% \*\*\*\*\*\* Start of file aipsamp.tex \*\*\*\*\*\*

%

% This file is part of the AIP files in the AIP distribution for REVTeX 4.

% Version 4.1 of REVTeX, October 2009

%

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% Use this file as a source of example code for your aip document.

% Use the file aiptemplate.tex as a template for your document.

\documentclass[%

aip,

jmp,%

amsmath,amssymb,

%preprint,%

reprint,%

%author-year,%

%author-numerical,%

]{revtex4-1}

\usepackage{graphicx}% Include figure files

\usepackage{grffile}

\usepackage{dcolumn}% Align table columns on decimal point

\usepackage{bm}% bold math

%\usepackage[mathlines]{lineno}% Enable numbering of text and display math

%\linenumbers\relax % Commence numbering lines

\usepackage{multirow}

\usepackage{color} % for the notes

\usepackage{etex}

\reserveinserts{58}

%\usepackage{morefloats}

\usepackage{hyperref}

\usepackage{xcolor}

\usepackage{amsmath}

\hypersetup{

colorlinks,

linkcolor={red!50!black},

citecolor={blue!50!black},

urlcolor={blue!80!black}

}

\maxdeadcycles=1000

\begin{document}

\preprint{XXXXX (preprint)}

%\title[Evolution of interaction networks]{On the evolution of interaction networks: primitive typology of vertex, prominence of measures and activity statistics}% Force line breaks with \\

%\title[Evolution of interaction networks]{On the evolution of interaction networks: a primitive typology of vertex}% Force line breaks with \\

\title[Stability of interaction networks]{Stability in human interaction networks: primitive typology of vertex, prominence of measures and time activity statistics}% Force line breaks with \\

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\date{\today}% It is always \today, today,

% but any date may be explicitly specified

\begin{abstract}

This article reports interaction networks stability by means of three quantitative criteria: activity distribution in time and among participants; a sound classification of vertices in peripheral, intermediary and hub sectors; the combination of basic measures into principal components with greater variance.

We analyzed the temporal activity and topology evolution of networks in four email lists by considering window sizes from 50 to 10,000 messages, which were made to slide to generate snapshots of the network along a timeline. Activity in terms of seconds and minutes exhibit an uniform pattern, while hours, days and months exhibit stable concentrations.

Participant activity follows the expected distribution of scale-free networks.

We compare these networks to Erd\"os-R\'enyi networks in order to assign members to three distinct sectors, namely hubs, intermediary and periphery.

Approximately 5\% of the vertices are hubs, 15-35\% are intermediary and the remainder belongs periphery.

The metrics that most contribute to data dispersion were found to be centrality-related (degree, strength and betweenness), followed by symmetry-related, and then clustering coefficient.

The results also embrace a sketch of a physics-based typology of agents, with proper social and psychological speculations.

Because the network properties reported did not depend on the email list and were stable over time, and because observed structure is in accordance with expectations driven from literature for human interaction networks, we believe that the properties observed are also present in general human interaction networks.

Current unfoldings include governance and accountability proposals and implementations, anthropological physics experiments, audiovisual reconnaissance, and the report of quantitative differences of textual production as connectivity of agents changes.

\end{abstract}

\pacs{89.75.Fb,05.65.+b,89.65.-s}% PACS, the Physics and Astronomy

\keywords{complex networks, social network analysis, pattern recognition, statistics, anthropological physics}

\maketitle

\begin{quotation}

`The reason for the persistent plausibility of the typological approach, however, is not a static biological one, but just the opposite: dynamic and social. The fact that human society has been up to now divided into classes affects more than the external relations of men. The marks of social repression are left within the individual soul.'

% `The conception of personality structure is the

%best safeguard against the

% inclination to attribute persistent trends in the

% individual to something

% "innate" or "basic" or "racial" within him. The

% Nazi allegation that natural, biological traits decide the total being of a % person

% would not have been such

% a successful political device

% had it not been possible to point to numerous

% instances of relative fixity in human behavior and to

% challenge those who

% thought to explain them on any basis other than a biological one.'

\emph{- Adorno et al, 1969, p. 747}

\end{quotation}

\section{Introduction}\label{sec:into}

Studies on human interaction networks have started long before modern computers, dating back to the nineteenth century, while the foundation of

social network analysis is generally attributed to the psychiatrist Jacob Moreno~\cite{newmanBook}. With the increasing availability of data related to human interactions, research on these networks has grown continuously. Contributions can now be found in a variety of fields in the literature, from social sciences and humanities~\cite{latour2013} to computer science~\cite{gmane} and physics~\ref{barabasiHumanDyn,newmanFriendship}, given the multidisciplinary nature of the topic. One of the approaches from an exact science perspective is to represent interaction networks as complex networks [gmane,barabasiHumanDyn,newmanFriendship], with which

several features of human interaction have been revealed. For example, the topology of human interaction networks exhibits a scale-free trace, which points to the existence of a small number of highly connected hubs and a large number of poorly connected nodes. The dynamics of complex networks representing human interaction has also been addressed ~\cite{barabasiEvo,newmanEvolving}, but only to a limited extent, since research is normally focused on a particular metric or functionality, such as accessibility or community detection~\cite{access,newmanModularity}.

In this paper we analyze the evolution of human interaction networks, by considering interaction in email lists as their representative. Using a timeline of activity snapshots with a constant number of contiguous messages in email lists, we found a remarkable stability for several of the network properties. Because this stability was shared by all email lists, we advocate that some of the conclusions can be valid for more general classes of interaction networks. In particular, this allows us to discuss typologies in the context of such networks, in an attempt to bridge the gap between approaches based solely on data analysis (i.e. from a hard sciences perspective) and those relevant to the social sciences. This is important insofar as typologies are the canon of scientific literature for classification of human agents~\cite{typCanon}.

The paper is organized as follows. Section~\ref{sec:related} describes related work, while details of the data and methods of analysis are given in Section~\ref{sec:data} and Section~\ref{sec:carac}. Section~\ref{sec:results} brings the results and discussion, leading to Section~\ref{sec:conc} for conclusions and further work.

\subsection{Related work}\label{sec:related}

Works on network evolution often consider solely network growth, in which there is a monotonic increase in the number of events considered~\cite{barabasiEvo}. Exceptions are reported in this section, with emphasis on those more closely related to the present article.

The evolution of human interaction networks was addressed with a community focus, where the direction of edges was not taken into account~\cite{barabasiEvo}. Two topologically different networks emerged from human interaction networks, depending on the frequency of interactions, which can either be a generalized power law or an exponential connectivity distribution~\cite{barabasiTopologicalEv}. In email list networks, scale-free properties were reported with $\alpha=1$~\cite{bird} (as are web browsing and library loans~\cite{barabasiHumanDyn}), and different linguistic traces were related to weak and strong ties~\cite{GMANE2}.

Unreciprocated edges often exceed 50\% in the networks analyzed, which matches empirical evidence from the literature~\cite{newmanEvolving}. No correlation of topological characteristics and geographical coordinates was found~\cite{barabasiGeo}, therefore geographical positions were not considered in our study. Gender related behavior in mobile phone datasets has been reported~\cite{barabasiSex}, but this was not considered in the present article because email messages and addresses have no gender related metadata~\cite{GMANE}.

\section{Data description: email lists and messages}\label{sec:data}

Email list messages were obtained from

the GMANE email archive~\cite{GMANE}, which consists of more than 20,000 email lists and more than 130,000,000 messages~\cite{GMANEwikipedia}. These lists cover a variety of topics, mostly technology-related. The archive can be described as a corpus with metadata of its messages, including sent time, place, sender name, and sender email address.

The GMANE usage in scientific research is reported in studies of isolated lists and of lexical innovations~\cite{GMANE2,bird}.

We analyzed many email lists, but selected only four in order to make a thorough analysis, from which general properties can be inferred. These lists, selected as representing both a diverse set and ordinary lists, are:

\begin{itemize}

\item Linux Audio Users list\footnote{gmane.linux.audio.users is list ID in GMANE.}, with participants holding hybrid artistic and technological interests, from different countries. English is the language used the most. Abbreviated as LAU from now on.

\item Linux Audio Developers list\footnote{gmane.linux.audio.devel is list ID in GMANE.}, with participants from different countries, and English is the language used the most. A more technical and less active version of LAU. Abbreviated LAD from now on.

\item Development list for the standard C++ library\footnote{gmane.comp.gcc.libstdc++.devel is list ID in GMANE.}, with computer programmers from different countries. English is the language used the most. Abbreviated as CPP from now on.

\item List of the MetaReciclagem project\footnote{gmane.politics.organizations.metareciclagem is list ID in GMANE.}, with Brazilian activists holding digital culture interests. Portuguese is the most used language, although Spanish and English are also incident. Abbreviated MET from now on.

\end{itemize}

The first 20,000 messages of each list were considered, with total timespan, authors, threads and missing messages indicated in Table~\ref{tab:genLists}.

\begin{table}

\centering

\caption{Columns $date\_1$ and $date\_M$ have dates of first and last messages from the 20,000 messages considered in each email list.

$N$ is the number of participants (number of different email addresses).

$\Gamma$ is the number of threads (count of messages without antecedent).

$\overline{M}$ is the number of messages missing in the 20,000 collection, $100\frac{23}{20000}=0.115$ percent in the worst case.

A relation holds for all lists carefully considered: as the number of participants increases, the number of threads decreases.

This underpins a typology sketch of networks, as discussed in Section~\ref{sec:pty}.}

\label{tab:genLists}

\begin{tabular}{|l|c|c|c|c|c|}\hline

list & $date\_1$ & $date\_{M}$ & $N$ & $\Gamma$ & $\overline{M}$ \\\hline

\input{tables/tab1Geral}

\end{tabular}

\end{table}

\section{Characterization methods}\label{sec:carac}

The email lists and the networks generated from them were characterized by using five procedures, namely: 1) statistics of activity along time, from seconds to years; 2) sectioning of the networks in hubs, intermediary and peripheral vertices; 3) topological metrics and their dispersion; 4) iterative visualization and data mining; 5) typological speculation about networks and participants.

Each of these procedures are described below.

\subsection{Time activity statistics}\label{sec:mtime}

Messages were counted along time with respect to seconds, minutes, hours, days of the week, days of the month, and months of the year. This resulted in histograms from which patterns could be drawn. The ratio $\frac{b\_h}{b\_l}$ between the highest and lowest incidences on the histograms served as a hint of how the observed distribution is compared to a uniform distribution.

The average and the dispersion were taken using circular statistics, in which each $measurement$ (data point) is represented as a complex number with modulus equal to one, $z=e^{i\theta}=\cos(\theta)+i\sin(\theta)$, where $\theta=measurement\frac{2\pi}{period}$. The moments $m\_n$, lengths of moments $R\_n$, mean angle $\theta\_\mu$, and rescaled mean angle $\theta\_\mu'$ are defined as:

\begin{align}\label{eq:cmom}

m\_n&=\frac{1}{N}\sum\_{i=1}^N z\_i^n \nonumber\\

R\_n&=|m\_n|\\

\theta\_\mu&=Arg(m\_1) \nonumber \\

\theta\_\mu'&=\frac{period}{2\pi} \theta\_\mu \nonumber

\end{align}

$\theta\_\mu'$ is used as the measure of location. Dispersion is measured using the circular variance $Var(z)$, the circular standard deviation $S(z)$, and the circular dispersion $\delta(z)$:

\begin{align}\label{eq:cmd}

Var(z)&=1 - R\_1 \nonumber\\

S(z)&= \sqrt{-2\ln(R\_1)}\\

\delta(z)&=\frac{1-R\_2}{2 R\_1^2} \nonumber

\end{align}

\subsection{Interaction networks}\label{intNet}

Interaction networks can be modeled both weighted or unweighted, both directed or undirected~\cite{bird,newmanCommunityDirected,newmanCommunity2013}.

Networks in this article are directed and weighted, the more informative of trivial possibilities, i.e. we did not investigate directed unweighted, undirected weighted, and undirected unweighted representations of the interaction networks.

The networks were obtained as follows: a direct response from participant B to a message from participant A yields an edge from A to B, as information went from A to B. The reasoning is: if B wrote a response to a message from A, he/she read what A wrote and formulated a response, so B assimilated information from A, thus $A \rightarrow B$. Inverting edge direction yields the status network: B read the message and considered what A wrote worth responding, giving status to A, thus $B\rightarrow A$. This article uses the information network as described above and depicted in Figure~\ref{formationNetwork}. Edges in both directions are allowed. Each time an interaction occurs, one is added to the edge weight. Self-loops were regarded as non-informative and discarded. These human social interaction networks are reported in the literature as exhibiting scale-free and small world properties, as expected for (some) social networks~\cite{bird,newmanBook}.

\begin{figure}[!h]

\centering

\includegraphics[width=0.5\textwidth]{figs/criaRede\_}

\caption{Formation of interaction network from email messages. Each vertex represents a participant. A reply message from participant B to a message from participant A is regarded as evidence that B received information from A and yields a directed edge. Multiple messages add ``weight'' to a directed edge. Further details are given in Section~\ref{intNet}.}

\label{formationNetwork}

\end{figure}

Edges can be created from all antecedent message authors on the message-response thread to each message author.

We only linked the immediate antecedent to the new message author, both for simplicity and for the valid objection that in adding two edges, $x\rightarrow y$ and $y\rightarrow z$, there is also a weaker connection between $x$ and $z$. Potential interpretations for this weaker connection are: double length, half weight or with one more ``obstacles''. This suggests the adequacy of centrality measurements to account for the connectivity with all nodes, such as betweenness centrality and accessibility~\cite{luMeasures,access}.

%\subsubsection{Sectioning of networks in peripheral, intermediary and hubs sectors}\label{sectioning}

\subsection{Erd\"os sectioning}\label{sectioning}

In scale-free networks, the peripheral, intermediary and hubs sectors can be derived from a comparison with an Erd\"os-R\'enyi network with the same number of edges and vertices~\cite{3setores}, as depicted in Figure~\ref{fig:setores}. We shall refer to this procedure as \emph{Erd\"os sectioning}, with the resulting sectors being referred to as \emph{Erd\"os sectors} or \emph{primitive sectors}.

The degree distribution $\widetilde{P}(k)$ of an ideal

scale-free network $\mathcal{N}\_f$ with $N$ vertices and $z$ edges has less

average degree nodes than the distribution $P(k)$ of an Erd\"os-R\'enyi

network with the same number of vertices and edges. Indeed, we define in this work the intermediary sector of a network to be the set of all the nodes whose degree is less abundant in the real network than on the Erd\"os-R\'enyi model:

\begin{equation}\label{criterio}

\widetilde{P}(k)<P(k) \Rightarrow \text{k is intermediary degree}

\end{equation}

If $\mathcal{N}\_f$ is directed and has no self-loops, the probability

of an edge between two arbitrary vertices is $p\_e=\frac{z}{N(N-1)}$ (see Appendix~\ref{ap:ded}). (a numeração de figuras, tabelas, apêndices, etc. tem que começar de 1 ou A)

A vertex in the ideal Erd\"os-R\'enyi digraph with the same number of vertices and edges, and thus the same probability $p\_e$ for the presence of an edge, will have degree $k$ with probability:

\begin{equation}

P(k)=\binom{2(N-1)}{k}p\_e^k(1-p\_e)^{2(N-1)-k}

\end{equation}

The lower degree fat tail represents the border vertices, i.e. the peripheral sector or periphery where $\widetilde{P}(k)>P(k)$ and $k$ is lower than any intermediary sector value of $k$. The higher degree fat tail is the hub sector, i.e. $\widetilde{P}(k)>P(k)$ and $k$ is higher than any intermediary sector value of $k$. The reasoning for this classification is: 1) vertices so connected that they are virtually inexistent in networks connected at pure chance (e.g. without preferential attachment) are correctly associated to the hubs sector. Vertices with very few connections, which are way more abundant than expected by pure chance, are assigned to the periphery. Vertices with degree values predicted as the most abundant if connections are created by pure chance, near the average, and less frequent in scale-free phenomena, are classified as intermediary.

\begin{figure}[!h]

\centering

\includegraphics[width=0.5\textwidth]{figs/fser\_}

\caption{Degree distribution of scale-free and Erd\"os-R\'enyi ideal networks. The latter has more

intermediary vertices, while the former has more peripheral and hub vertices. The sector borders are defined by the two intersections $k\_\Leftarrow$ and $k\_\Rightarrow$ of the connectivity distributions. Characteristic degrees

are in compact intervals of degree: $[0,k\_\Leftarrow]$, $(k\_\Leftarrow,k\_\Rightarrow]$, $(k\_\Rightarrow,k\_{max}]$ for the Erd\"os sectors (periphery, intermediary and hubs).}

\label{fig:setores}

\end{figure}

To ensure statistical validity of the histograms, bins can be chosen to contain at least $\eta$ vertices of the real network. Thus, each bin, starting at degree $k\_i$, spans $\Delta\_i=[k\_{i},k\_{j}]$ degree values, where $j$ is the smallest integer with which there are at least $\eta$ vertices with degree larger than or equal $k\_i$, and less than or equal $k\_{j}$. This changes equation~\ref{criterio} to:

\begin{equation}\label{criterio2}

\sum\_{x=k\_i}^{k\_j} \widetilde{P}(x) < \sum\_{x=k\_i}^{k\_j} P(x) \Rightarrow \text{i is intermediary}

\end{equation}

If strength $s$ is used for comparison, $P$ remains the same, but $P(\kappa\_i)$ with $\kappa\_i=\frac{s\_i}{\overline{w}}$ should be used for comparison, with $\overline{w}=2\frac{z}{\sum\_is\_i}$ the average weight of an edge and $s\_i$ the strength of vertex $i$. For in and out degrees ($k^{in}$, $k^{out}$) comparison of the real network should be made with:

\begin{equation}

\hat{P}(k^{way})=\binom{N-1}{k^{way}}p\_e^k(1-p\_e)^{N-1-k^{way}}

\end{equation}

\noindent where \emph{way} can be \emph{in} or \emph{out}. In and out strengths ($s^{in}$, $s^{out}$) are divided by $\overline{w}$ and compared also using $\hat{P}$. Note that $p\_e$ remains the same, as each edge yields an incoming (or outgoing) edge, and there are at most $N(N-1)$ incoming (or outgoing) edges, thus $p\_e=\frac{z}{N(N-1)}$ as with the total degree.

In other words, let $\gamma$ and $\phi$ be integers in the intervals $1 \leq \gamma \leq 6$, $1 \leq \phi \leq 3$, and the basic six Erd\"os sectioning possibilities $\{E\_{\gamma}\}$ have three Erd\"os sectors $E\_{\gamma}= \{e\_{\gamma, \phi} \}$ defined as:

\begin{alignat}{3}\label{eq:part}

e\_{\gamma,1}&=\{\;i\;|\;\overline{k}\_{\gamma,L}\geq&&\overline{k}\_{\gamma,i}\} \nonumber \\

e\_{\gamma,2}&=\{\;i\;|\;\overline{k}\_{\gamma,L}<\;&&\overline{k}\_{\gamma,i}\leq\overline{k}\_{\gamma,R}\} \\

e\_{\gamma,3}&=\{\;i\;|\;&&\overline{k}\_{\gamma,i}<\overline{k}\_{\gamma,R}\} \nonumber

\end{alignat}

\noindent where $\{\overline{k}\_{\gamma,i}\}$ is:

\begin{equation}

\begin{split}

\overline{k}\_{1,i}&=k\_i \\

\overline{k}\_{2,i}&=k\_i^{in} \\

\overline{k}\_{3,i}&=k\_i^{out} \\

\overline{k}\_{4,i}&=\frac{s\_i}{\overline{w}} \\

\overline{k}\_{5,i}&=\frac{s\_i^{in}}{\overline{w}} \\

\overline{k}\_{6,i}&=\frac{s\_i^{out}}{\overline{w}} \\

\end{split}

\end{equation}

\noindent and both $\overline{k}\_{\gamma,L}$ and $\overline{k}\_{\gamma,R}$ are found using $P(\overline{k})$ or $\hat{P}(\overline{k})$ as described above.

Since different metrics can be used to identify the three types of vertices, compound criteria can be defined. For example, a very stringent criterion can be used, according to which a vertex is only regarded as pertaining to a sector if it is so for all the metrics. After a careful consideration of possible combinations, these were reduced to six:

\begin{itemize}

\item Exclusivist criterion $C\_1$: vertices are only classified if the class is the same according to all metrics. In this case, vertices classified (usually) do not reach 100\%, which is indicated by a black line in the figures of Appendix~\ref{figures}.

\item Inclusivist criterion $C\_2$: a vertex has the class given by any of the metrics. Therefore, a vertex may belong to more than one class, and total members may add more than 100\%, which is indicated by a black line in the figures of Appendix~\ref{figures}.

\item Exclusivist cascade $C\_3$: vertices are only classified as hubs if they are hubs according to all metrics. Intermediary are the vertices classified either as intermediary or hubs with respect to all metrics. The remaining vertices are regarded as peripheral.

\item Inclusivist cascade $C\_4$: vertices are hubs if they are classified as so according to any of the metrics. The remaining vertices are classified as intermediary if they belong to this category for any of the metrics. Peripheral vertices will then be those which were not classified as hub or intermediary with any of the metrics.

\item Exclusivist externals $C\_5$: vertices are only hubs if they are classified as such according to all the metrics. The remaining vertices are classified as peripheral if they fall into the periphery or hub classes by any metric. The rest of the nodes are classified as intermediary.

\item Inclusivist externals $C\_6$: hubs are vertices classified as hubs according to any metric. The remaining vertices will be peripheral if they are classified as such according to any metric. The rest of the vertices will be intermediary vertices.

\end{itemize}

Using equations~\ref{eq:part}, these compound criteria $C\_\delta$, with $\delta$ integer in the interval $1<\delta<6$ can be described as:

%\begin{alignat}{3}

\begin{equation}

\begin{split}

%\begin{multline}

C\_1&=\{c\_{1,\phi}=\left\{i\mid i\;\in e\_{\gamma,\phi}, \;\forall\; \gamma\}\right\} \\

C\_2&=\{c\_{2,\phi}=\left\{i\mid \exists \;\;\gamma: i \in e\_{\gamma,\phi}\}\right\} \\

C\_3&=\{c\_{3,\phi}=\left\{i\mid i\;\in e\_{\gamma,\phi'}, \;\forall\; \gamma,\;\forall\;\phi'\geq \phi\}\right\} \\

C\_4&=\{c\_{4,\phi}=\left\{i\mid i\;\in e\_{\gamma,\phi'}, \;\forall\; \gamma,\;\forall\;\phi'\leq \phi\}\right\} \\

C\_5&=\{c\_{5,\phi}=\left\{i\mid i\;\in e\_{\gamma,\phi'}, \;\forall\; \gamma,\right.\\

&\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\; \left.\;\forall\;(\phi'+1)\%4\leq (\phi+1)\%4\}\right\} \\

C\_6&=\{c\_{6,\phi}=\left\{i\mid i\;\in e\_{\gamma,\phi'}, \;\forall\; \gamma,\right.\\

&\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\;\; \left.\;\forall\;(\phi'+1)\%4\geq (\phi+1)\%4\}\right\} \\

%\end{multline}

\end{split}

\end{equation}

%\end{alignat}

The simplification of all the compound possibilities to the small set listed above can be formalized in strict mathematical terms, but this was considered out of the scope for current interests. It is worth noting that the exclusivist cascade is the same sectioning of an inclusivist cascade from periphery to hubs, but with inverted order of sectors precedence. These compound criteria can be used to examine network sections in the case of a low number of messages, such as in the last figures of Appendix~\ref{figures}.

\subsection{Topological metrics for Principal Component Analysis}\label{measures}

The topology of the networks was studied using Principal Component Analysis (PCA~\cite{pca}) with a small selection of the most basic and fundamental measurements for each vertex, as follows:

\begin{itemize}

\item Degree $k\_i$: number of edges linked to vertex $i$.

\item In-degree $k\_i^{in}$: number of edges ending at vertex $i$.

\item Out-degree $k\_i^{out}$: number of edges departing from vertex $i$.

\item Strength $s$: sum of weights of all edges linked to vertex $i$.

\item In-strength $s\_i^{in}$: sum of weights of all edges ending at vertex $i$.

\item Out-strength $s\_i^{out}$: sum of weights of all edges departing from vertex $i$.

\item Clustering coefficient $cc\_i$: fraction of pairs of neighbors of $i$ that are linked. The standard clustering coefficient for undirected graphs was used.

\item Betweenness centrality $bt\_i$: fraction of geodesics that contain vertex $i$. The betweenness centrality index considered directions and weight, as specified in~\cite{faster}.

\end{itemize}

In order to capture symmetries in the activity of participants, the following metrics were introduced for a vertex $i$:

\begin{itemize}

\item Asymmetry: $asy\_i=\frac{k\_i^{in}-k\_i^{out}}{k\_i}$.

\item Mean of asymmetry of edges: $\mu\_i^{asy}=\frac{\sum\_{j\in J\_i} e\_{ji}-e\_{ij}}{|J\_i|=k\_i}$. Where $e\_{xy}$ is 1 if there is and edge from $x$ to $y$, $0$ otherwise. $J\_i$ is the set of neighbors of vertex $i$, and $|J\_i|=k\_i$ is the number of neighbors of vertex $i$.

\item Standard deviation of asymmetry of edges: $\sigma\_i^{asy}=\sqrt{\frac{\sum\_{j\in J\_i}[\mu\_{asy} -(e\_{ji}-e\_{ij}) ]^2 }{k\_i} }$.

\item Disequilibrium: $dis\_i=\frac{s\_i^{in}-s\_i^{out}}{s\_i}$.

\item Mean of disequilibrium of edges: $\mu\_i^{dis}=\frac{\sum\_{j \in J\_i}\frac{w\_{ji}-w\_{ij}}{s\_i}}{k\_i}$, where $w\_{xy}$ is the weight of edge $x\rightarrow y$ and zero if there is no such edge.

\item Standard deviation of disequilibrium of edges: $\sigma\_i^{dis}=\sqrt{\frac{\sum\_{j\in J\_i}[\mu\_{dis}-\frac{(w\_{ji}-w\_{ij})}{s\_i}]^2}{k\_i}}$.

\end{itemize}

\subsection{Evolution of the networks}

The evolution of the networks was observed within a fixed number of messages, which we refer to as the window size $ws$. This same number of contiguous messages is considered with different shifts in the message timeline to obtain snapshots. Each snapshot was used both to perform the Erd\"os sectioning and apply PCA for the topological metrics.

The $ws$ used were 50, 100, 200, 400, 500, 800, 1000, 2000, 2500, 5000 and 10000. Within a same $ws$, the number of vertices and edges vary in time, as do other network characteristics. Such changes could be visualized with the tools described below.

\subsection{Visualization of network evolution}\label{sec:viz}

The evolution of the networks was visualized with animations, image galleries and online gadgets developed specifically for this research~\cite{animacoes,galGMANE,appGMANE}. Such visualizations were crucial to guide research into the most important features of network evolution, and prompted us to capture the prominence of topological metrics along time using mean and standard deviations. Furthermore, the size of three sectors could be visualized in a timeline fashion (Appendix~\ref{figures}). Visualization of network structure was especially useful as part of the email lists data mining, from which parts of relevant structures and results were driven.

\subsection{Typology speculation}\label{subsec:typ}

(queria discutir pessoalmente este ponto)

Qualitative, typological speculations were the result of all the methodology. More specifically, the Erd\"os sectors was regarded as yielding a \emph{primitive typology} of human agents in social contexts with at least dozens of participants.

Visualization and data mining were efficient in fueling speculations about the qualities of each type.

The stability found in principal components of topological measures suggested that this primitive typology is general for (practically) all human contexts.

Also, the first author is a developer with cultural interests and has been directly and indirectly part of these communities for more than a decade. This gave further safety about assumptions although care was taken not to regard this acquaintanceship as primary source or as definitive evidence.

The interested reader should see Appendix~\ref{ap:typ} for further context,

as it might be considered audacious to bridge from a physics-based,

quantitative classification to a qualitative and speculative approach.

\section{Results and discussion}\label{sec:results}

Remarkable features from the analysis of the four email lists are:

\begin{itemize}

\item The activity along time is practically the same for all lists, thus suggesting stable patterns.

\item The fraction of participants in each Erd\"os sector is stable along time and can be determined even with very few messages

\item The topological metrics combine into principal components in PCA in the same way for all lists and all snapshots.

\subsection{Activity along time}\label{constDisc}

\begin{table\*}[t]

\caption{The rescaled circular mean $\theta\_\mu'$, the standard deviation $S(z)$, the variance $Var(z)$, the circular dispersion $\delta(z)$ and the relation of maximum and minimum incidence at each time unit $\frac{max(incidence}{min(incidence}$. Also, $ \mu\_{\frac{max(incidence')}{min(incidence')}} $ and $ \sigma\_{\frac{max(incidence')}{min(incidence')} }$ are given for 1000 uniform distribution simulations within the same number of bins and with the same number of samples. Section~\ref{sec:mtime} describes the theoretical background of directional (or circular) statistics. This typical table was made using LAD list messages.}

\begin{center}

\begin{tabular}{ |l|| c|c|c|c|c||c|c| }

\hline

scale & $\theta\_\mu'$ & $S(z)$ & $Var(z)$ & $\delta(z)$ & $\frac{max(incidence)}{min(incidence)}$ & $ \mu\_{\frac{max(incidence')}{min(incidence')}} $ & $ \sigma\_{\frac{max(incidence')}{min(incidence')} } $ \\ \hline\hline

\input{tables/tab2TimeLAD}

\end{tabular}

\end{center}

\label{tab:circ}

\end{table\*}

The activity along time is practically the same for all lists, as exemplified with the circular statistics in Table~\ref{tab:circ} and Support information.

\subsubsection{Seconds and minutes}\label{sec:secmin}

Messages were slightly more evenly distributed in all lists than in simulations using uniform distribution\footnote{Numpy version 1.6.1, ``random.randint'' function, was used for simulations, algorithms in \url{https://pypi.python.org/pypi/gmane}.}: for both seconds and minutes $\frac{max(incidence)}{min(incidence)} \in (1.26,1.275]$ in the lists. Simulations reach these values but have in average more discrepant higher and lower peaks $\xi=\frac{max(incidence')}{min(incidence')} \Rightarrow \mu\_\xi=1.2918 \text{ and } \sigma\_\xi=0.04619$.

Therefore, the incidence of messages at each second of a minute and at each minute of an hour was considered uniform, i.e. no trend was detected and the pattern is the uniformity. Circular dispersion is maximized and the mean has little meaning.

\begin{table}[!h]

\caption{Example of activity percentages along the hours of the day. Higher activity was observed between noon and 6pm, followed by the time period between 6pm and midnight. Around 2/3 of the whole activity takes place from noon to midnight. Nevertheless, the activity peak occurs around midday, with a slight skew toward one hour before noon.}

\footnotesize

\input{tables/tabHoursCPP\_}

\label{tab:hin}

\end{table}

\begin{table}[!h]

\caption{Example of activity percentages along the days of the week. Higher activity was observed during weekdays, with a decrease of activity on weekends of at least one third and two thirds in extreme cases.}

\begin{center}

\begin{tabular}{ | l | c | c | c | c | c | c | c |}

\hline

& Mon & Tue & Wed & Thu & Fri & Sat & Sun \\ \hline

\input{tables/tabWeekdays}

\end{tabular}

\end{center}

\label{tab:win}

\end{table}

\begin{table}[!h]

\caption{No significant variation of activity in the days along the month was observed. One cannot point much more than a - probably not statistically relevant - tendency of first and second weeks to be more active. The most important trait seems to be homogeneity.}

\footnotesize

\input{tables/tabMonthdaysCPP}

\label{tab:min}

\end{table}

\begin{table}[!h]

\caption{Example of activity percentages of the months along the year. Activity is concentrated in Jun-Aug for MET and LAD, and in Dec-Mar for CPP, LAU and LAD (see Table~\ref{ano}). These observations fit academic calendars, vacations and end-of-year holidays.}

\footnotesize

\input{tables/tabMonthsLAD}

\label{tab:min2}

\end{table}

\subsubsection{Activity along years}\label{sec:years}

Literature reports that big communities have greater longevity when hubs are changed all the time, while smaller communities have greater longevity when hubs are stable~\cite{barabasiEvo}. Also, activity should follow trends such as economic, climate and technological and periodicity should be observed to some extent. Nevertheless, the time period examined here was not sufficient for the analysis of activity along the years.

\subsection{Scalable fat-tail structure: constancy of membership fractions in the Erd\"os sectors}\label{subsec:pih}

There is a concentration of hub activity and of vertex with few connections. Table~\ref{autores} shows this expected distribution of activity among participants in a scale-free context.

\begin{table}[!h]

\caption{Distribution of activity among participants. The first column presents the percentage of messages sent by the most active participant. The column for the first quartile ($1Q$) shows the minimum percentage of participants responsible for at least 25\% of total messages. Similarly, the column for the first three quartiles $1-3Q$ gives the minimum percentage of participants responsible for 75\% of total messages. The last decile $-10D$ column brings the maximum percentage of participants responsible for 10\% of messages.}

\begin{center}

\begin{tabular}{ | l || c | c | c | c | }

\hline

list & hub & $ 1Q $ & $ 1-3Q $ & $-10D$ \\ \hline

\input{tables/userTab}

\end{tabular}

\end{center}

\label{autores}

\end{table}

The distribution of vertices in the hubs, intermediary, periphery Erd\"os sectors defined in Section~\ref{sectioning} is remarkably stable along time, provided that a sufficiently large sample of 200 or more messages is considered.

Moreover, the same distribution applies to the networks of all the four email lists, as demonstrated in the various figures in the Support Information.

Typically, $\approx [3-12]\%$ of the vertices are found to be hubs, $\approx [15-44]\%$ are intermediary and $\approx [44-82]\%$ are peripheral, which is consistent with the literature~\cite{secFree}.

These results hold for the total, in and out degrees and strengths.

Stable distributions can also be obtained for 100 or less messages if classification of the three sectors is performed with one of the compound criteria established in Section~\ref{sectioning}.

The networks hold their basic structure with as few as 10-50 messages; concentration of activity and the abundance of low-activity participants take place even with very few messages, which is highlighted in the last figures of the Support Information.

A minimum window size for observation of more general properties might be inferred by monitoring the giant component and the degeneration of the Erd\"os sectors.

\begin{figure\*}

\centering

\includegraphics[width=\textwidth]{figs/InText-WLAU-S1000}

\caption{Fraction of agents in each Erd\"os sector. Hubs, intermediary and periphery fractions are represented in red, green and blue. For this figure, we used two simple criteria, namely degree and strength, for the graphics on the left. For the graphs on the right we employed the Exclusivist and inclusivist compound criteria, with black lines representing the fraction of vertices without class and with more than one class, respectively. See Appendix~\ref{figures} for a collection of such timeline figures with all simple and compound criteria and metrics.}

\label{tab:sectIL}

\end{figure\*}

For the histograms used in the classification process, the use of at least $\eta$ vertices for each bin did not yield significant differences.

That was understood as a consequence of the observation scale (see Appendix~\ref{ap:ded}).

\subsection{Variance prevalence of centrality over symmetry and symmetry over clusterization}\label{prevalence}

The topology was analyzed using standard, well-established metrics of centrality and clustering.

We also introduced symmetry metrics because of evidence of their importance in social contexts~\cite{newmanEvolving}.

The contribution of each metric to the variance is very similar for all the networks, and did not vary with time.

In applying PCA to the snapshots, the contribution of each metric to the principal components resulted in very small standard deviation. Table~\ref{tab:pcain} exemplifies the principal components formation with all the metrics considered for the MET email list. Similar results are presented in the Support Information for the other lists, and considering only a few metrics.

\begin{table}[!h]

\caption{Loadings for the 14 metrics into the principal components for the MET list, $ws=1000$ messages in 20 disjoint positioning. The clustering coefficient (cc) appears as the first metric in the Table, followed by 7 centrality metrics and 6 symmetry-related metrics. Note that the centrality measurements, including degrees, strength and betweenness centrality, are the most important contributors for the first principal component, while the second component is dominated by symmetry metrics. The clustering coefficient is only relevant for the third principal component. The three components have in average 80.36\% of the variance.}

\footnotesize

\input{tables/tabPCA3CPP}

\label{tab:pcain}

\end{table}

The first principal component is an average of centrality metrics: degrees, strengths and betweenness centrality. Therefore, all of these centrality measurements are equally important for characterizing the networks. On one hand, the relevance of all centrality metrics is not surprising since they may be highly correlated. The degree and strength, for instance, are highly correlated, with Spearman correlation coefficient $\in [0.95,1]$ and Pearson coefficient $\in [0.85,1)$ for $ws>1000$.

On the other hand, each measure relate to a different participation characteristic, and their equal relevance is noticeable.

The clustering coefficient is presented in almost perfect orthogonality to centrality measures.

Dispersion was more prevalent in symmetry-related metrics than the clustering coefficient. These relations are presented in Figure~\ref{fig:sym} and Table~\ref{tab:pcain}.

Plots of vertices in the components exhibited in Table~\ref{tab:pcain} are shown in Figure~\ref{fig:sym}, where each vertex is colored according to the sector they belong to. As expected, peripheral vertices have very low values in the first component (centrality related) and greater dispersion in the third component (clustering related).

The PCA plot in the third system of Figure~\ref{fig:sym}, where all metrics are considered, reflects symmetry metrics relevance for the variance.

This can be observed in Table~\ref{tab:pcain} where the clustering coefficient is only relevant for the third principal component (with contributions from out-degree and out-strength).

We concluded that the symmetry-related measurements can be more meaningful in characterizing interaction networks (and their participants) than the clustering coefficient, especially for hubs and intermediary vertices.

%\begin{figure}

% \centering

% \includegraphics[width=\columnwidth]{figs/ev0pr3PCA}

% \caption{Scatter plot of vertices for the LAU list using two principal components from a PCA in the metrics space of in- and out- degree and strength, betweenness centrality and clustering coefficient, as specified in Section~\ref{measures}. The principal component is a weighted average of centrality measures: degrees, strengths and betweenness centrality. The second component is mostly clustering coefficient Table~\ref{compPCA} shows the composition of principal components. Similar plots were obtained for all window sizes $ws\;\in\;[500,10000]$, and for the networks of the other email lists, which demonstrates a common relation held by degree, strength and betweenness measures to clustering coefficient.}

% \label{PCA}

%\end{figure}

\begin{figure\*}

\centering

\includegraphics[width=.6\textwidth,height=10cm]{figs/im13PCAPLOT\_}

\caption{Prevalence of the symmetry-related metrics over clustering for data dispersion, which was an important result from the PCA analysis, together with stability on component formation. The first plot shows degree versus clustering coefficient. The second plot is similar, but the first component is an average of centrality metrics (see Table~\ref{compPCA}). The third plot resulted from applying PCA with symmetry-related metrics (see Table~\ref{compPCA2}), where greater dispersion can be observed in all sectors, although more pronounced in intermediary and hubs sectors.

For this figure, a window size of $ws = 1000$ messages was used from LAU list. The general layout is recurrent and consistent with the literature: most connected vertices have low clusterization while higher clusterization is gradually more incident as the number of connections is lowered.

Similar structures were observed in all window sizes $ws\;\in\;[500,10000]$ and for networks of other email lists, which points to a common relationship between degree, strength and betweenness metrics and clustering coefficient. In the third plot, the clustering coefficient was omitted as it is only relevant for the third component. In this case, the second component is representative of symmetry measurements of vertex interactions. Dispersion suggests symmetry-related metrics as being more powerful for characterizing interaction networks than clustering coefficient, especially for hubs and intermediary vertices.

}

\label{fig:sym}

\end{figure\*}

%\begin{figure}

% \centering

% \includegraphics[width=\columnwidth]{figs/ev0pr11CC}

% \caption{Clustering coefficient versus degree of vertices with a window size of $ws = 1000$ email messages, LAU list. The general layout is consistent with the literature: most connected vertices have low clusterization while higher clusterization is gradually more incident as the number of connections is lowered.}

% \label{clust}

%\end{figure}

%\begin{figure}

% \centering

% \includegraphics[width=\columnwidth]{figs/ev0pr1PCA}

% \caption{Scatter plot of vertices for the LAU list using two principal components from a PCA in the metrics space of (in-, out- and total) degree, (in-, out- and total) strength, betweenness centrality, clustering coefficient and symmetry-related measurements. The composition of the first three components are shown in Table~\ref{compPCA2} and metrics details are given in Section~\ref{measures}. Most importantly, clustering coefficient is only relevant for third component, being second component representative of symmetry measurements of vertex interactions. Dispersion suggests symmetry related measures are more powerful for characterizing interaction networks than clustering coefficient, specially for hubs and intermediary vertices.}

% \label{PCA2}

%\end{figure}

\subsection{Primitive typology from Erd\"os sectors}\label{sec:pty}

Não entendi as mensagens que você queria passar com a parte inicial desta seção, e queria discutir depois.

Such stability of activity along time, Erd\"os sector relative sizes, principal components formation and concentration of variance suggests that understanding types of networks and participants might benefit from a characterization within such framework.

We considered the most trivial case, in which the sector to which a participant belongs is regarded as her/his type. This is useful in deriving more elaborate typologies, and yield a sketch of or a ``primitive'' typology. General considerations:

\begin{itemize}

\item A participant belongs to many networks (his family, family of a friend, the email list to which he belongs, work friends, etc.).

\item A participant might belong to all three sectors at the same time. Actually, it is reasonable to assume that almost every person belongs to all three sectors for some of the networks.

\item It is given by construction that a participant is of just one type at a network in a given snapshot (exception for the compound inclusive and exclusive criterion given in Section~\ref{sectioning}).

\item The participant often transitions from one sector to another within a network.

\item Reported stability of network structure arises from activity with continuous change of the participant types.

\item Type often changes with the scale of the activity window. For example, two snapshots of 200 and 10000 messages will probably reveal participants with more than one type.

\end{itemize}

This ephemerality of the human type is in accordance with canonical literature on psychological types. The observance of often transitions between types is even though of as an argument against prejudice~\cite{adorno}.

Visualizations and raw data manipulations suggests further typological peculiarities. These are initial observations, which inspired this article and other ongoing research~\cite{rcText,versinus}:

\begin{itemize}

\item Core hubs usually have intermittent activity. Very stable activity was found on MET hubs, which motivated its integration to this work. There are reports in the literature of greater stability of participation in smaller communities~\cite{barabasiEvo}, which is the reason why the smaller number of participants in MET was considered coherent with the stable activity of hubs.

\item Typically, the activity of hubs is trivial: they interact as much as possible, in every occasion with everyone. The activity of peripheral vertices also follows a simple pattern: they interact very rarely, in very few occasions. Therefore, intermediary vertices seem responsible for the network structure. For example, intermediary vertices may exhibit preferential communication to peripheral, intermediary, or hub vertices; can be marked by stable communication partners; can involve stable or intermittent patterns of activity.

\item Some of the most active participants receive many responses with relative few messages sent, and rarely are top hubs. These seem as authorities and contrast with participants that respond much more than receive responses.

\item The most obvious community structure, as observed by a high clustering coefficient, is found only in peripheral and intermediary sectors.

\end{itemize}

This ``primitive typology'', characterized by peripheral, intermediary and hub types, can be further scrutinized using concepts from other typologies, such as Meyer-Briggs, Pavlov or F-Scale. This is not a direct result of numeric analysis, it is a description refinement of the found structure, in typological terms, and coherent with complex networks literature. Although initial, this bridges human and exact sciences in the most pertinent way authors were able to, as is herein considered a result.

Another typology suggested by the results is about the networks themselves. This and paired articles~\cite{rcText,versinus} reports a dipole in human interaction network types: networks with few and stable agents, and (relative) many threads per number of messages contrasts with networks with many agents of intermittent activity and (relative) few threads per number of messages.

This network typology is endorsed by the seminal Nature Letter by Palla, Barab{\'a}si and Vicsek~\cite{barabasiEvo}, which suggests that the smaller size of MET community is responsible for the stronger hubs observed.

\section{Conclusions and further work}\label{sec:conc}

The characterization of interaction networks resulted from stability observations. Along temporal activity statistics, this work reports the stability of the formation of principal components and of the relative sizes of periphery, intermediary and hubs Erd\"os sectors. These results suggested typologies for both agents and the networks.

Observed systems were coherent with literature in different aspects, such as concentration of activity or such as the clusterization versus connectivity pattern.

Even so, analysis of data from other virtual environments, such as Facebook, Twitter and LinkedIn, might help understanding how general are these structures and what are proper uses.

Further work should inspect other topological measures in each sector.

The subtraction $\widetilde{P}(k)-P(k)$ (see Section~\ref{subsec:typ}) results in two positive clusters for periphery and hubs, and a negative cluster for intermediary vertices. This might support classification of the three sectors by clustering, a more traditional approach to classification.

Observance of attributes with greater contribution to principal components of LDA should reveal best chances to present these three sections as clusters in the network measurements space.

Another possibility, especially for a brute-force characterization of such sectors, is to remove vertices with degree close to $k\_\Leftarrow$ or $k\_\Rightarrow$ depicted in figure~\ref{fig:setores}.

Stability here reported eases typologization of both outliers and usual participation patterns (see Sections~\ref{sec:related} and~\ref{sec:pty}). (por quê?)

A paired article with this one reports significant differences in the textual production of each Ed\"os sector~\cite{rcText}. Resulting knowledge purposes networks and participant typologies.

Another paired article describes a network time evolution visualization method~\cite{versinus}.

The usage of such results are taking place in software packages, linked data, electronic government technologies, and anthropological physics experiments~\cite{gmanePack,ops,opa,ensaio,anPhy}.

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\end{acknowledgments}

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

\appendix

\section{More graph-related results}

\subsection{Edge existence probability in a directed network without self-loops}\label{ap:ded}

Be $\mathcal{N}$ a directed network without self-loops with $z$ edges and $N$ vertices. The probability that an edge exists between two arbitrary vertex is $p\_e=\frac{z}{max( \text{number of edges} |\ \text{N vertices})}$, where $max( \text{number of edges} |\ \text{N vertices})=2[(N-1)+(N-2)+...+1]=2[\sum\_1^{N-1}i]=2[\frac{N(N-1)}{2}]$ is the maximum number of edges for a network with $N$ vertices. Therefore:

\begin{align}

p\_e&=\frac{z}{max( \text{number of edges} |\ \text{N vertices})} \nonumber \\

&=\frac{z}{2[(N-1)+(N-2)+...+1]}=\frac{z}{2\frac{N(N-1)}{2}} \nonumber \\

p\_e &=\frac{z}{N(N-1)}

\end{align}

\subsection{Effect of scale in histogram smoothing}\label{ap:ded}

There are between 20 and 200 participants in the message window sizes used to derive most of the results ($ws \in [200,1500]$ messages). As peripheral vertices are abundant and span few degrees, there are more than $\eta$ vertices with each low degree value. For the case of higher degrees, one should consider that with the $ws$ used, each participant is $p \in [0.1\%,0.5\%]$ of all participants. Therefore, if incident connectivity is very improbable in an Erd\"os R\'enyi network (less than $p$, the probability that a single participant represents when the histogram is normalized to the density function), than it is not an intermediary connectivity, but a hub. Therefore, using at least $\eta$ vertices for each bin did not impact the results.

\section{Typologies}\label{ap:typ}

There are other ways to split and characterize networks. To point a common example, the center of the network is defined as all the nodes whose maximum distance to any other node is the radius (the radius is the minimum maximum distance to all vertices , i.e. the radius is the minimum eccentricity).

In the same framework, the periphery (as opposed to the center) consists of the nodes whose maximum distance to any node is the diameter (diameter being the maximum geodesic on the network). Accordingly, the intermediary sector can be defined as the nodes that are not in the center or in the periphery. Interestingly, in the email networks analyzed, with such criteria, the center can often be a factor of 4 times larger than the periphery and the intermediary group often exceeds 90\% of the nodes~\cite{networkx}.

Models of human dynamics can be used to predict and classify activity. In this case, human activity is commonly considered a Poisson process, as a consequence of the randomly distributed events in time. Even so, evidence-based models suggests that human activity patterns follow non-Poisson statistics, characterized by a long tail of inactivity with bursts of rapidly occurring events~\cite{barabasiHumanDyn,barabasiPhone}.

Typologies can also be conveniently adapted from psychiatric, psychological and psychoanalytic theories.

Concerning empirical research,

Theodor Adorno is a core conceiver of an one-of-a-kind typology that resulted from observing authoritarian

personality traces to detect Nazism adoption, antisemitism and potential fascists, depicted as an authoritarian syndrome~\cite{adorno}.

Other classic typologies of interest include Jung's extroversion-introversion trait with four modes of orientation. This four modes are divided in two perceiving functions (sensation and intuition) and two judging functions (thinking and feeling), each individual manifesting one of these four modes as dominant, and each mode expressed primarily as introverted or extroverted~\cite{jung}. Myers-Briggs Type Indicator extrapolated Jungian theories into a questionnaire and added perceiving and judging as a fourth dipole~\cite{myers}. Even plain Freudian criteria, such as neurosis, psychosis, perversity and denegation, can be used directly for such categorization, as they have verbal and behavioral typical traces~\cite{freud,freud2}.

It was considered central to benefit from key human typologies, both by describing types and by further characterizing classes in the terms encountered. A primitive physics-based typology is described in Section~\ref{sec:pty} as a consequence of the periphery, intermediary and hub sectors yielded by comparing the real networks with the Erd\"os R\'enyi model.

Also, ethic and moral issues are developed by such legacy. For example, Adorno et al. conceptualized that personality is dynamic, not static or immutable, and that recognizing this was important for an ethic empirical study of human authoritarian traces~\cite{adorno}.

Indeed, this dynamic typological approach is so vital to secure an ethic study of human systems that our epigraph is devoted to make this point explicit.

\section{Data and scripts}\label{scripts}

Messages are downloaded from the GMANE database by RSS in the mbox email text format.

They are requested one by one to avoid reaching maximum size of the requests accepted by

GMANE API.

Every message has about 30 fields, from which the following are crucial

for the present work:

\begin{itemize}

\item ``From'' field, as it specifies the sender of the message, in the usual format of ``First\\_name Last\\_Name $<email>$''.

\item ``Date'' field, which is given with the resolution of a second.

\item ``Message-ID'', important to state antecedent/consequent relation between messages and therefore from an author to a replier.

\item ``References'', has the ID of the message it is an answer to, if any, and earlier messages in the thread.

\end{itemize}

Field ``In-Reply-To'' has only the ID of the message it replies and can be sometimes

a shortcut or an alternative to ``References''. Also, the textual content of the messages,

accessed through ``payload'' method of the mbox message object, is of central interest and

the authors dedicated an article to include the textual content of the messages to the analysis~\cite{rcText}.

\subsection{Python scripts}\label{ap:os}

Basic constructs for obtaining all results are the product of scripts written in the Python programming language. These are kept in a public git repository for backup and sharing with research community~\cite{scriptsFim}. Core scripts, for deriving structures and results exhibited in this article, are in the LEIAME file.

\subsection{Third party libraries and software}

The programming framework used

is mainly Python-based, with emphasis on usual

scientific tools. More specifically,

scripts where written for 2.7.3 version of Python,

with the following third party libraries: Numpy, Pylab/Matplotlib, NetworkX, IGraph.

Behind the scenes, Graphviz is accessed via PyGraphviz to make network drawings.

\clearpage

\section{Tables}\label{sectables}

\subsection{PCA tables}\label{sec:pcat}

%\begin{table}[!h]

% \centering

% \caption{Principal components composition in the simplest case: with degree, clustering coefficient and betweenness centrality. LAU list, $ws=1000$ messages in 20 disjoint positioning was used for statistics. The first component is a weighted average of degree and betweenness centrality. The second component is mostly clustering coefficient. The first and second components represent more than 95\% of total variance. The $\lambda$ bottom line holds the percentage of total variance attributed to each component.}

% \begin{tabular}{|l|c|c| c|c| c|c|}\hline

% & \multicolumn{2}{c|}{PC1} & \multicolumn{2}{c|}{PC2} & \multicolumn{2}{c|}{PC3} \\\hline

% & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ \\\hline

%$d$ & {\bf 48.02} & 1.39 & 2.82 & 1.74 & 48.09 & 0.32 \\

%$cc$ & 4.12 & 2.94 & {\bf 90.45} & 3.98 & 3.98 & 0.77 \\

%$bt$ & {\bf 47.87} & 1.55 & 6.74 & 4.08 & 47.93 & 0.46 \\ \hline

%$\lambda$ & 64.67 & 0.52 & 33.26 & 0.23 & 2.08 & 0.40 \\ \hline

% \end{tabular}

% \label{compPCA0}

%\end{table}

%

%\begin{table}[!h]

% \centering

% \caption{Principal components composition in percentages. LAU list, $ws=1000$ messages in 20 disjoint positioning was used for statistics. First component is a weighted average of degree and strength and betweenness centrality. The second component is mostly related to the clustering coefficient. The first and second components represent more than 90\% of the variance.}

% \begin{tabular}{|l|c|c| c|c| c|c|}\hline

% & \multicolumn{2}{c|}{PC1} & \multicolumn{2}{c|}{PC2} & \multicolumn{2}{c|}{PC3} \\\hline

% & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ \\\hline

%$d$ & {\bf 14.58} & 0.14 & 0.43 & 0.35 & 1.51 & 1.08 \\

%$d^{in}$ & {\bf 14.12} & 0.14 & 1.71 & 1.22 & 17.80 & 6.20 \\

%$d^{out}$ & {\bf 13.95} & 0.12 & 2.80 & 1.83 & 21.15 & 5.62 \\

%$s$ & {\bf 14.48} & 0.13 & 0.78 & 0.65 & 5.51 & 4.71 \\

%$s^{in}$ & {\bf 14.10} & 0.14 & 2.17 & 1.28 & 17.32 & 6.11 \\

%$s^{out}$ & {\bf 14.05} & 0.13 & 2.08 & 1.14 & 19.31 & 4.86 \\ \hline

%$cc$ & 0.99 & 0.70 & {\bf 83.38} & 4.83 & 2.75 & 1.62 \\

%$bt$ & {\bf 13.73} & 0.19 & 6.65 & 1.31 & 14.66 & 10.14 \\ \hline

%$\lambda$ & 81.80 & 0.83 & 12.53 & 0.09 & 3.24 & 0.62 \\ \hline

% \end{tabular}

% \label{compPCA}

%\end{table}

%

%

%\begin{table}[!h]

% \centering

% \caption{Principal components formation with symmetry-related metrics (see Section~\ref{measures}). LAU list, $ws=1000$ messages in 20 disjoint positioning was used for statistics. In this case, clusterization is pushed to the third principal component. The second component is primarily derived from symmetry measurements, but also out-degree and out-strength, and disequilibrium standard deviation. Betweenness centrality again has a role similar to degree, but weaker. The clusterization component combines with disequilibrium, while asymmetry is combined to out-degree and out-strength. The three components have in average 80.36\% of the variance.}

% \begin{tabular}{|l|c|c| c|c| c|c|}\hline

% & \multicolumn{2}{c|}{PC1} & \multicolumn{2}{c|}{PC2} & \multicolumn{2}{c|}{PC3} \\\hline

% & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ & $\mu$ & $\sigma$ \\\hline

%$d$ & {\bf 11.51} & 0.42 & 2.00 & 0.76 & 2.39 & 0.49 \\

%$d^{in}$ & {\bf 11.45} & 0.34 & 2.86 & 0.91 & 1.68 & 0.67 \\

%$d^{out}$ & {\bf 10.68} & 0.60 & {\bf 7.43} & 1.00 & 3.00 & 1.02 \\

%$s$ & {\bf 11.37} & 0.42 & 1.75 & 0.71 & 4.31 & 0.63 \\

%$s^{in}$ & {\bf 11.33} & 0.35 & 2.39 & 1.10 & 3.69 & 0.86 \\

%$s^{out}$ & {\bf 10.74} & 0.55 & {\bf 6.14} & 1.05 & 4.75 & 0.98 \\ \hline

%$cc$ & 0.91 & 0.64 & 2.68 & 1.67 & {\bf 22.27} & 6.43 \\

%$bt$ & {\bf 10.87} & 0.38 & 1.17 & 0.93 & 4.03 & 1.42 \\ \hline

%$asy$ & 3.99 & 1.45 & {\bf 18.13} & 1.67 & 2.55 & 1.77 \\

%$\mu\_{asy}$ & 4.15 & 1.40 & {\bf 17.07} & 1.78 & 2.49 & 1.67 \\

%$\sigma\_{asy}$ & 1.21 & 0.67 & {\bf 17.49} & 0.79 & 3.29 & 2.33 \\

%$dis$ & 5.78 & 0.51 & 1.94 & 1.28 & {\bf 24.75} & 3.73 \\

%$\mu\_{dis}$ & 0.79 & 0.49 & {\bf 14.00} & 1.14 & 3.73 & 3.13 \\

%$\sigma\_{dis}$ & 5.18 & 0.72 & 4.93 & 2.48 & {\bf 17.04} & 4.78 \\ \hline

%$\lambda$ & 51.09 & 1.07 & 20.04 & 1.31 & 9.23 & 6.63 \\ \hline

% \end{tabular}

% \label{compPCA2}

%\end{table}

%

%\subsection{Tables for activity along time and among participants}\label{tabTime}

%

%\begin{table}[!h]

% \caption{Distribution of activity among agents. First column is dedicated to percentage of messages sent by the most active participant. Column for the first quartile ($1Q$) exhibits minimum percentage of participants responsible for at least 25\% of total messages. Similarly, the column for the first three quartiles $1-3Q$ exhibits minimum percentage of participants responsible for 75\% of total messages. The last decile $10D$ column has maximum percentage of participants responsible for 10\% of messages.}

%\begin{center}

% \begin{tabular}{ | l || c | c | c | c | }

% \hline

% list & hub & $ 1Q $ & $ 1-3Q $ & $10D$ \\ \hline

% CPP & 14.41 & 0.19 (27.8\%) & 4.09 (75.13\%) & 83.65 (-10.04\%) \\

% MET & 11.14 & 0.81 (30.61\%) & 8.33 (75,11\%) & 80.49 (-10.02\%) \\

% LAU & 2.78 & 1.10 (25.16\%) & 13.02 (75,04\%) & 67.37 (-10.03\%) \\

% LAD & 4.00 & 0.95 (25.50\%) & 11.83 (75,07\%) & 71.13 (-10.03\%) \\\hline

% \end{tabular}

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%\label{autores}

%\end{table}

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%\begin{table\*}

%%\tiny

% \caption{Percentage of activity ($100\frac{\text{counted messages}}{\text{total messages}}$) in each hour, 6 hours and 12 hours. Maximum activity rates are in bold. In 1h columns, minimum activity is also bold. The less active period of the day is around 4-6h. Maximum activity is between 10-13h. Afternoon is most active in 6h division of the day. The noon has $\approx \frac{2}{3}$ of 24h activity. }\label{dia}

%\begin{center}

% \begin{tabular}{ |l|| c|c|c| c|c|c| c|c|c| c|c|c|}

% \hline

% & \multicolumn{3}{c|}{CPP} & \multicolumn{3}{c|}{MET} & \multicolumn{3}{c|}{LAU} & \multicolumn{3}{c|}{LAD} \\ \hline

% & 1h & 6h & 12h & 1h & 6h & 12h & 1h & 6h & 12h & 1h & 6h & 12h \\ \hline\hline

%0h & 3.66 & \multirow{6}{\*}{10.67} & \multirow{12}{\*}{33.76} & 2.87 & \multirow{6}{\*}{7.15} & \multirow{12}{\*}{29.33} & 3.58 & \multirow{6}{\*}{10.14} & \multirow{12}{\*}{36.88} & 4.00 & \multirow{6}{\*}{10.77} & \multirow{12}{\*}{33.13} \\

%1h & 2.76 & & & 1.77 & & & 2.22 & & & 2.52 & & \\

%2h & 1.79 & & & 1.04 & & & 1.63 & & & 1.79 & & \\

%3h & 1.10 & & & 0.64 & & & 1.06 & & & 1.06 & & \\

%4h & {\bf 0.68} & & & 0.47 & & & 0.84 & & & 0.75 & & \\

%5h & 0.69 & & & {\bf 0.38} & & & {\bf 0.82} & & & {\bf 0.66} & & \\\cline{3-3}\cline{6-6}\cline{9-9}\cline{12-12}

%6h & 0.83 & \multirow{6}{\*}{23.09} & & 0.72 & \multirow{6}{\*}{22.18} & & 1.17 & \multirow{6}{\*}{26.74} & & 0.85 & \multirow{6}{\*}{22.36} & \\

%7h & 1.24 & & & 1.33 & & & 2.37 & & & 1.56 & & \\

%8h & 2.28 & & & 2.67 & & & 3.54 & & & 2.96 & & \\

%9h & 4.52 & & & 4.40 & & & 6.04 & & & 4.68 & & \\

%10h & 6.62 & & & 6.29 & & & {\bf 6.83} & & & 5.93 & & \\

%11h & {\bf 7.61} & & & 6.78 & & & 6.79 & & & 6.40 & & \\\hline

%12h & 6.44 & \multirow{6}{\*}{\bf 37.63} & \multirow{12}{\*}{\bf 66.24} & {\bf 7.33} & \multirow{6}{\*}{\bf 42.22} & \multirow{12}{\*}{ \bf 70.66} & 6.11 & \multirow{6}{\*}{\bf 35.65} & \multirow{12}{\*}{ \bf 63.12} & {\bf 6.41} & \multirow{6}{\*}{\bf 37.25} & \multirow{12}{\*}{\bf 66.87} \\

%13h & 6.04 & & & 7.08 & & & 6.26 & & & 6.12 & & \\

%14h & 6.47 & & & 7.09 & & & 6.38 & & & 6.33 & & \\

%15h & 6.10 & & & 7.14 & & & 5.93 & & & 5.98 & & \\

%16h & 6.22 & & & 6.68 & & & 5.52 & & & 6.40 & & \\

%17h & 6.36 & & & 6.89 & & & 5.46 & & & 6.02 & & \\\cline{3-3}\cline{6-6}\cline{9-9}\cline{12-12}

%

%

%18h & 6.01 & \multirow{6}{\*}{28.61} & & 5.99 & \multirow{6}{\*}{28.44} & & 5.24 & \multirow{6}{\*}{27.46} & & 5.99 & \multirow{6}{\*}{29.63} & \\

%19h & 5.02 & & & 5.23 & & & 4.52 & & & 5.03 & & \\

%20h & 4.85 & & & 4.98 & & & 4.55 & & & 4.63 & & \\

%21h & 4.38 & & & 4.37 & & & 4.42 & & & 4.59 & & \\

%22h & 4.06 & & & 4.24 & & & 4.51 & & & 4.88 & & \\

%23h & 4.30 & & & 3.64 & & & 4.23 & & & 4.53 & & \\\hline

% \end{tabular}

%\end{center}

%\end{table\*}

%

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%

%\begin{table}[h]

% \caption{Percentage of activity on days along the week. Weekend days are at least $\frac{1}{3}$ less active and can reach $\frac{1}{3}$ of activity. MET concentrates activity in weekdays the most, leaving only 13.98\% of total activity to Saturday and Sunday. LAU is the one that less concentrates activity in weekdays, reaching 20.94\% of total activity in weekends. These might suggest professional relation of CPP and MET participants to the topics of interest, or a hobby relation of LAU and LAD participants.}

%\begin{center}

% \begin{tabular}{ | l | c | c | c | c | c | c | c |}

% \hline

% & Mon & Tue & Wed & Thu & Fri & Sat & Sun \\ \hline

% CPP & 17.06 & 17.43 & 17.61 & 17.13 & 16.30 & 6.81 & 7.67 \\ \hline

% MET & 17.53 & 17.54 & 16.43 & 17.06 & 17.46 & 7.92 & 6.06 \\ \hline

% LAU & 15.71 & 15.80 & 15.88 & 16.43 & 15.13 & 10.13 & 10.91 \\ \hline

% LAD & 14.91 & 17.73 & 17.01 & 15.40 & 14.25 & 10.39 & 10.30 \\\hline

% \end{tabular}

%\end{center}

%\label{semana}

%\end{table}

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%\begin{table\*}

%%\tiny

% \caption{Activity along the days of the month. The pattern is to have no clear prevalent period. One might point a slight tendency for the first two weeks to be more active, although this table does not present statistical foundation for such an assumption. For the scope of this study, differences of activity along the month is assumed to be inexistent.}

%\begin{center}

% \begin{tabular}{ |l|| c|c|c| c|c|c| c|c|c| c|c|c|}

% \hline

% & \multicolumn{3}{c|}{CPP} & \multicolumn{3}{c|}{MET} & \multicolumn{3}{c|}{LAU} & \multicolumn{3}{c|}{LAD} \\ \hline

%day & 1 day & 7 days & 14 days & 1 day & 7 days & 14 days & 1 day & 7 days & 14 days & 1 day & 7 days & 14 days \\ \hline\hline

%1 & 3.19 & \multirow{7}{\*}{23.05} & \multirow{14}{\*}{45.63} & 3.01 & \multirow{7}{\*}{25.16} & \multirow{14}{\*}{48.08} & 3.34 & \multirow{7}{\*}{23.06} & \multirow{14}{\*}{47.31} & 3.22 & \multirow{7}{\*}{21.96} & \multirow{14}{\*}{46.70} \\

%2 & 3.07 & & & 3.38 & & & 3.38 & & & 3.42 & & \\

%3 & 3.20 & & & 3.55 & & & 3.20 & & & 2.87 & & \\

%4 & 3.63 & & & 4.34 & & & 3.52 & & & 2.91 & & \\

%5 & 2.85 & & & 3.93 & & & 2.68 & & & 3.30 & & \\

%6 & 3.67 & & & 3.76 & & & 3.18 & & & 3.52 & & \\

%7 & 3.45 & & & 3.18 & & & 3.77 & & & 2.27 & & \\\cline{3-3}\cline{6-6}\cline{9-9}\cline{12-12}

%8 & 3.12 & \multirow{7}{\*}{22.57} & & 3.36 & \multirow{7}{\*}{22.92} & & 3.62 & \multirow{7}{\*}{24.25} & & 3.72 & \multirow{7}{\*}{24.73} & \\

%9 & 2.57 & & & 3.44 & & & 3.82 & & & 3.97 & & \\

%10 & 2.92 & & & 3.17 & & & 3.06 & & & 3.77 & & \\

%11 & 3.54 & & & 3.88 & & & 3.11 & & & 3.27 & & \\

%12 & 3.23 & & & 2.94 & & & 3.40 & & & 2.75 & & \\

%13 & 3.39 & & & 3.29 & & & 3.55 & & & 3.34 & & \\

%14 & 3.81 & & & 2.83 & & & 3.69 & & & 3.93 & & \\\hline

%15 & 3.35 & \multirow{7}{\*}{23.02} & \multirow{14}{\*}{46.31} & 2.72 & \multirow{7}{\*}{21.87} & \multirow{14}{\*}{ 43.56} & 3.23 & \multirow{7}{\*}{22.84} & \multirow{14}{\*}{ 44.01 } & 3.37 & \multirow{7}{\*}{22.82} & \multirow{14}{\*}{46.00} \\

%16 & 3.77 & & & 2.96 & & & 2.94 & & & 3.37 & & \\

%17 & 3.45 & & & 3.01 & & & 3.02 & & & 2.95 & & \\

%18 & 3.47 & & & 3.39 & & & 3.63 & & & 3.22 & & \\

%19 & 2.90 & & & 3.42 & & & 3.16 & & & 3.59 & & \\

%20 & 2.80 & & & 3.09 & & & 3.25 & & & 3.21 & & \\

%21 & 3.29 & & & 3.27 & & & 3.61 & & & 3.13 & & \\\cline{3-3}\cline{6-6}\cline{9-9}\cline{12-12}

%

%22 & 2.88 & \multirow{7}{\*}{23.29} & & 2.92 & \multirow{7}{\*}{21.69} & & 3.80 & \multirow{7}{\*}{21.17} & & 3.07 & \multirow{7}{\*}{23.18} & \\

%23 & 4.01 & & & 3.27 & & & 3.03 & & & 3.06 & & \\

%24 & 3.13 & & & 2.92 & & & 2.31 & & & 2.72 & & \\

%25 & 3.57 & & & 2.83 & & & 2.38 & & & 3.16 & & \\

%26 & 3.27 & & & 2.97 & & & 3.49 & & & 3.57 & & \\

%27 & 3.27 & & & 3.41 & & & 2.92 & & & 3.92 & & \\

%28 & 3.17 & & & 3.36 & & & 3.26 & & & 3.69 & & \\\hline

%29 & 3.68 & \multirow{3}{\*}{8.06} & \multirow{3}{\*}{8.06} & 2.93 & \multirow{3}{\*}{8.36} & \multirow{3}{\*}{8.36} & 3.34 & \multirow{3}{\*}{8.68} & \multirow{3}{\*}{8.68} & 3.15 & \multirow{3}{\*}{7.30} & \multirow{3}{\*}{7.30} \\

%30 & 2.76 & & & 3.14 & & & 3.75 & & & 2.71 & & \\

%31 & 1.63 & & & 2.29 & & & 1.60 & & & 1.45 & & \\\hline

% \end{tabular}

%\end{center}

%\label{mes}

%\end{table\*}

%

%

%\begin{table\*}[t]

%\scriptsize

% \caption{Activity along the year, in months, trimesters, quadrimesters and semesters. Engagement in list participation seem to concentrate in two periods: middle of the year (Jun-Aug, lists MET and LAD), and transition from years (Dec-Mar, lists CPP, LAU and LAD). Messages were considered as to complete 12 months slots, so every month has the same time of occurrences.}

%\begin{center}

% \begin{tabular}{ |l|| c|c|c|c|c| c|c|c|c|c| c|c|c|c|c| c|c|c|c|c|}

% \hline

% & \multicolumn{5}{c|}{CPP} & \multicolumn{5}{c|}{MET} & \multicolumn{5}{c|}{LAU} & \multicolumn{5}{c|}{LAD} \\ \hline

% & m. & b. & t. & q. & s. & m. & b. & t. & q. & s. & m. & b. & t. & q. & s. & m. & b. & t. & q. & s. \\ \hline\hline

%Jan & 8.70 & \multirow{2}{\*}{17.00} & \multirow{3}{\*}{\bf 27.23} & \multirow{4}{\*}{\bf 36.48} & \multirow{6}{\*}{\bf 54.26} & 4.88 & \multirow{2}{\*}{11.01} & \multirow{3}{\*}{16.90} & \multirow{4}{\*}{23.32} & \multirow{6}{\*}{47.74} & 10.22 & \multirow{2}{\*}{\bf 19.56} & \multirow{3}{\*}{\bf 28.23} & \multirow{4}{\*}{\bf 35.09} & \multirow{6}{\*}{49.17} & 11.23 & \multirow{2}{\*}{18.49} & \multirow{3}{\*}{26.43} & \multirow{4}{\*}{36.04} & \multirow{6}{\*}{\bf 57.95} \\

%Fev & 8.29 & & & & & 6.13 & & & & & 9.34 & & & & & 7.26 & & & & \\\cline{3-3}\cline{8-8}\cline{13-13}\cline{18-18}

%Mar & {\bf 10.23} & \multirow{2}{\*}{\bf 19.49} & & & & 5.89 & \multirow{2}{\*}{12.31} & & & & 8.67 & \multirow{2}{\*}{15.52} & & & & 7.94 & \multirow{2}{\*}{17.55} & & & \\\cline{4-4}\cline{9-9}\cline{14-14}\cline{19-19}

%Apr & 9.26 & & \multirow{3}{\*}{27.03} & & & 6.42 & & \multirow{3}{\*}{30.84} & & & 6.85 & & \multirow{3}{\*}{20.94} & & & 9.61 & & \multirow{3}{\*}{\bf 31.51} & & \\\cline{3-3}\cline{5-5}\cline{8-8}\cline{10-10}\cline{13-13}\cline{15-15}\cline{18-18}\cline{20-20}

%Mai & 9.41 & \multirow{2}{\*}{17.78} & & \multirow{4}{\*}{33.46} & & 10.46 & \multirow{2}{\*}{\bf 24.42} & & \multirow{4}{\*}{\bf 47.83} & & 7.27 & \multirow{2}{\*}{14.09} & & \multirow{4}{\*}{30.37} & & 8.94 & \multirow{2}{\*}{\bf 21.91} & & \multirow{4}{\*}{\bf 37.56} & \\

%Jun & 8.37 & & & & & {\bf 13.96} & & & & & 6.81 & & & & & {\bf 12.97} & & & & \\\cline{3-3}\cline{4-4}\cline{6-6}\cline{8-9}\cline{11-11}\cline{13-14}\cline{16-16}\cline{18-19}\cline{21-21}

%Jul & 8.70 & \multirow{2}{\*}{15.68} & \multirow{3}{\*}{22.94} & & \multirow{6}{\*}{45.73} & 13.23 & \multirow{2}{\*}{23.41} & \multirow{3}{\*}{\bf 31.16} & & \multirow{6}{\*}{\bf 52.26} & 8.96 & \multirow{2}{\*}{16.28} & \multirow{3}{\*}{24.47} & & \multirow{6}{\*}{\bf 50.82} & 9.02 & \multirow{2}{\*}{15.65} & \multirow{3}{\*}{22.29} & & \multirow{6}{\*}{42.05} \\

%Ago & 6.98 & & & & & 10.28 & & & & & 7.31 & & & & & 6.63 & & & & \\\cline{3-3}\cline{5-5}\cline{8-8}\cline{10-10}\cline{13-13}\cline{15-15}\cline{18-18}\cline{20-20}

%Set & 7.26 & \multirow{2}{\*}{15.36} & & \multirow{4}{\*}{30.06} & & 7.75 & \multirow{2}{\*}{16.80} & & \multirow{4}{\*}{28.86} & & 8.18 & \multirow{2}{\*}{16.24} & & \multirow{4}{\*}{34.54} & & 6.63 & \multirow{2}{\*}{12.38} & & \multirow{4}{\*}{26.40} & \\\cline{4-4}\cline{9-9}\cline{14-14}\cline{19-19}

%Oct & 8.10 & & \multirow{3}{\*}{22.80} & & & 9.05 & & \multirow{3}{\*}{21.10} & & & 8.06 & & \multirow{3}{\*}{26.36} & & & 5.74 & & \multirow{3}{\*}{19.77} & & \\\cline{3-3}\cline{8-8}\cline{13-13}\cline{18-18}

%Nov & 7.86 & \multirow{2}{\*}{14.69} & & & & 7.46 & \multirow{2}{\*}{12.06} & & & & 7.63 & \multirow{2}{\*}{18.30} & & & & 7.63 & \multirow{2}{\*}{14.02} & & & \\

%Dec & 6.81 & & & & & 4.59 & & & & & {\bf 10.66} & & & & & 6.39 & & & & \\\hline

% \end{tabular}

%\end{center}

%\label{ano}

%\end{table\*}

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%\clearpage

%\section{Figures of vertex classification fractions as the network evolves}\label{figures}

%

%Two lists are exhibited in this section, CPP and LAD. These structures are very similar in all

%four lists and laying extensively all figures is redundant. Window sizes of $ws =$ 10000, 5000,

%1000, 500, 250, 100 and 50 messages were used.

%

%\begin{figure\*}[hb]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/10000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp10000}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/10000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification is plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp10000\_}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/5000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp5000}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/5000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp5000\_}

%\end{figure\*}

%

%%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/1000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp1000}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/1000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp1000\_}

%\end{figure\*}

%

%

%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/500}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp500}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/500\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp500\_}

%\end{figure\*}

%

%

%%%%%%%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/250}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp250}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/250\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp250\_}

%\end{figure\*}

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%%%%%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/100}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp100}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/100\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp100\_}

%\end{figure\*}

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%%%%%%%%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/50}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. CPP Std library official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:cpp50}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/CPP/50\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:cpp50\_}

%\end{figure\*}

%

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/10000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad10000}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/10000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad10000\_}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/5000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad5000}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/5000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad5000\_}

%\end{figure\*}

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/1000}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad1000}

%\end{figure\*}

%

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/1000\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad1000\_}

%\end{figure\*}

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/500}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad500}

%\end{figure\*}

%

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/500\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad500\_}

%\end{figure\*}

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/250}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad250}

%\end{figure\*}

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/250\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad250\_}

%\end{figure\*}

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/100}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad100}

%\end{figure\*}

%

%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/100\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad100\_}

%\end{figure\*}

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%%%%%%%%%%%

%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/50}

% \caption{Distribution of vertices with respect to each centrality measure: in and out degrees and strengths. Linux Audio Users (LAD) official mailing list. In the first six plots, red is fraction of hubs, green is the fraction of intermediary and blue is for peripheral fraction. On the last plot, red is the center (maximum distance to another vertex is equal to radius), blue is periphery (maximum distance equals to diameter) of the giant component. On the same graph, green counts the disconnected vertices.}

% \label{fig:lad50}

%\end{figure\*}

%

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%\begin{figure\*}[hbtp]

% \centering

% \includegraphics[width=\textwidth]{figs/LAD/50\_2}

% \caption{Distribution of vertex with respect to compound criteria. Red, green and blue designate hubs, intermediary and border (peripheral) vertex fractions. The first two plots exhibit classifications that are not functions. Thus, in the first plot, the fraction of vertices with unique classification in plotted in black. On the second plot, black represents the fraction of vertices that has more than one class: $\frac{\text{number of classifications} - \text{number of nodes}}{\text{number of nodes}}$. Compound criteria is described in Section~\ref{sectioning}.}

% \label{fig:lad50\_}

%\end{figure\*}

%

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%

%\begin{figure\*}

% \centering

% \includegraphics[width=\textwidth]{pcm}

% \caption{Pulse Code Modulation (PCM) audio: an analogical signal is represented by 25 samples with 4 bits each.}

% \label{fig:PCM}

%\end{figure\*}

%

\nocite{\*}

\bibliography{paper}% Produces the bibliography via BibTeX.

\end{document}

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% \*\*\*\*\*\* End of file aipsamp.tex \*\*\*\*\*\*