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Communication Between Process and Structure: Modelling and Simulating Message Reference Networks with COM/TE

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Abstract

Focusing on observable message signs and referencing structures, communication processes can be described and analysed as message reference networks which are characterized by dynamic pattern evolution. Computational simulation provides a way of obtaining insights into the factors driving such processes. Our paper describes a theoretical framework for communication-oriented modelling — the COM approach — that is centred around the notion of social visibility as a reputation mechanism. The approach contrasts with agent-based social networks on the one hand, and with bibliometric document networks on the other. In introducing our simulation environment COM/TE, typical properties of message reference networks are discussed in terms of a case study which deals with the impact of different media and styles of communication on emergent patterns of social visibility.

Keywords:
Communication, Communication-Oriented Modelling, Message Sign, Dynamic Networks, Bottom-up Approach, Temporality, Social Visibility, Reputation, Socionics

Introduction

1.1

This paper presents the results of a simulation study on social visibility as an emergent or generic feature of message reference networks. Social visibility is an operational definition of what sociologists usually refer to as reputation or prestige. However, while reputation is usually attributed to social agents or actor networks, we suggest that it be construed as a structural property of messages and publications for the purpose of attracting attention. In contrast to mainstream actor-based sociology our approach is communication-based. In adopting communication as the foundational category of social theory (Mead 1934; Luhmann 1984), we have developed the COM approach[1] as a methodological framework for social simulation.

1.2

With COM and COM/TE, the simulation test-bed introduced in this paper, we want to answer the question of how social structures such as reputation patterns are generated from dynamically interwoven messages. To pose the problem of pattern generation in a tractable way, we need to

describe and explain the dynamics of social communication in a concise and coherent vocabulary. Accordingly, COM must incorporate two design principles into its architecture: first, high-level concepts such as social visibility must be generated from low-level or basic concepts (bottom-up approach); second, all concepts must be defined in strictly temporal terms (time-based approach).

1. To meet the requirements of a bottom-up approach, the basic *unit* of communication is defined as consisting of three components: an observable object called the *message sign* (book, e-mail, document, utterance) and two unobservable operations called *inception*[2] and *reception*. The operation called inception creates or inceives a message (by speaking or writing), whereas a reception understands or receives a message (by listening or reading). Whenever a reception triggers an inception, a new *reference* link is established between a previous and a successive message sign. Hence, a social *process* is defined as a chain of interrelated units of communication, while a social *structure* is defined as a process which is always repeated in the same way, forming a regularly observable pattern. Since structure implies process and process implies unit, we end up with a coherent body of neatly integrated concepts. What is more, these concepts are organized along the lines of a generative principle: units generate processes, processes generate structures.
2. (2) To meet the demand for temporalisation (Luhmann 1984), inception and reception are conceived of as transient operations which exist only for a moment. Although relatively persistent, message signs have a limited life-span too, being exposed to social and/or physical decay. Letters are lost, e-mails are deleted, and oral utterances vanish with their sound waves. Or, even if physically still accessible, they are socially ignored and forgotten. Consequently, communication processes, rather than being static chains, are streams of messages which are continuously and simultaneously appearing and disappearing again, while social structures are patterns of dynamically interwoven message events which are reproduced and stabilized against entropic decay and deterioration.

1.3

COM/TE has been designed to describe and explain the structural properties of generic communication patterns for (online) communication with thousands of concurrent messages processed in parallel. These messages are not addressed to a particular recipient but published "to whom it may concern" — which is typical of mass media communication. Accordingly, in this paper we do not zoom in on the fine-grained interplay of transient inceptions and receptions. Rather we treat inception and reception as one single reference link, pointing from a successor message to a predecessor message. Hence, in our approach to social networks, references are treated as the edges of a social network and messages are defined as nodes. What is different in COM/TE's message reference networks compared to conventional social network analysis is that messages and references are permanently being exchanged and replaced. In COM, message turnover works as a dynamic social memory which highlights the social visibility of a few outstanding events by selectively forgetting most other events. According to this view, we present a simulation study focusing on message properties, showing how different media environments will influence the evolution and stabilisation of patterns of social visibility in communication processes.

1.4

In section 2, in an overview, we introduce our modelling decisions and strategies. In section 3, different properties of message reference networks are described and explained in more detail, thus enabling a deeper understanding of our modelling approach. In discussing the impact of different forms of media on prototypical styles of communication, section 4 presents the results of our simulation experiments and discusses the issues of pattern evolution. Finally, section 5 provides a summary and an overview of ongoing work.

Related work

2.1

1. Communication plays only a minor role in most work on social simulation and artificial social systems. On the one hand, simulating micro-phenomena usually relies on multi-

agent systems (MAS) based on complex motivational agents (BDI architectures) with individual communicative abilities represented by speech acts (Wooldridge 2000). On the other hand, based on extremely simplified reactive agents, social macro-phenomena are simulated with models such as SUGARSCAPE with its generalisations (Epstein and Axtell 1996, Buzing et al. 2005). Both concepts adhere to the message-sending paradigm of communication, in which messages are transmitted from a sender to a receiver on a one-to-one basis. However, modern mass media do not easily accommodate mapping communication onto the message-sending paradigm because here messages are published rather than sent: they are addressed to everybody willing to invest time in reading them and represent a tremendous selection problem for the individual agent. However, the selection problem is almost absent from the MAS literature which instead concentrates its attention on pre-structuring communication by interaction protocols and designing appropriate agent communication languages (Eijk et al. 2005). This sharply contrasts with our approach in which the problem of message selection motivates an essential part of the COM/TE architecture.

2. Research in bibliometry and scientometry focuses on publications citing other publications. Here, the first generative models of message events referencing or referring to other message events were proposed. DeSolla Price's (1965) citation analysis already describes pretty much the same mechanism for generating scale-free networks as Barabási's and Albert's model (1999) which has gained so much attention recently.[3] Similarly, the co-citation analysis of Pinski and Narin (1976) anticipates the formula that Brin and Page (Page et. al. 1998, Brin and Page 1998) have specified for Google's PageRank™ computation. While networks usually are designed as growth nets with new nodes (such as events, actors, organisations or other entities) added, COM is unique in systematically accounting for node deletion and modelling network evolution (Albrecht et al. 2005). However, the goal of COM is not merely to propose yet another generative model, but to provide a general framework for comparing different classes of generative models in the perspective of evolving social visibility.
3. In focusing on references between observable message signs, our work is also related to studies on computer semiotics. Applied to "social intelligent agents" (Petric et al. 2001) or to signs enhancing the visibility of information (Bihanic 2003, Kerne and Sundaram 2003), these studies are intended to support users in the field of computer-mediated communication. Here we should mention a number of studies on hidden semantic structures or "conversation maps" (Sack 2000), visualizing the reading activities of newsgroup users (Lueg 2000) or dividing users into groups of pros and cons by analysing citation structures (Agrawal et al. 2003). Moreover, dynamic changes in newsgroups are visualized by Netscan (Smith 1999, 2003). Again, COM tries to overcome the temporal restrictions of these studies by modelling a continuous process with messages produced or published at every time-step.

Modelling Communication Processes

3.1

In open communication processes with extremely large numbers of messages, it is obvious that not all messages will gain the same amount of attention. As a criterion for selecting relevant messages, we propose a concept of social visibility (prominence, reputation, prestige[4]) . A closer look at message reference networks reveals that emergent patterns of social visibility are not all alike but expose different structural properties. This indicates that social visibility or reputation patterns are not always generated and sustained in the same way.

3.2

Indeed, there are high variations in message accessibility and message decay, in speed and quantity of message turnover. These differences correspond to different media and fields of discourse. While nothing is as old as yesterday's newspaper, new websites linking to older ones or scientific papers citing much older but highly prominent papers are not unusual. As long as new messages are continuously created and old ones are easily accessible and highly attractive, a message reference network should be expected to grow steadily. However, in case of inaccessibility due to physical deterioration or social decay, any communication network may decrease and shrink, eventually to the point of complete breakdown. As we shall show, this

feature is represented in COM/TE by deleting message nodes from a network.

3.3

The COM framework introduced in this section deals with two basic aspects of modelling reputation patterns in communication processes. The *descriptive part* is based on the concept of social visibility, which describes the probability of any given message being noticed by others within a certain communication process. The number and position of messages with high or low social visibility within a given message reference network is used to identify, observe, and analyse communication patterns in communication processes. The *generative part* of the framework is the message distribution function. It describes how new messages and references are created and specifies the conditions for deleting old messages and their respective references.

The Concept of Social Visibility

3.4

In COM, visibility is conceived as a social phenomenon. It should not be confused with visual perception in a cognitive sense. The notion of social visibility expresses the amount of attention a message receives from other messages in an ongoing process of communication. Here, the point of departure is "St. Mathew's law": the more visible a message already is, the higher are its chances of gaining more visibility, that is, attention from others, and the more likely it is that its social visibility will continue to grow in the future course of referencing events. As already mentioned, communication as a social process is driven by complementary operations (reception plus inception) which produce references between message signs. Focussing on the distribution of references, it is possible to analyse and characterize different kinds of visibility patterns with regard to a diversity of media of communication.

Message References

3.5

Message signs are connected by reference links. A reference is established when a given message sign is understood (reception) and a new message is created (inception). In the first place, linking a successor message to its predecessor implies that the predecessor message's visibility is furthered. Accordingly, the more references a message obtains the higher its social visibility. Moreover, referencing also increases the successor message's visibility. Searching for a paper with citeseer.org, for example, will not only provide the user with the requested paper but additionally with a list of all other papers citing it. Hence, citing highly visible publications could prove to be a successful strategy to enhance one's own reputation. The example also illustrates the fact that quantity alone will not do. Not all references support a message's social visibility equally well. While a reference from or to a famous article may support the visibility of the referencing and/or referenced article enormously, a reference set from and/or to a no-name article in a no-name journal may have no effect at all.

Message Attributes

3.6

COM's concept of a message's social visibility is open to extension: a message can additionally be specified with attributes such as author, topic, keyword, relevance, acceptance, rejection, and so on. Depending on corresponding circumstances and styles of communication, these attributes may influence the social visibility of a message in different ways. A specific attribute to be considered here is the number of receptions. Normally we would expect that the more receptions a message sign can attract, the more reference links should be established. It is interesting to note, however, that this is not quite the case. In large-scale communication the number of receptions usually far exceeds the number of new references (or inceptions). The more receptions a message obtains, the smaller the probability that any one of those receptions will trigger a new inception and, hence, a new reference. Examples are manifold: a bestselling book will attract millions of readers or recipients but reviews will only be written in their hundreds; an online discussion is followed by hundreds of "lurkers" but only some of them will come up with a contribution of their own, and so on. In contrast, if a message has only one

recipient, just as an utterance in a face-to-face conversation between two people has, the chances are high that each single reception will trigger a new reference.

Message Ageing

3.7

While references and attributes are defined at the unit level of communication, ageing is defined at the process level. Ageing is the essential factor that reduces the visibility of a message on a regular temporal basis. COM systematically accounts for message ageing in terms of a time-step-based, progressive reduction in social visibility, due to social and/or physical decay, which in the course of the communication process terminates in the deletion of a message (message cut-off point). Of course, there are other network models which also insert new nodes at run-time and delete old ones. However, most of these models consider deletion and insertion as discrete or contingent events that may or may not occur, just as the software agents in Hewitt's open systems approach may freely enter and leave a system at any time (Hewitt 1991). In fact, most models are interested in "age" as a message attribute rather than "ageing" as a process category. In searching for specific postings in groups.google.com, for example, the results are sorted by age or recency. Instead of regarding message age just as an attribute, we need to build on a theoretical concept of time-as-decay which allows us to exploit the dynamics of pattern evolution in a more promising way.

Message Distribution

3.8

COM makes possible a distribution of new messages by inceiving several messages in each time step simultaneously. Simultaneity of message distribution is another important temporal concept at the process level of communication. Message distribution is concerned with network growth and network shrinking. It describes in operational terms how for each new message one or more older messages are selected to be referenced. Message visibility and message distribution are connected in a circular or recursive mode. The way in which social visibility in a network is distributed influences the way in which references are set which, in turn, influence the visibility of the messages. Message deletion may also result from unevenly distributed references. Deletion, therefore, depends on two parameters: message age and/or message visibility. Both parameters together define the relative persistence of a message. Another temporal parameter that influences the distribution of references is reception duration. Unless a given message has obtained a reception in a time span defined by the parameter reception duration, a new reference may not be made to that message.

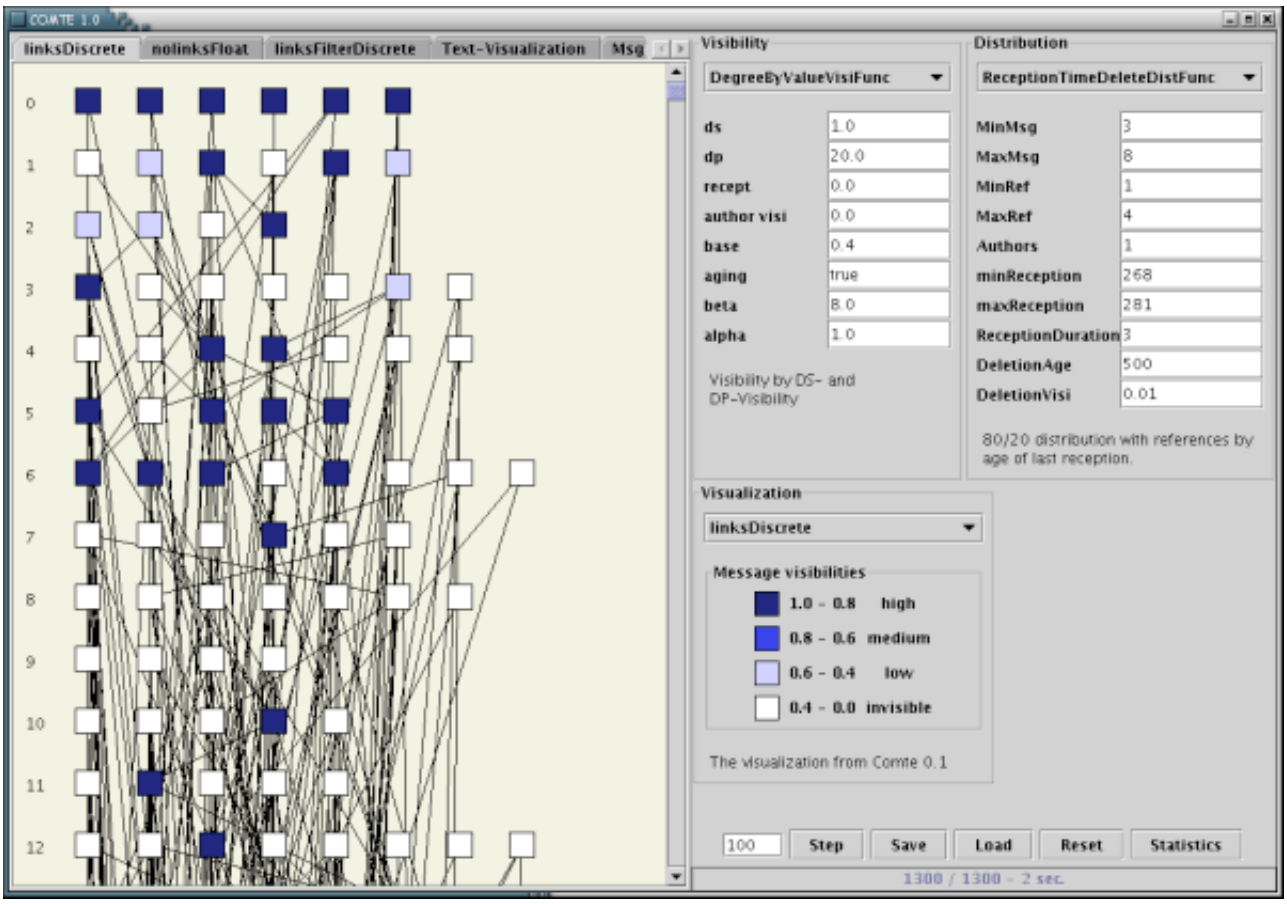

Figure 1. COM/TE, the COM Test Environment for analysing and simulating communication processes. The frame to the left displays the message reference network (in this view messages created in the last 12 time steps are shown, with the newest messages on top). Note that in the simulation tool the network grows from bottom to top, with the oldest messages at the bottom

Simulating Message Reference Networks

4.1

Using our test environment COM/TE, we can create a message reference network as a stream of communication in a time-step-based approach according to the procedure described so far. COM/TE allows us to choose from a number of different visibility functions and distribution functions to run time-step-based simulations. In each time step:

1. the visibility of all existing messages is calculated and
2. new messages are created (distributed) which reference older messages;
3. messages gain receptions and
4. messages are deleted.

4.2

The two main elements of the simulation are a visibility function computing the visibility of each message and a distribution function generating new messages and references or deleting older ones. In each time step $m \in \{m_{min},\ldots,m_{max}\}$ messages each with $r \in \{r_{min},\ldots,r_{max}\}$ references are created. As already stated, referencing mainly depends on the current visibility of the existing messages: the probability of an existing message being referenced by a newly created one is directly proportional to its visibility.

4.3

The same applies in the case of receptions. In each time step $c \in \{c_{min},\ldots,c_{max}\}$ receptions are set, where the probability of a message being received is directly proportional to its visibility. It is possible for one message to get more than one reception in one time step. Receptions restrict the messages to be referenced: only messages received in the last t_c time steps may be referenced. This models the idea that a message which not has been read (received) cannot be referenced. [5]

4.4

Message deletion is based on visibility and age: messages older than a given limit t_{del} and less visible than vis_{del} are deleted. Moreover, references set by and on these messages are also deleted.

Modelling Social Visibility in COM/TE

4.5

The simplest case is to use the number of references a message *m* gets from other messages (in-degree, *in(m)*) and the number of references which it sets to other messages (out-degree, *out(m)*) to calculate the message's visibility[6] at time *t* (with a constant base visibility *b* for each message (no message is totally invisible)):[7]

$$vis_t(m) = b + \delta_{out}\, out(m) + \delta_{in}\, in(m) \qquad (1)$$

4.6

The probability of a message *m* gaining a reference is

$$\frac{vis_t(m)}{\sum vis_t(n)} \qquad (2)$$

With growing numbers of messages, the probability of a single message attracting a new reference (its relative social visibility) decreases, even if its present visibility is high, because the number of visible messages increases $\Sigma vis_t(m)$. To ensure that most messages have a visibility close to zero and only a few stand out, we modify the visibility function by introducing a parameter β to increase contrast:

$$vis_t(m) = \left(b + \delta_{out}\, out(m) + \delta_{in}\, in(m)\right)^{\beta} \qquad (3)$$

The values of *b*, δ_{in} and δ_{out} are chosen small enough to keep the value in parenthesis below 1, so $\beta > 1$ will do the trick.[8]

4.7

In its present form, the visibility function leads to a "preferential attachment": any new message will reference the most visible messages with a high probability. However, this would immediately lead to a power law distribution of visibility, with the oldest messages becoming hubs (Barabási 2003). To avoid such an unrealistic "winner-takes-all" situation, message ageing is used as a parameter that makes it possible to support new messages:

$$vis_t(m) = \left(b + \frac{\delta_{out}\, out(m) + \delta_{in}\, in(m)}{age(m)^{\alpha}}\right)^{\beta} \qquad (4)$$

with α determining the degree of ageing. By ageing, the visibility of messages not being supported by links from other messages decreases in time. This models the idea that if a document is not noticed by more recent documents, it seems to be unimportant for the current discussion. Here, α simply controls the "speed" of ageing.

4.8

It is useful to weigh references according to the visibility of the message which set them. We introduce weighted references in both directions from successors and predecessors to get a more "realistic" visibility function:

$$vis_t(m) = \left(b + \frac{\delta_{Out} vis_{t-1}(Out(m)) + \delta_{In} vis_{t-1}(In(m))}{age(m)^{\alpha}} \right)^{\beta} \quad (5)$$

with $vis_t(M)=\Sigma vis_t(m)$, $In(m)$ the set of messages referencing m and $Out(m)$ the set of messages being referenced by m.

Communication Styles and Forms of Media

Viewing Visibility Patterns as Communication Styles

5.1

Pattern reconstruction in communication processes is a demanding task. With COM/TE, communication patterns can be extracted from value distributions of social visibility. However, analysing data distributions based on a structural value such as visibility will not do, unless we know what we are actually looking for. What we are looking for is a set of communication styles which is said to be typical of a certain domain of social reality, such as scientific communication. Based on empirical findings, different citation practices have been reported in the humanities, the social sciences, and the natural sciences (Lesk 1997).

5.2

Taking these findings as a typology, three ideal types can be distinguished: (1) Modernist style: papers in the computer sciences typically refer to the most recent texts and avoid quoting papers more than five years old; (2) Classicist style: publications in sociology typically refer to classic works such as Mead's *Mind, Self, and Society* or Luhmann's *Social Systems*; (3) Historicist style: publications in history and theology typically refer to extremely old documents or foundational texts such as the Bible. In an idealized sense, a communication style may therefore be characterized by its focus of attention and, consequently, by repeatedly re-occurring "anomalies" in its visibility distribution: How many messages are visible (with a visibility $vis(m)>vis_{threshold}$)[9] and where are they located or clustered?

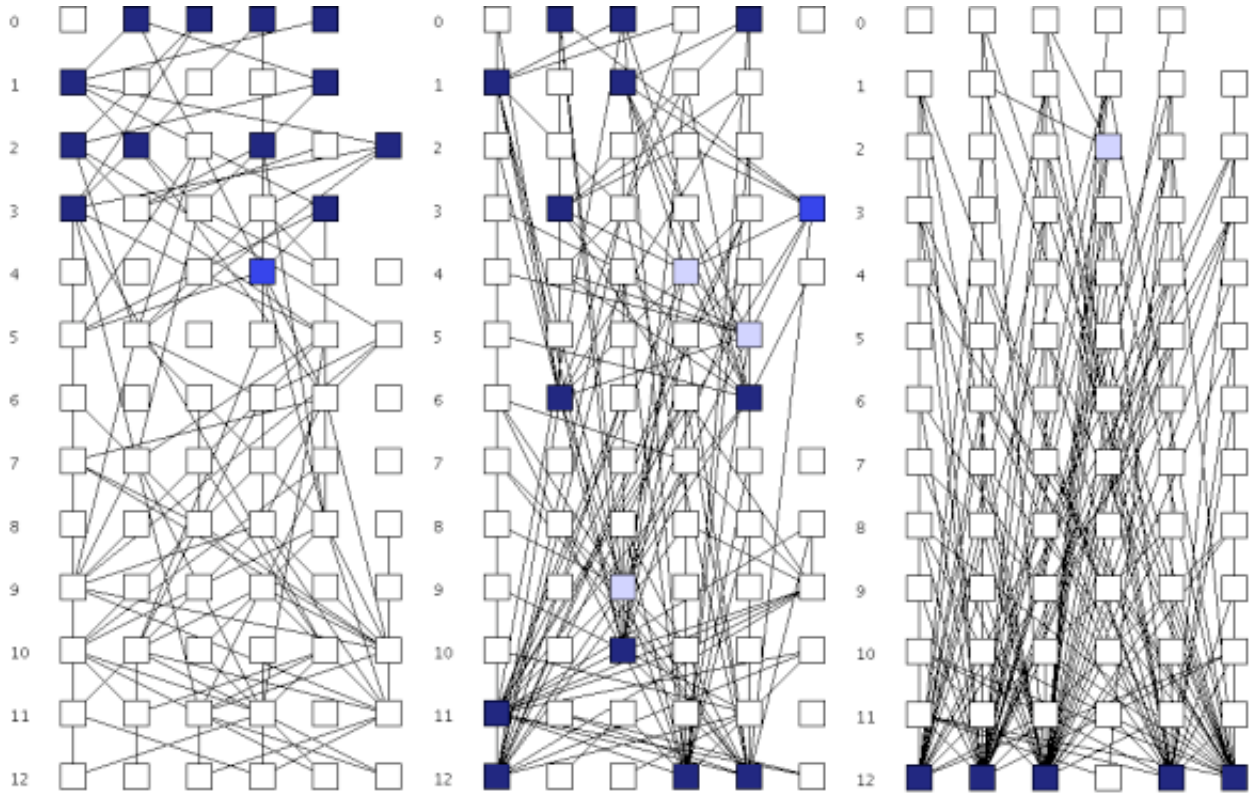

Figure 2. Modernist, Classicist and Historicist patterns. The most visible messages are clustered in the last few time steps (modernist, left network), in the oldest time step (historicist, right network) or are fairly distributed (classicist, middle network)

Modernist Style

5.3

The modernist style of communication matches the practice of citation in the natural sciences and computer sciences and focuses its attention on messages produced within the last few time steps. Accordingly, visible messages are clustered at the upper present end of the communication process. Since attention is always triggered by the "latest news", messages as they grow older gradually lose their visibility.

Classicist Style

5.4

The classicist style is defined by a "fair" distribution of visibility throughout the process. There are no strong clusters of visible messages concentrating at the beginning (past) or the end (present) of the process. Attention is selectively triggered by some message highlights which seem to be quite independent of their date of publication. "Classics" may appear at any time and sometimes they may stabilize their status against temporal decay.

Historicist Style

5.5

Inspired by the data on citation practice in theology and history, what we call the historicist style of communicative attention apparently focuses on the past, that is, the first few generations of the process. While visible messages are clustered at the lower end, we assume that "foundational texts" remain visible over the whole temporal length of the communication process by attracting most of the references, over and over again.

5.6

With its broad and abstract definition of communication styles, our typology covers a wide range of different empirical communication processes. However, a word of caution should be given regarding the expressiveness of such a broad and abstract definition. We do not claim that our typology is valid for all kinds of empirically observable communication processes. Indeed, visibility patterns and other possible regularities are manifold and often cannot be boiled down to three ideal types. Online forums are just one example of socio-technical communication among many others which demonstrate that more than one pattern of referencing can be generated from the same sort of communication process. In online forums, the "interactivity" between messages (Rafaeli and Sudweeks 1997)[10], sometimes is highest in the latest cycles of a proceeding thread (modernist style), while in other threads also older messages are referenced. This leads to a kind of intermediate pattern of visibility and message connectivity (a hybrid style) which is not covered by an ideal typology consisting of three types only. Figure 3 illustrates how hybrids are located between ideal patterns.

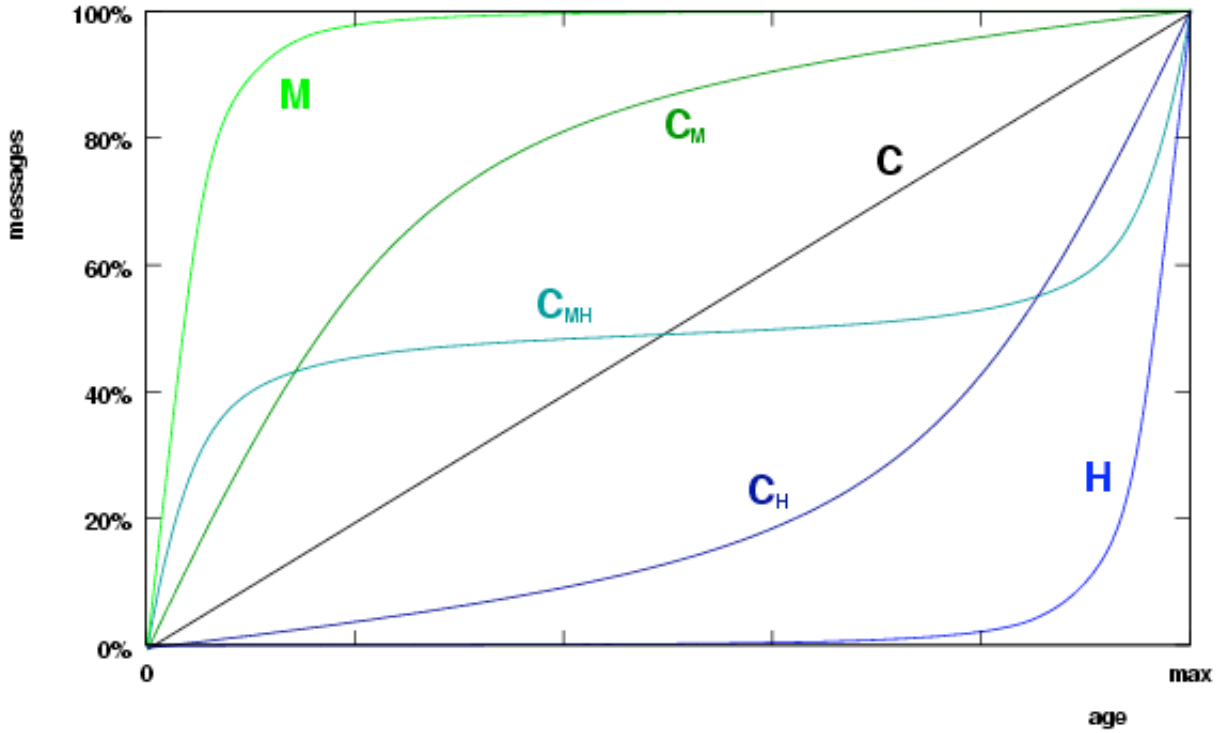

Figure 3. Distribution of visible messages. The summed percentage of visible messages up to a certain age is shown. H indicates the historicist pattern with no visible messages of low age. M, in contrast, indicates the modernist pattern and in between, several classicist patterns with visible messages distributed over the whole length are shown

Design of the Simulation Study

6.1

By changing the parameters of COM/TE's visibility function, processes and patterns of communication can be simulated which resemble the styles described above. Moreover, it is possible to detect these patterns along with their hybrid forms by analysing how visible messages are distributed over time (Figure 3). It is interesting to note that communication styles usually do not emerge in a pure form. Rather we find hybrid or intermediate forms like a historicist-like classicist style with a cluster of highly visible messages in the oldest generations; a modernist-like classicist style with a cluster in more recent generations; or a historicist-modernist style with two clusters of visible messages at the beginning and at the end of an episode but without any visible messages in-between. Figure 4 shows the distribution of visible messages after 1000 generations for three sets of parameters (40 iterations) with about 5500 messages.

Table 1: Parameter sets

	M	**C**	**H**
δ_{In}	20.000	1000.000	60.000
δ_{Out}	1.000	0.500	0.002
b	0.400	0.023	0.700
α	1.000	1.150	1.000
β	8.000	8.000	8.000

The parameter sets in **M**, **C,** and **H** (Table 1) will be referred to as "standard" in the following sections. For all communication processes there are $m \in \{3,\ldots,8\}$ messages with $r \in \{1,\ldots,4\}$ references created in each time step. However, it is important to note that no messages are deleted and no receptions are set ($c=0$) in our standard setting. While the standard parameter sets in **M** lead to modernist-style communication patterns with a small variance, **C** generates classicist-style patterns with a modernist touch and a much larger variance, while **H** generates a

historicist-style pattern together with a small modernist cluster but with almost no visible messages in-between. As we will see below, this style of communication can be transformed into a pure historicist-style pattern.

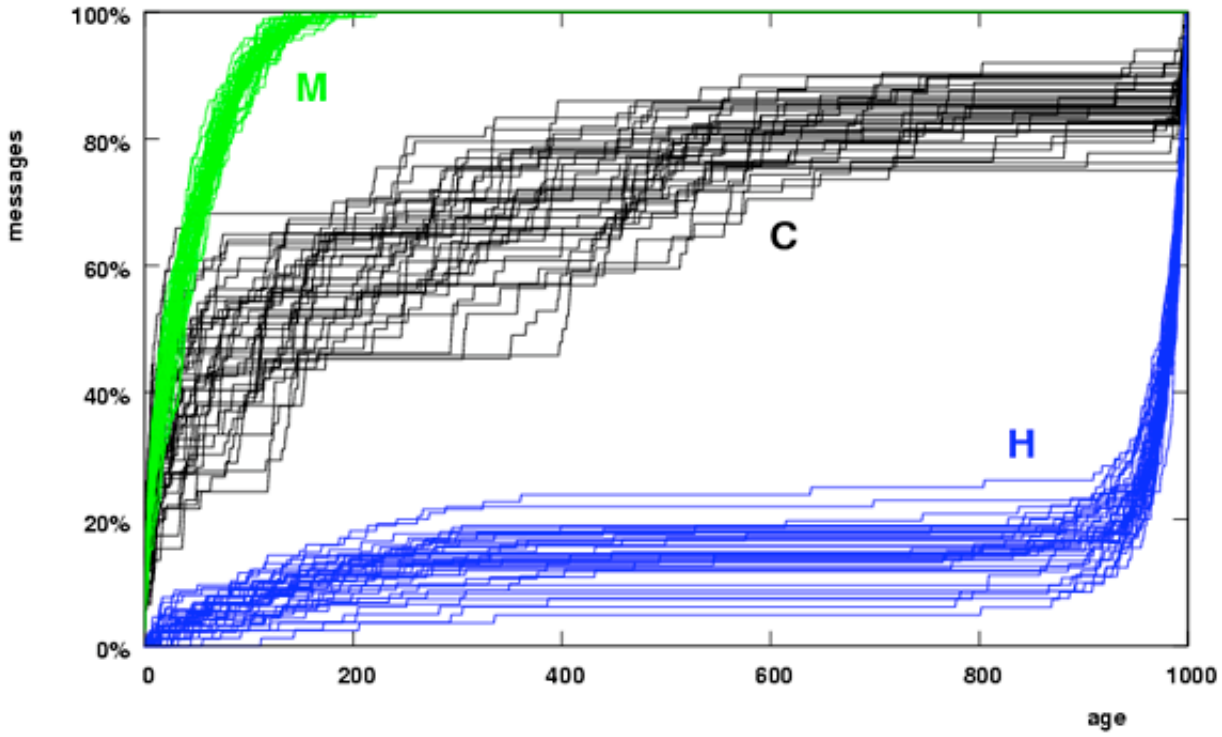

Figure 4. Distribution of visible messages. Three different sets of parameters with 40 runs each over 1000 generations resembling the modernist, classicist and historicist patterns

6.2 Media Forms as Environmental Conditions

The communication patterns introduced above are based solely on the parameters of the visibility function, COM/TE's descriptive part. But what happens to these patterns if the parameters of the distribution function, COM/TE's generative part, are changed by assuming more realistic conditions and making it possible for receptions to outnumber the amount of references and message deletion leading to accelerated message turnover? What happens, in other words, if we start to exploit COM/TE's potential for temporalisation and amplification? Considering different environmental conditions or different communication media, we want to find out whether the combined effect of deletion and reception stabilizes or destabilizes our patterns of communication, generates new patterns, or produces chaos and decay. What we consider is:

- The ratio of reference and reception: with this ratio, the difference between an inception (producing a reference) and a reception (an inception's precondition) is modelled. A high reference/reception ratio means that many receptions do not trigger new messages. A low ratio means that most receptions trigger new inceptions.
- Message persistence and cut-off points: persistence is expressed by the two cut-off points introduced above, accounting for age and visibility. Persistence accounts for the fact that, under certain conditions, messages are forgotten from one moment to the next (for example, small talk), while under other conditions they are stored and kept accessible for a long time.

6.3

By cross-tabulating both dimensions, we can distinguish four kinds of environmental media: (i) Archive-based communication features highly persistent messages with a large number of receptions which exceed the number of messages drastically. (ii) Receptions in mass media communication also exceed the number of messages enormously, but message persistence is low since referencing is restricted to the latest news. (iii) In contrast, message persistence in scientific communication is high, whereas the number of messages is not drastically exceeded

by receptions. (iv) In face-to-face communication message persistence is extremely low, while the number of receptions is not much higher than the amount of new message references.

Table 2: Media forms

		Reference/reception ratio	
		High $c \in \{268,\ldots 281\}$	Low $c \in \{27,28\}$
Message persistence	High $t_{del}=500$, $vis_{del}=0.01$	(i) Archive-based communication	(ii) Scientific communication
	Low $t_{del}=50$, $vis_{del}=0.39$	(iii) Mass media communication	(iv) Face-to-face communication

6.4

We chose the following parameter settings for our simulations:

- High reference/reception ratio: for each reference produced between two messages, 20 receptions are made. This 1:20 ratio is expressed in the distribution function by choosing a minimum number of receptions of $c_{min}=268$ and a maximum of $c_{max}=281$.
- Low reference/reception ratio: for each reference two receptions are made. In each round $c_{min}=27$ or $c_{max}=28$ receptions are distributed between the messages.
- High message persistence: messages are deleted only if they are older than $t_{del}=500$ generations having a visibility equal to or lower than $vis_{del}=0.01$.
- Low message persistence: messages are deleted after $t_{del}=50$ generations having a visibility equal to or lower than $vis_{del}=0.39$ and less.

6.5

The reference-reception distance was not varied: $t_c=3$.

6.6

In the following section we describe the three patterns under the influence of the different environmental conditions which are evaluated in 40 runs with 1000 generations for each setting. Figures 5 to 7 show the distribution of visible messages (in percentage terms) for the different communication styles[11], while Table 3 provides the average of the interesting statistical values of these runs with a more detailed view than given in the following Figures 5 to 7.

Table 3: Average of 40 runs with 1000 generations

		Standard	high r/r-ratio, high persistence	low r/r-ratio, high persistence	high r/r-ratio, low persistence	low r/r-ratio, low persistence
number of messages	*Modernist*	5492	2748.9	2750.9	313.8	286.3
	Historicist	5498.9	5485.9	5500.9	346.6	303.4
	Classicist	5502.3	2770.3	2759.2	306.2	294.8
number of visible messages ≥ 0.4	*Modernist*	123.9	119.4	68.4	121.3	67.6
	Historicist	88.9	64.7	21.6	84.3	38.2
	Classicist	51.7	50.9	35	51.2	36.4
average visibility	*Modernist*	0.023	0.044	0.025	0.381	0.232
	Historicist	0.079	0.069	0.061	0.278	0.173
	Classicist	0.009	0.018	0.012	0.165	0.122
number of	*Modernist*	13711	6119.9	4455.6	594.8	383.3

references						
	Historicist	13726.9	7439.4	2523.2	685.7	435.7
	Classicist	13765.9	5858.5	5406.6	699.4	594.5
1. Quartile	*Modernist*	7.1	6.9	4.4	6.8	4.1
	Historicist	936.5	967.8	990	70.9	77.7
	Classicist	22.8	13.1	15.6	25.2	14.8
2. Quartile	*Modernist*	27.4	27	19.2	26.2	19.5
	Historicist	982.1	985.6	995.4	173.1	149.2
	Classicist	166.3	127.3	126.8	134.9	105.1
3. Quartile	*Modernist*	61.2	61	49	56.6	46.5
	Historicist	993.4	994.3	998.2	347.6	285.5
	Classicist	497.9	442.8	390.1	430.7	324.8
rounds between first and last visible message	*Modernist*	174.5	168.9	141.9	162.1	141.4
	Historicist	987.5	652.5	52.7	922.3	641.1
	Classicist	1000	1000	999.9	999.6	999.9
		1	**2**	**3**	**4**	**5**

Message Persistence and the Modernist Pattern

6.7

Analysing the impact of different media forms on the modernist pattern, it is obvious that this communication style is hardly affected by the environmental conditions of the referencing process in our simulations. As shown in Figure 5, the pattern always maintains its typical shape. Comparing the results of the four simulations, message persistence influences the modernist pattern in an expected way — for example, on average, the length of the pattern decreases with more restrictive cut off-points. (2) In case of the high reference/reception ratio and high message persistence simulation setting, the modernist pattern maintains its typical shape, although it has shortened a bit in length which means that it has become slightly "more" modernist. (3) Interestingly, the low reference/reception ratio in combination with high message persistence shortens the modernist pattern far more, without changing the average visibility, however. (4) The average visibility drastically increases with choosing a high reference/reception ratio and a low message persistence, but the length of the pattern stays quite constant compared to the high reference/reception ratio and high message persistence setting. Nevertheless, one is able to observe a kind of concentration process, with the most visible messages being clustered in the most recent generations, while only one to two single visible messages remain in those generations that make up the end of the visible pattern (oldest cycles). (5) A similar trend is observable in the last setting. Combined, the low message persistence and low reference/reception ratio always "push" the communication process towards a "more" modernistic style which is typical of forms of oral communication that do not allow infinite access to messages. Face-to-face interactions are one example of forms of communication that shape the process of referencing in a modernist style. Generally speaking, this is due to the normally limited possibilities of message storage, the limited cognitive capacities of participants, and the need to keep going to avoid the abortion of the conversation.

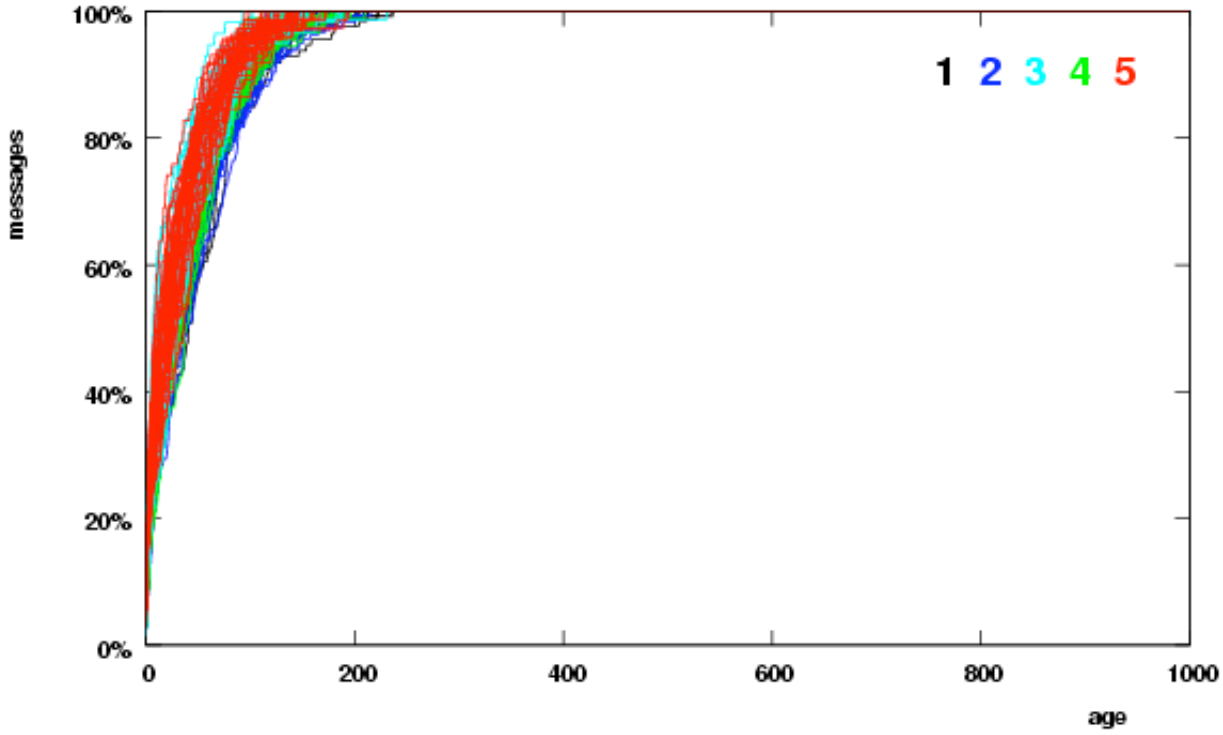

Figure 5. Distribution of visible messages for the modernist style (M) parameter set. Colours correspond to the different parameters for reception and deletion (see Table 3)

Message Persistence and the Classicist Pattern

6.8

Surprisingly, changes in the simulation setting influence the classicist pattern in a similar way to the modernist pattern. The pattern length spans the whole 1000 rounds in almost every simulation run, indicating that the pattern is robust under all environmental conditions. This was an unexpected result because one might easily assume that low message persistence would generally lead to a modernist pattern/bias. Technically speaking, the classicist pattern is stable even under high message deletion. But simulation runs show a greater variance compared to the modernist setting. (2) A high reference/reception ratio, together with a high message persistence, reinforces the modernist tendency within the classicist pattern. The first, second, and third quartiles are reached slightly earlier than with the standard setting, while the amount of highly visible messages remains constant on average. (3) A low reference/reception ratio and a high message persistence lead to similar results, displaying a reinforcement of the modernistic tendency during the first and second quartiles, while the number of visible messages decreases drastically. (4) A high reference/reception ratio, combined with a low message persistence, produces the highest average visibility measured for the classicist pattern, while the absolute number of visible messages throughout 1000 rounds is still 50. (5) A low reference/reception ratio and a low message persistence produce the most "modernistic" classicist pattern. All in all, the general course of the graph is quite similar under all parametric or environmental conditions. Generally, it can be concluded that communication media which do not attract many listeners or readers tend to produce smaller amounts of visible messages, with smaller numbers of average references and a smaller average visibility in the classicist pattern, while the number of invisible messages and holes (rounds without a visible message) increases.

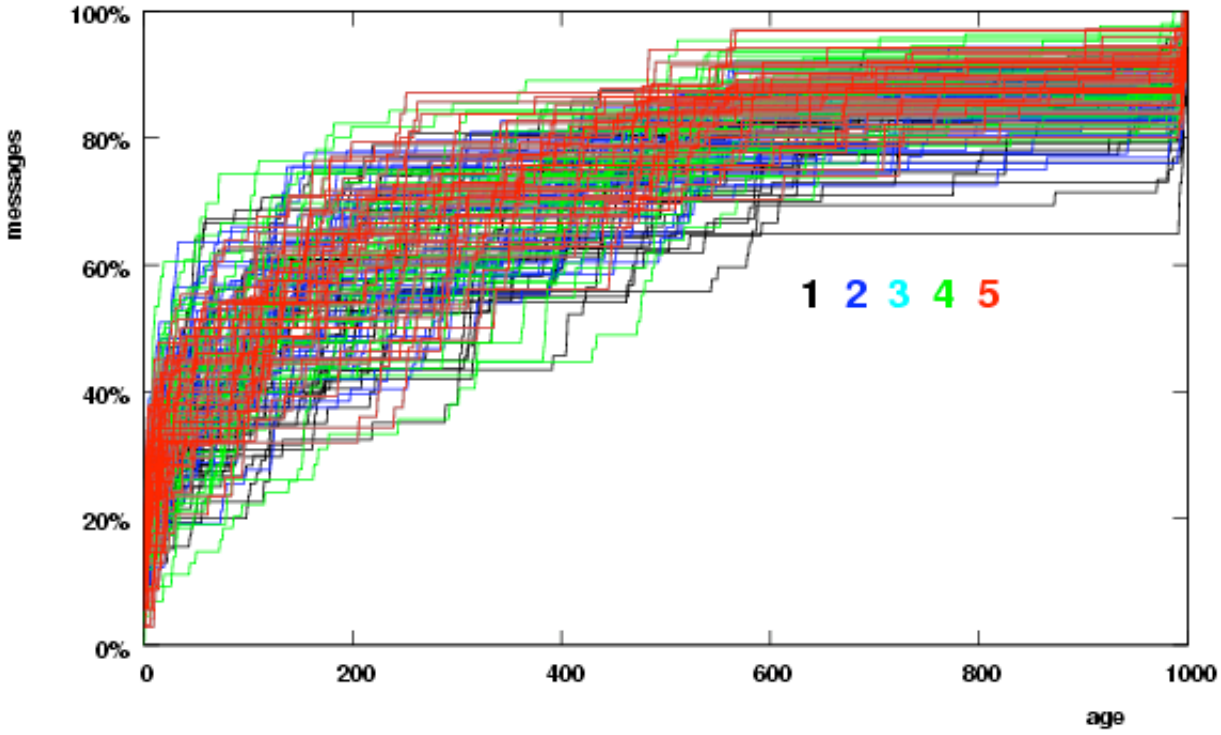

Figure 6. Distribution of visible messages for the classicist style (C) parameter set. Colours correspond to the different parameters for reception and deletion (see Table 3)

Message Persistence and the Historicist Pattern

6.9

As expected, in contrast to the modernist and classicist patterns, changes in the settings have a deep impact on the historicist pattern. (2) Combining a high reference/reception ratio with high message persistence leads to a historicist pattern that is shorter and steeper. Thus the historicist style is stabilized, but with fewer visible messages, which indicates a kind of centralization of the network. (3) A low reference/reception ratio and a high persistence strengthen this effect. Again, the resulting pattern is shorter and steeper and the historicist style is strongly reinforced. However, the amount of visible messages is further reduced so that the emerging historicist pattern is extremely short, while the time-span of visible messages is relatively small. As depicted in Figure 7, the distribution comes very close to the ideal type of an historicist pattern. (4) In sharp contrast, a high reference/reception ratio and low persistence lead to the destruction of the historicist pattern. Instead of being clustered in the earliest period of the process, as in the original historicist setting, visible messages are scattered all over the process which tends to be stretched in length. (5) Similarly, a low reference/reception ratio, combined with a low message persistence, also destroys the historicist pattern. In comparison with the previous distribution, this one looks slightly more modernist and is shorter in length. Interestingly, both historicist settings exposed to low persistence degrade gracefully after about 500 rounds in simulation experiments with 1000 rounds: they just stop producing noteworthy amounts of visible messages. This is a clear indication that the historicist pattern cannot be maintained when it has been trapped in a vicious circle beginning with rapid deletion and turnover of messages, leading to diminishing amounts of attractable receptions, diminishing visibility, further deletions, and so on.

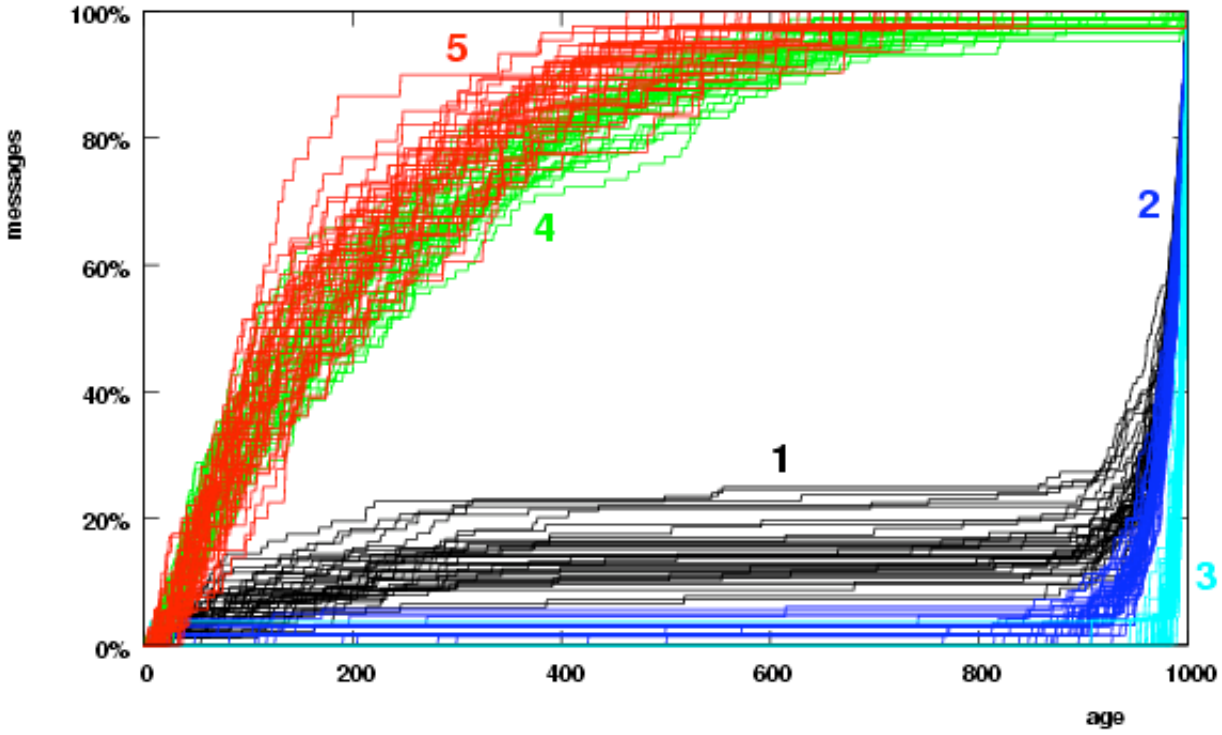

Figure 7. Distribution of visible messages for the historicist style (H) parameter set. Colours correspond to the different parameters for reception and deletion (see Table 3)

6.10 Conclusions

If we compare the influence of environmental conditions on our three original communication patterns, some interesting differences can be observed.

1. By and large, the modernist and the classicist pattern both keep their typical shape for all simulation settings. Regarding the modernist pattern this is not an astonishing observation, since modernist patterns can easily subsist in different social environments. As a result of being permanently confronted with the relevance of the latest news in everyday life, a lot of communicative attention is concentrated on what is new and different. As soon as a focus on recency is established and consolidated, communication is likely to pursue a modernist track. On the Internet, modernist styles of communication can be observed in the blogosphere. Here the communication is usually driven by the latest news, although weblogs provide archives to keep older postings accessible. However, the physical accessibility of older messages does not mean that the focus of attention changes quickly. Online (chat) and face-to-face interactions are further examples of media forms that support a modernist style of communication. Because of a low reference/reception ratio and low message persistence, conversations tend to focus on what has been said in the last few time steps. Another example is news broadcasting which triggers the emergence of communication processes that are characterized by novelty, topicality, and difference. And even in scientific communication some sciences refer mainly to the most recent publications, as in the natural or computer sciences.
2. As we have seen, the classicist pattern too is largely maintained and has been easily reproduced under different simulation settings. Examples of a classicist style can be found in scientific communication (sociologists quoting their classic texts, see above) or in archive-based newsgroup discussions which refer to key postings repeatedly. In all sorts of ongoing discussion forums, online or otherwise, it is an important task of facilitators or moderators to refer to and to highlight important contributions again and again to keep them referable as key messages, so that they eventually become "classics". While such communicative mechanisms are not unusual for some types of direct personal communication, they are not easily substituted in mass media. The existence of a classicist pattern seems to be highly unusual. In the most exceptional cases there might occur some classic messages but at the core of attention will usually be the most recent publications, leading to a hybrid pattern with a strong modernistic touch.

3. Contrary to the first two patterns, the historicist style of communication is strongly affected by the massive deletion of old and invisible messages. Low message-storing abilities destroy the original pattern and transform it into something which roughly resembles a classicist pattern with a strong modernistic bias. High message-storing abilities, on the other hand, strongly reinforce the historicist style, especially when coupled with a low ratio of receptions to references to produce a pure historicist pattern. To illustrate these findings, we can refer to the different media types mentioned above. While historicist modes of communication are plausible to a certain degree for scientific communication (in the case of text-based sciences like history and theology) and archive-based communication, the pattern dissolves when media conditions are introduced that resemble either face-to-face interactions or mass-media communication. The outcome of a deteriorated historicist pattern looks like a mixture of classicist and modernist styles of communication. Generally speaking, historicist communication styles are unlikely to appear in interactions with their turn-taking structure, nor will we expect to observe them in mass media due to their weak message-preserving ability.

Discussion and Future Work

7.1

In this paper, we have presented COM, a theoretical framework for modelling message reference networks with messages and references representing the nodes and edges of the network. What is new in COM in contrast to other network approaches is that messages and references are modelled taking into account the temporal dynamic of the communication process (time-based approach). At the process level of communication we have introduced the social visibility of messages as a concept of reputation. Based on the concept of social visibility we have developed our test environment COM/TE which is suitable for analysing large-scale communication processes and simulating emergent patterns of visibility at the structural level of communication.

7.2

As we have shown, message visibility makes it possible to discriminate various communication patterns (modernist, classicist, historicist, and intermediate or hybrid patterns). Using the distribution function, the generative part of the framework, we demonstrated how these patterns behave under different environmental conditions, including different reference/reception ratios and message deletion. The latter is simulated by the introduction of cut-off points which depend on a message's visibility and age. Equipped with these concepts, COM/TE is a highly extendable simulation framework. It is able to cope with social complexity and offers the possibility of generating sociologically sound and interesting hypotheses which focus on the temporal aspects of communication.

7.3

Based on COM and COM/TE, message reference networks pave the way for a temporal understanding of emergent communication patterns. In this paper we have tacitly assumed that receptions are message attributes. In our future work we will re-model COM/TE on the assumption that receptions, just like inceptions, are independent selections. Modelling these two concepts independently should help us, for example, to obtain new insights into evolutionary system dynamics based on conflicts and conflict resolution.

7.4

Additionally, we will draw more attention to the concept of typed messages, that is, attaching certain fixed attributes such as keywords, topics or authors to each message. From message authors it is just a short step to the introduction of a pending new concept: an explicit author network that can be used to determine which authors will inceive a message at which time, together with whom, and which messages from which authors will be cited. Based on this author concept we are currently developing a JADE-based multi-agent system to enable us to simulate agent-driven mass communication processes.

7.5

Process visualization is another area of our current research. Good visualizations are needed not only to help researchers to detect interesting communication patterns, but also to support

users who are navigating in mass communication networks and would like to find interesting starting points for joining a discussion. It should be noted here that COM/TE is meant to be more than a sophisticated tool for scientific purposes. In providing a powerful selection mechanism, COM/TE has the potential to assist human actors (or artificial agents) to cope with information overload on the Web, by providing the "reader's view" with information about the social visibility of messages as the main criterion for information selection in different fields of application, such as citation analysis or online discussions.[12] This may help authors to decide how to publish and connect new messages successfully, pushing the communication process forward. Developing COM/TE with regard to the agent's selection problem, the simulation tool can be transformed into a powerful software application which can be used for observing and understanding the courses of large-scale online communication processes to support publication decisions.

Notes

[1] COM (communication-oriented modelling) is funded by the German Research Society (DFG) as a project of the Socionics Priority Program 1077 — cf.Malsch and Schlieder 2004, Albrecht et al. 2005, Malsch 2005 and http://www.tu-harburg.de/tbg/. The COM simulation tool COM/TE is available via http://www.kinf.wiai.uni-bamberg.de/COM/. Note that we do not deny that society "in reality" is made up of interacting human beings and is, of course, unable to exist without them. What is at stake, however, is how to explain social phenomena "in theory". And here the individual actor or human action may not be the best candidate.

[2] The original meaning of "inception" is "to begin", "to enact", or "to found". Here, in our theoretical context, inception is the beginning of something which is expected to happen afterwards: it denotes a reception as the next complementary operation needed to continue the communication process.

[3] This is an example of social visibility in the process of scientific communication: both publications appeared in the same journal. The paper by DeSolla Price was not cited by Barabási and Albert, thus we conclude that it was not visible for the follow-up paper nor for the current scientific discourse.

[4] These "translations" of social visibility have to be used with caution because they inherit value-judgments (for example, credibility).

[5] In the simulation design currently being used, the number of receptions a message receives does not influence its visibility directly — receptions only keep the message accessible for later references.

[6] In COM/TE, we limit the visibility of a message to the interval [0,1], greater values are cut off. In the following sections any function calculating the visibility of a message $vis(m)=f(m)$ has to be read as $vis(m)=\min\{1,f(m)\}$. This is for the sake of readability.

[7] In many communication processes $\delta_{in}>\delta_{out}$ reflects the fact that the references a message obtains have a greater impact on its visibility than the references it establishes.

[8] Otherwise, $vis(m)$ will be cut off anyway.

[9] In our setting $vis_{threshold}$ is 0.4: every message with a visibility smaller than 0.4 is counted as being invisible.

[10] "Interactivity is not a characteristic of the medium. It is a process-related construct about communication. It is the extent to which messages in a sequence relate to each other, and especially the extent to which later messages recount the relatedness of earlier messages" (Rafaeli and Sudweeks 1997).

[11] The distribution is shown in percentage terms, therefore changes in density of visible

messages do not show up in the figures but only in the statistical values.

[12] For an application of COM at the micro level of Multiagent Systems (MAS) cf. Stein and Schlieder 2005.

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