴ has many of the described characteristics of social networks like FaceBook and LinkedIn, plus it has a simplicity which makes it a very good case study to experiment the idea presented in this work without worrying about inessential complications. The important characteristics of Twitter for our purposes are the followings:

- Information as it is presented in FaceBook and LinkedIn is structured and varied (like text, pictures, sounds ecc...). Twitter instead enables its users to send and read only text-based posts of up to 140 characters (the "tweets"). This makes easier to collect and store them for analysis purposes.
- Having Twitter mostly text information, analysis can be only text-based (no picture recognition etc...). We believe this is an important aspect related to user privacy and policy of use.
- Number of tweets exchanged in a given timeframe is much higher than number of FaceBook or LinkedIn posts. This is in particular true when we consider news. For analysis purposes it is faster therefore to construct a collection of data and the amount of available relevant data (news) is more significant.
- Tweets messages contains hashtags which are relevant for analysis

Polidoxa@twitter is the realization of (some of) the Polidoxa's principles on top of the Twitter platform. Polidoxa@twitter has the following incremental requirements. At the moment only a few of those are implemented (in the conclusion section we explain how we intend to proceed in the development of this project):

1. **Static trust:** users can set static (default) trust values for their followers (for example, 0% to 100%)
 - Tweets are visualized/ranked/ordered according to this value
2. **Swarm intelligence for dynamic trust (basic):** followers who have a specific activities history have to be considered more relevant and have an automatic offset/boost of their trust values (for example a person with a default of 50% after some activity could rise to 55% and then 60 %)
 - Like button for Twitter, i.e. followers with many "likes" dynamically get more trust (for, example 0.1 % more trust for each "like")
 - This does not actually require any analysis of hashtag association
 - Again , tweets are visualized/ranked/ordered according to this value
3. **Swarm intelligence for dynamic trust (advanced):** the difficult question is: what is the best way to evaluate followers' activities and boost their trust values in a smarter way than just using "like"?
 - Use of hastags: for example: users can set keywords (for example "BMW") and high frequency of #BMW in followers' tweets gives them a higher trust score.
 - Associations of keywords: for example "BMW"+"reliable" with only followers with high frequency of both the keywords get extra trust.

4 <https://twitter.com/>

Related Works

In this section we compare the Polidoxa idea with Google and Grouplens. PageRank is the parameter used by Google and it is based on the links received by a page and on the “authority” of certain pages. Thus, when a page is linked by another page with “authority”, this gives more relevance to the page itself. The important question here is: how can we decide about the authority of a page? This is not clear and Google says nothing about it. Who works in SEO (Search Engine Optimization) — like one of the authors does — knows very well that inlinks evaluation (evaluation of links coming from other pages) is a process lasting for months. This means that a page with qualitatively valuable information actually needs months to acquire some “authority”. With Polidoxa, everything instead depends on the network’s activity, without a delay of months but, in the worst case, of hours. The Polidoxa algorithm evaluates the news propagation speed inside the network giving more importance to that news which propagates faster inside the user’s social network. While in Google the importance of information is decided like in a “black box” with a non-transparent process, and it can therefore be manipulated by SEO specialized agency (an online marketing branch which has the goal of bringing a page or document in search engines ranking top position), with Polidoxa we offer a very simple answer to this problem since the importance of information is determined by the user him/herself and by his/her social network. The importance of information is now transparent and cannot be influenced by SEO agency. Polidoxa introduces a trust ranking algorithm where:

1. The user determines a trust parameter (a numeric value) which is a static parameter for the page to be indexed and for his/her first level network
2. The user’s first level network determine a dynamic trust parameter on the basis of its activity (e.g., like, dislike, share)
3. The user further level network (indirect links) determine a trust parameter based on its activity and this value decreases with the distance (as discussed above)

The user has now a unique instrument for searching information which values more all the direct connections without limiting the use of traditional media or search engine. As a consequence, the user is forced to use his/her critical thinking when reading news; he/she is motivated to think about the sources and the process of news creation. Indeed, all the filters created by the so-called “subject matter experts” of Grouplens⁵ are, in reality, not very transparent. For example, who decides who is an expert? Furthermore, an “expert” can be easily manipulated. With Polidoxa the “subject matter experts” is instead precisely decided by the users and not by an unknown external entity.

Polidoxa gives the possibility to configure the search engine and the related ranking. It does not limit the general network activity but gives the user the possibility of monitoring the specific activity of his/her trusted network. The fundamental idea is that we tend to trust more the people we know and with these persons we usually discuss more, get more feedback, interact more, etc... However, the possibility to follow famous people we do not directly know but for some reason we trust is not prevented since we can directly override the trust value of every element of our indirect network. This is because a user may want to follow a distant person who is considered a role/spiritual model. Certainly, also in this virtual trusted network all the persuasion/influence mechanisms may still be valid and alter the trust relationship in a not obvious way. These aspects are described in detail in (R. Cialdini, 2000).

5 <http://www.grouplens.org/biblio>

Polidoxa users have the opportunity to be aware of the activity of the trusted network but still have to use their critical thinking to evaluate the information. This should give the opportunity to the “deep Web” (all that information not crawled by search engines) to eventually reach the Web surface. The Polidoxa ranking increases the quality of information, facilitates the discussion and could improve the lifestyle of participants simply exchanging information and sharing knowledge. Looking at the data of seo-scientist.com⁶, we discover that about 80% of the users just click the first three results given by a search engine. As a consequence, ranking of information is of extreme importance and offering a trust ranking based on the users activities is fundamental to offer qualitatively better results because that means improving the first three positions according to the user priorities and preferences. With Polidoxa the user and his/her trusted network influences the ranking and everybody has the chance to receive a customized and configurable ranking.

Future works

A Polidoxa based news search engine is a promising idea to explore. The engine would be based on a configurable ranking algorithm. Users will be able to choose the sources from which the engine should retrieve the news. Topics and ranking criteria may also be selected. The trustworthy social network permits to follow the information posted exclusively by trusted users on specific topics which can be set. In literature other approaches can be found supporting choices based on other people opinions, for example Google+. Polidoxa extends this idea proposing a built-in search engine and organizing people in a trustworthy social network where news positively evaluated by linked contacts have a higher priority than the ones evaluated by indirect contacts: the higher the separation degree, the lower the priority. The major difference with the Google algorithm is that Pagerank evaluates the link relationships of a document looking at the entire Web, while Polidoxa evaluates the link relationships of the network community, giving more importance to the network activities within a shorter relational distance.

Conclusions

This paper contributes with several principles and technicalities to build a social platform to achieve collective intelligence via information sharing among trusted contacts. It also presents a Twitter-based implementation of a subset of these principles. Trust modelling, social networks, collective intelligence, algorithms and the relative motivations supported by literature in communication sciences are a quite inedited interdisciplinary blend which has not been really investigated so far. We intend to pursue our investigation and move the human knowledge further on this topic

In this paper we emphasized the fact that people tend to passively receive TV information without verifying it. The gatekeeping process of traditional media, although generally safe and quality ensuring, poses new risks when control over the information is becoming more and more centralized. Internet has an enormous potential to fix this problem, but the current instruments commonly used like Google and Facebook lack the most important concept in this field: they do not embed the notion of individual trustworthiness of a source. Polidoxa, instead, connects local knowledge making it usable for everybody and it is conceived to promote public awareness and discussion in total freedom, like in an open piazza. Polidoxa is based on our philosophy: *“we believe first in what we can directly verify, then in what our closest contacts have verified. We doubt about what people we do not know say about things*

⁶ <http://www.seo-scientist.com/>

we have never seen (it does not matter if this is coming from official sources) until our network of trusted contacts allows us to trust it because it has been verified directly by them.” Today we tend not to verify mainstream information and this has the potential to become a problem in the future. Polidoxa may be an answer to this problem.

The same principles on which Polidoxa is based (collective intelligence, collaboration, stigmergy...) applies to the full implementation of the system as well. We are indeed looking for potential collaborators interested in developing aspects of this project both at the theoretical/algorithmic level and at the software engineering/implementation level. We indeed believe that only collective intelligence can create platforms for the exploitations of collective intelligence itself. We believe collaboration between individuals, knowledge sharing and quality of life in general can all be significantly improved by taking inspiration by nature and, in particular myrmecology (from Greek: μύρμηξ, myrmex, "ant" and λόγος, logos, "study").

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The idea of Polidoxa slowly emerged among friends and its basic principles have been discussed and experimented over time with information sharing via other experimental platforms or, sometime, just emails. This topic has been discussed with several friends and colleagues before taking shape. All of them contributed substantially to the idea or the realization. We want to thank, in particular, Georgios Papageorgiou, Luca Chiarabini, Giuseppe Marraffa, Luca Ermini, Matteo Dall’Osso, Fabrizio Casalin and Chiara Succi. We also want to thank members of the Reconfiguration Interest Group and the Dependability Group at Newcastle University and the people involved in the EU FP7 DEPLOY Project (Industrial deployment of system engineering methods providing high dependability and productivity). Finally, colleagues and friends at UNU-IIST, Macau cannot be forgotten.

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