Structural and geographic properties of online social interactions

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in collaboration with
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References

- Y. Volkovich, S. Scellato, D. Laniado, C. Mascolo, and A. Kaltenbrunner;
  “The length of bridge ties: structural and geographic properties of online social interactions”
  ICWSM-12 (International AAAI Conference on Weblogs and Social Media)
- A. Kaltenbrunner, S. Scellato, Y. Volkovich, D. Laniado, D. Currie, E. J. Jutemar, and C. Mascolo;
  “Far from the eyes, close on the Web: impact of geographic distance on online social interactions”;
  WOSN ’12 (ACM SIGCOMM Workshop on Online Social Networks)

online social connections:

- *explicit* (articulated)
  e.g. friendship connections
- *implicit* (behavioural)
  e.g. interactions

social graph: nodes and edges

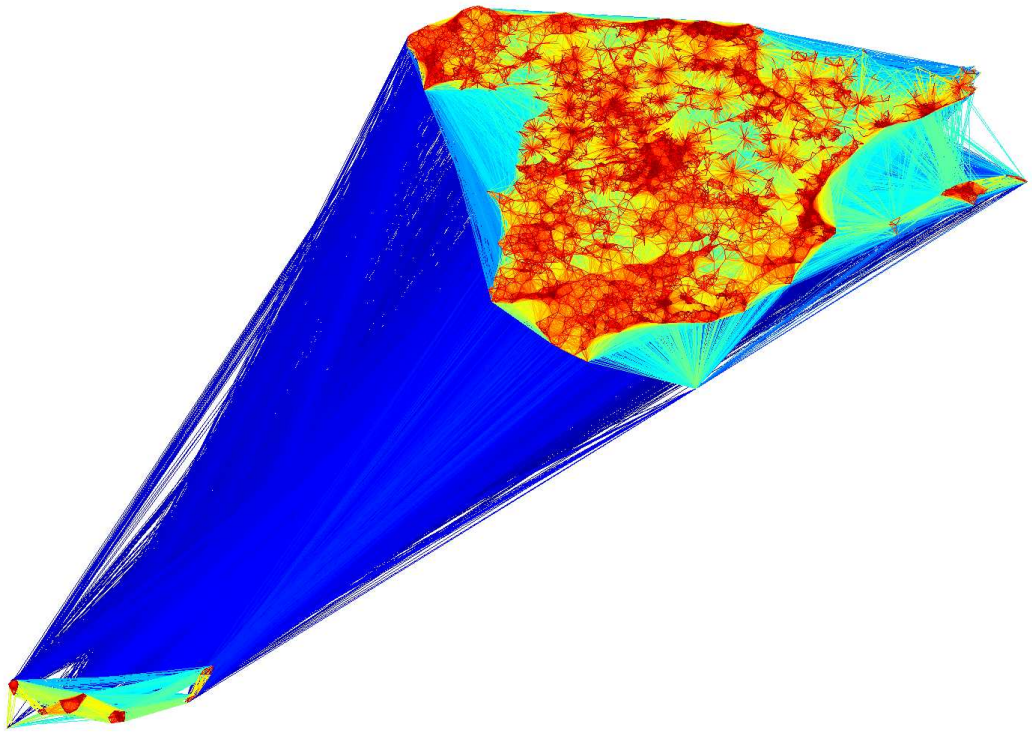
- connections could be more informative than nodes
- different types of social connections
- different ways to characterize social connections

different ways to characterize social connections

- interaction strength
- spatial distance
- structural position in a social graph

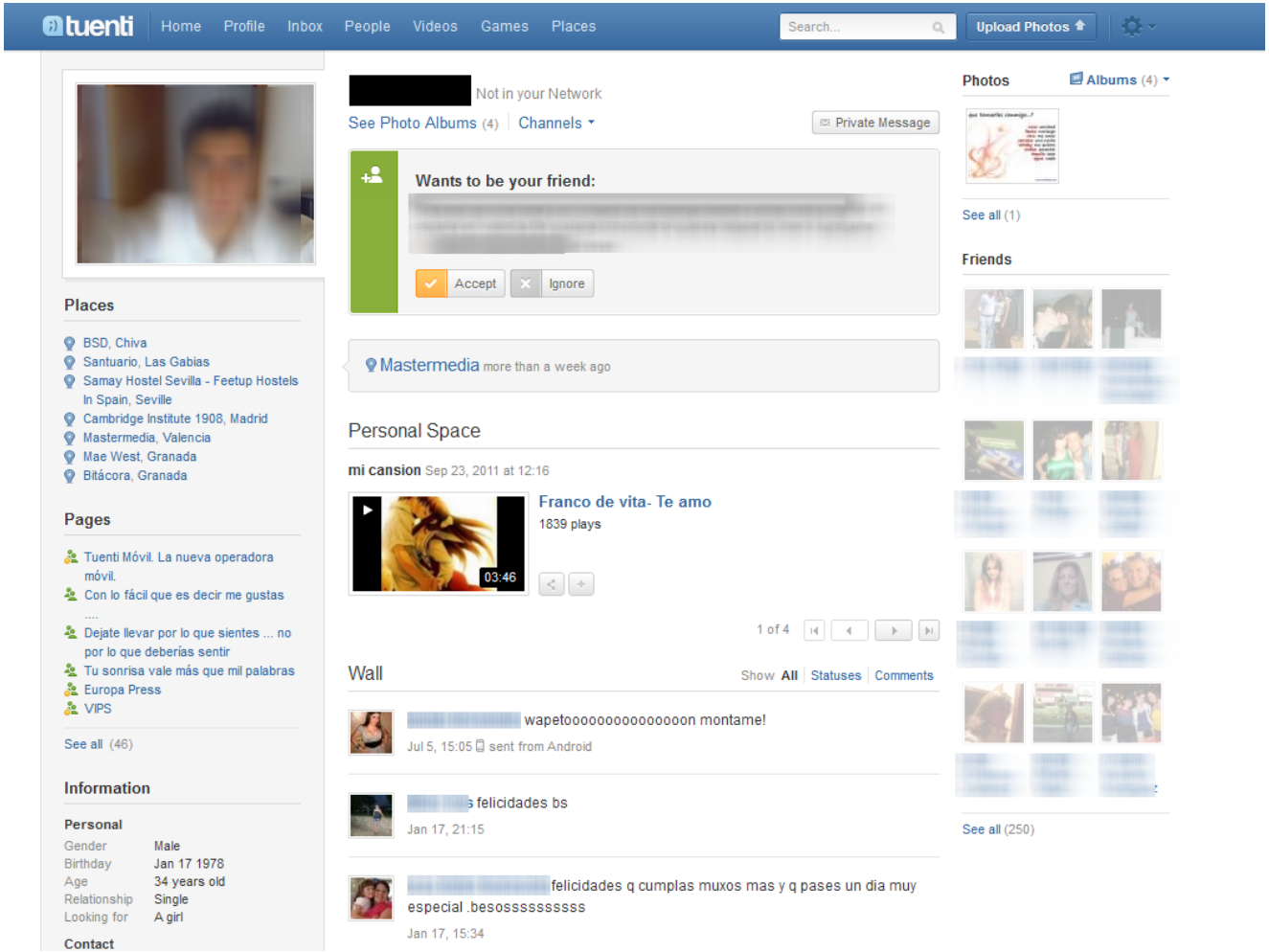
Dataset

Tuenti is the “Spanish Facebook”
a Spain-based, invitation-only social networking website



Tuenti

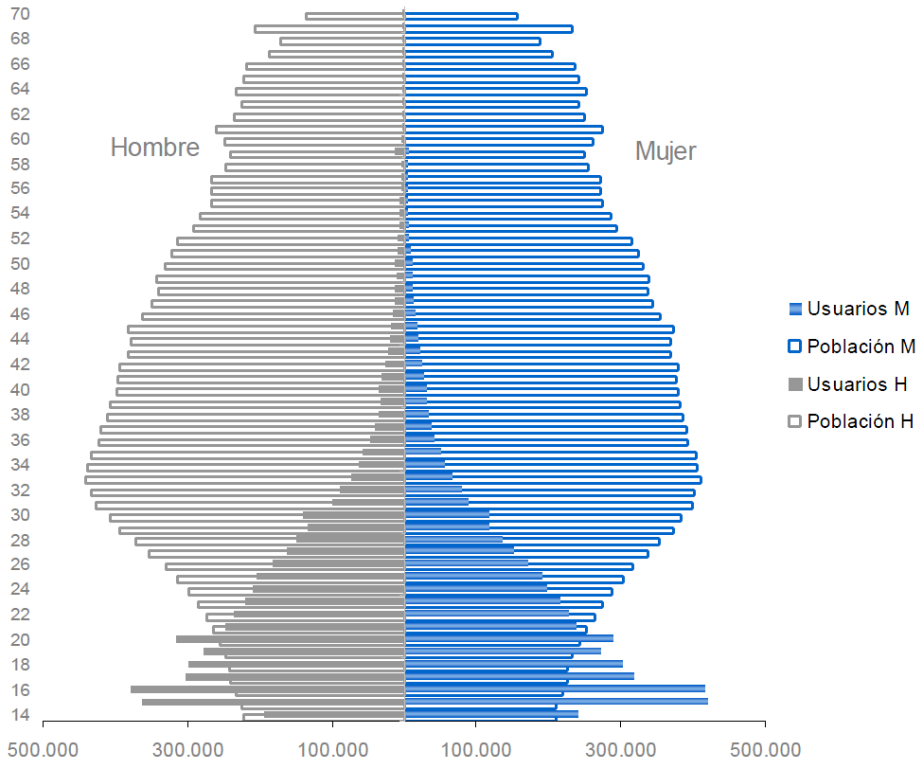
Tuenti website



Tuenti dataset:

- by Dec. 11, 2010;
- 9.88 million registered users (anonymous profiles);
- more than 1 174 million friendship links;
- 500 million messages exchanged during 3 months;

- age pyramid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Hombre
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500.000
Usuarios M
Población M
Usuarios H
Población H

by gender

- 50.6% female;
- 49.4% male.

by age (average)

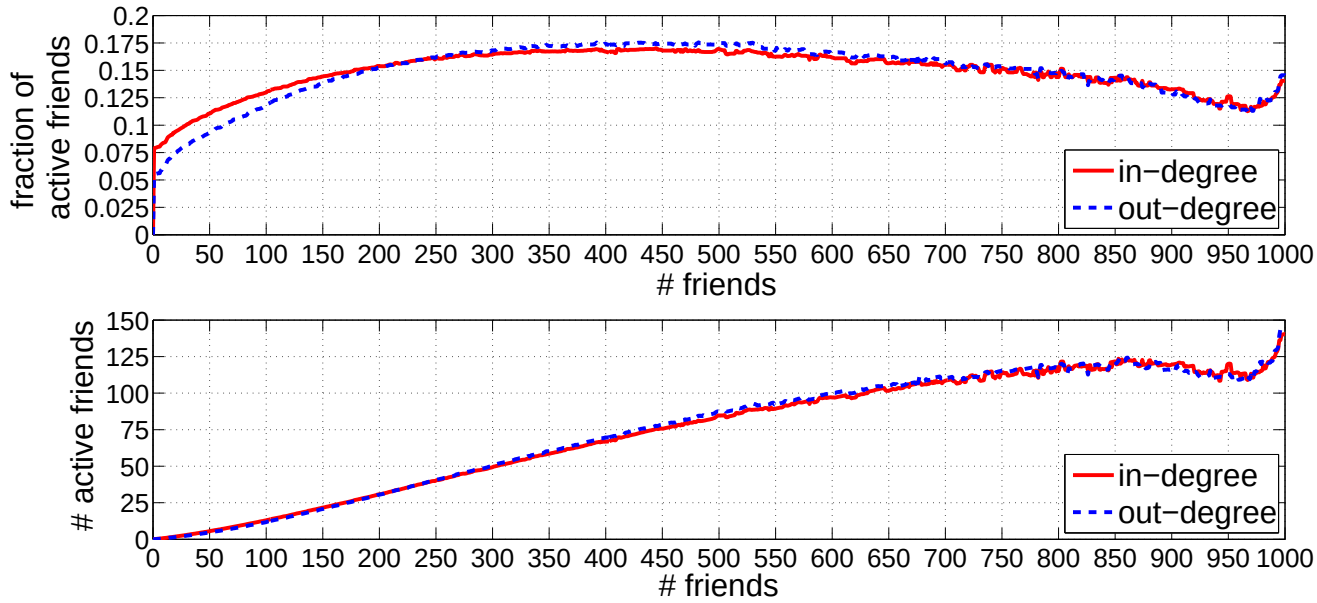
- female: 22 years;
- male: 28 years.

Tuenti users are very young

- 45% of users are between 14 and 20 years;
- 37.5% of users are between 21 and 30 years.
- 1.35 more teenagers than official population (due to Tuenti signing requirements).

implicit vs. explicit social connections

- Dunbar's number: an alleged theoretical cognitive limit to the number of people with whom one can maintain stable social relationship
- average fraction of friends and the average absolute number of friends a user interacts with as a function of the number of friends



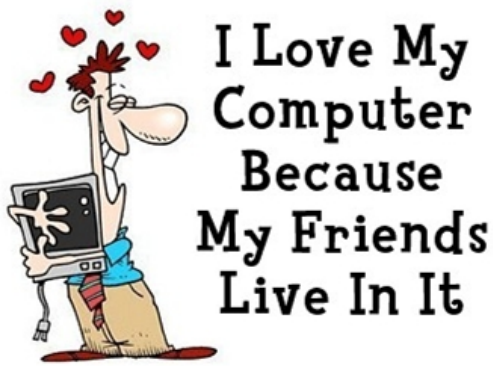
Characteristics for social connections

social ties and spatial distances:

- individuals try to minimize the efforts to maintain a friendship by interacting more with their spatial neighbors
- probability of a social interaction quickly decays as an inverse power of the relative geographic distance (Stewart [1941])

Social connections

spatial distance, related work



- online tools and long-distance travel might result in the ‘death of distance’
- probability of social connection between two individuals on online social networking services still decreases with their geographic distance (Backstrom et al. [2010], Liben-Nowell et al. [2005]).

spatial distance

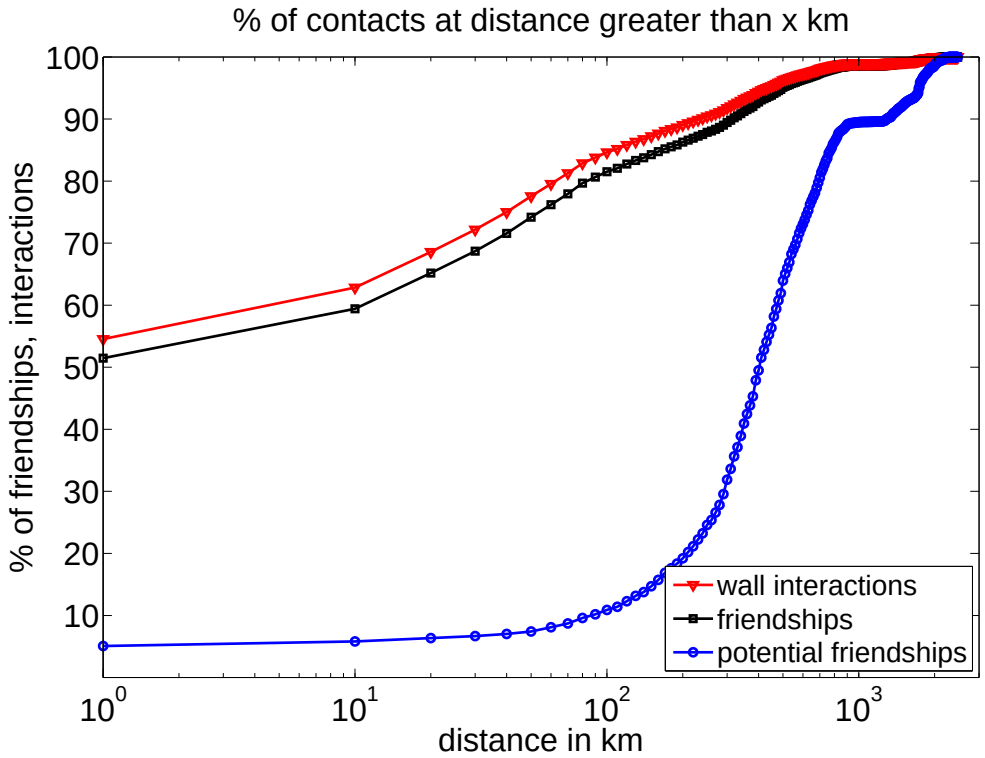
- $d_{i,j}$ is the geographic distance between the cities of residence of user i and user j;
  $d_{i,j} = 0$ if users report the same city of residence
- average geographic distances between users $< D >$ is about one order of magnitude larger than the average geographic distance between friends $< l >$

average geographic distance between nodes, km	531.2
average link length, km	79.9

Social connections

spatial distance

- spatially closer users are much more likely to engage in a social connection (e.g. become friends)
- about 50% of social links between users at a distance of 10 km or less



interaction strength

- close friends or just acquaintances
- quantitative estimation of a how much an online connection binds two users together

interaction strength

- $w_{i,j}$ is the number of messages user *i* posted on the wall of user *j*;
- $w_{i,j} = 0$ if user *i* has never left a message on user *j*'s wall;

balanced interaction weight:

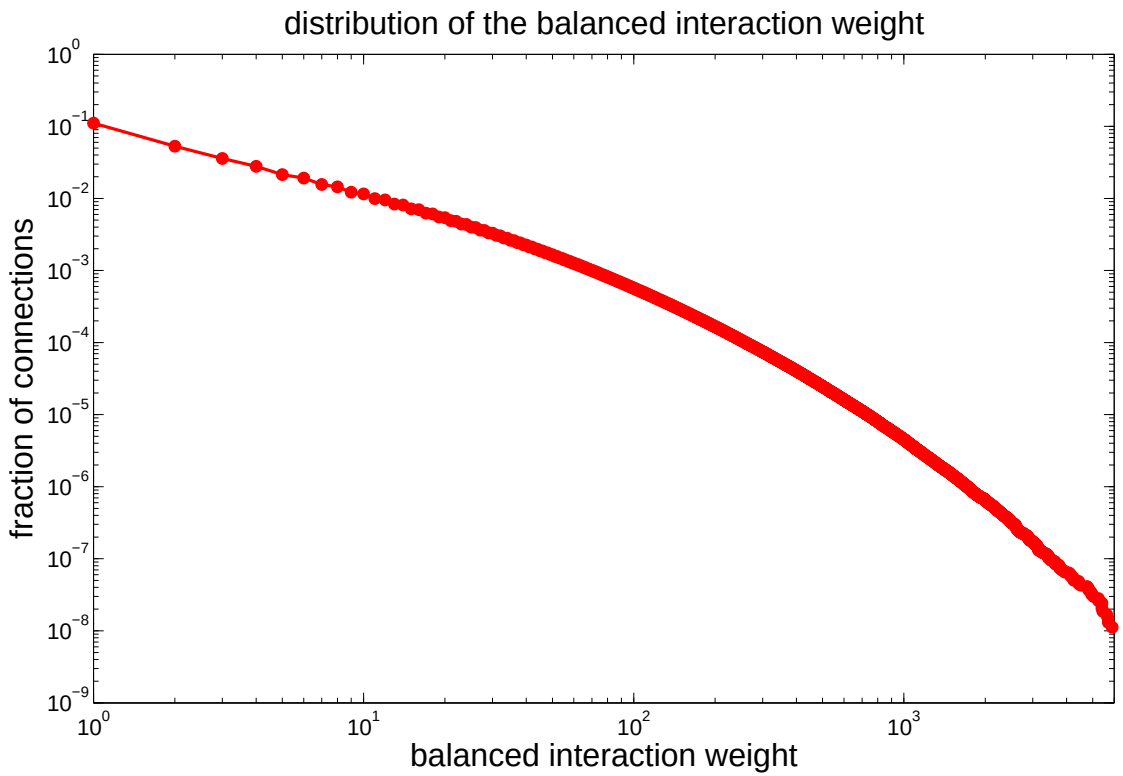
$$\bar{w}_{i,j} = \min(w_{i,j}, w_{j,i}) + (1 - \delta_{w_{i,j},w_{j,i}})/2,$$

Social connections

Interaction strength (log-log)

since non-reciprocated interactions may indicate spam:

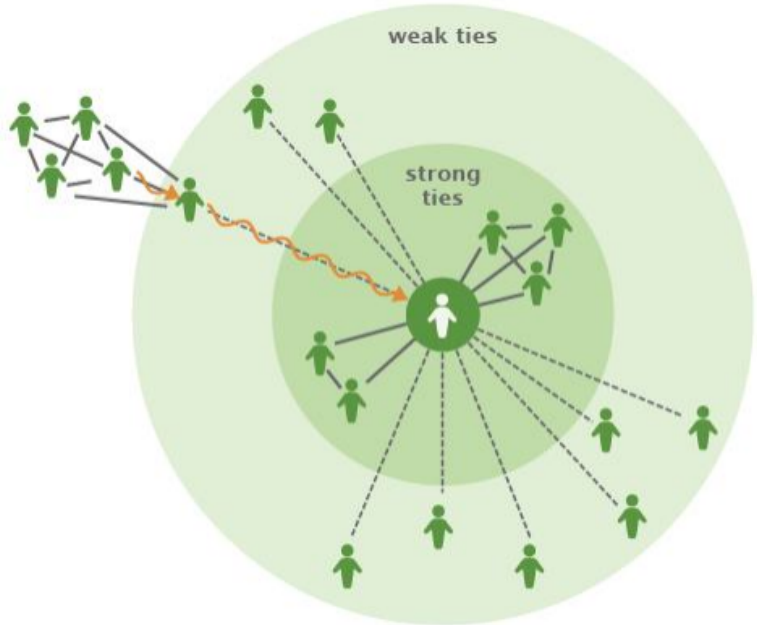
- the minimum of the interaction weights to emphasize reciprocated interactions;
- for the non-reciprocated interactions we only add 1/2 no matter the difference in the numbers of messages exchanged.



Social connections

structural properties

- weak ties are more likely to connect together otherwise separated portions of a network, playing an important role in information diffusion and resilience to network damage (Granovetter [1973])
- some social ties closing “structural holes” can be more powerful or more innovative (Burt [1992])



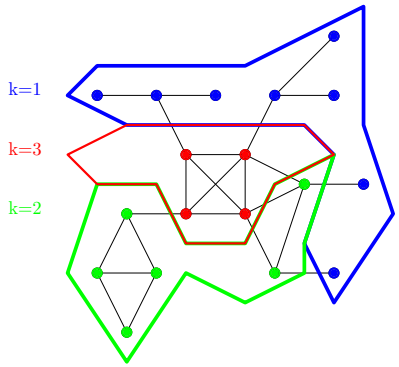
Bakshy [2012]

structural properties:

- **local position:** social overlap;
- *social overlap* of an edge $e_{i,j}$ as $o_{i,j} = |\Gamma_i \cap \Gamma_j|$, where Γ_i is the set of users connected to user i

structural properties:

- **global position:** k-index;
- *k*-core is the maximal subgraph in which each node is connected to at least *k* other nodes of the subgraph
- *k*-index of a node is *v* if it belongs to the *v*-core but not to the $(v+1)$-core
- *k*-index has been found to be an indicator of influential nodes within a social network (Kitsak et al. [2010])

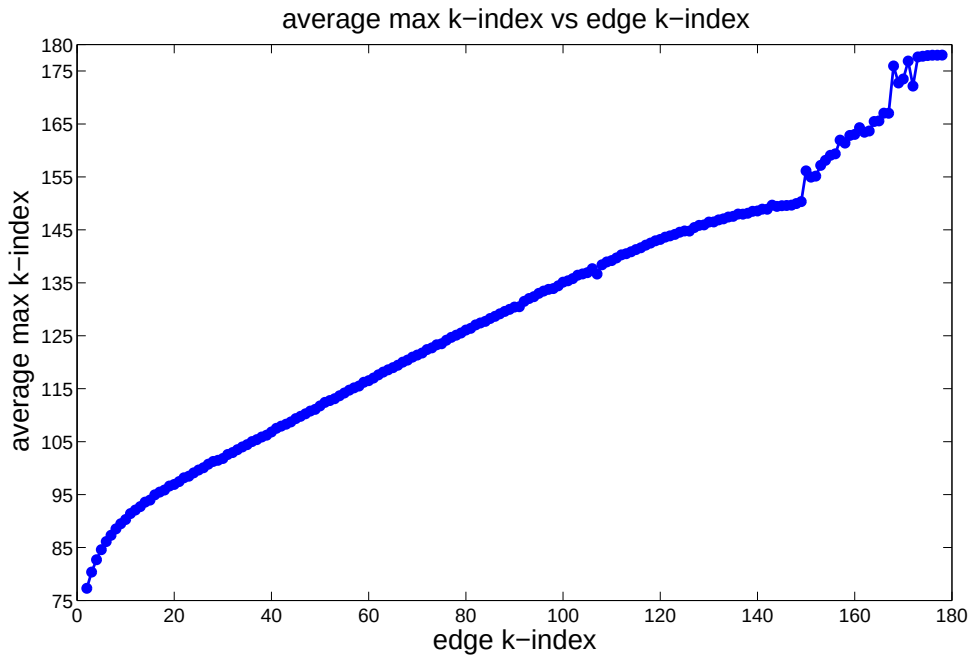


- central core/ smaller core in between/ periphery

Social connections

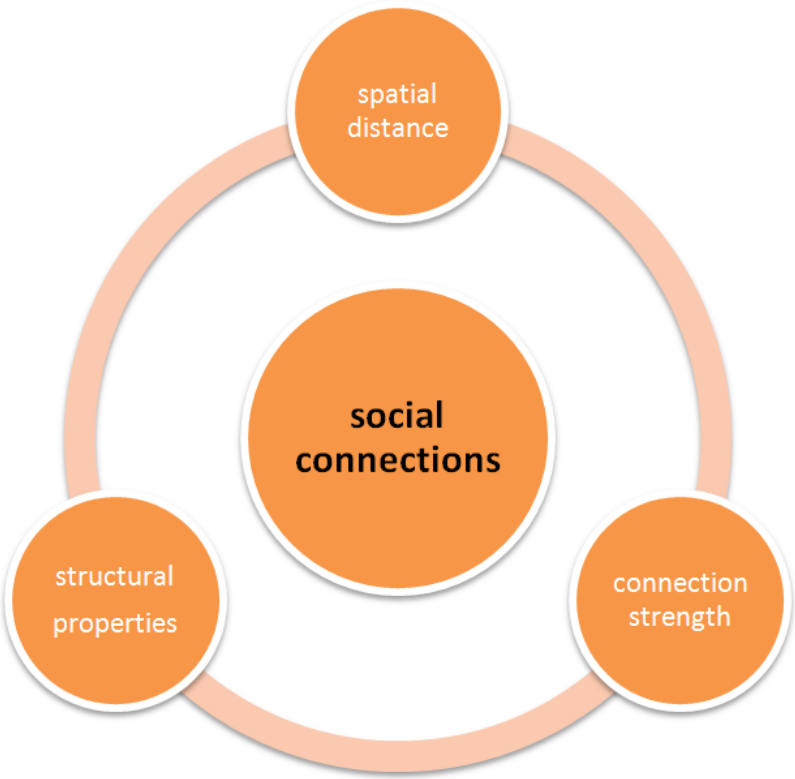
Structural properties:k-index of an edge

- *k-index* k_{ij} of an edge is the minimum of the *k*-indexes of two endpoints
- we distinguish if an edge connects nodes inside a network core or links to a node in the periphery



Combined analysis of social connections

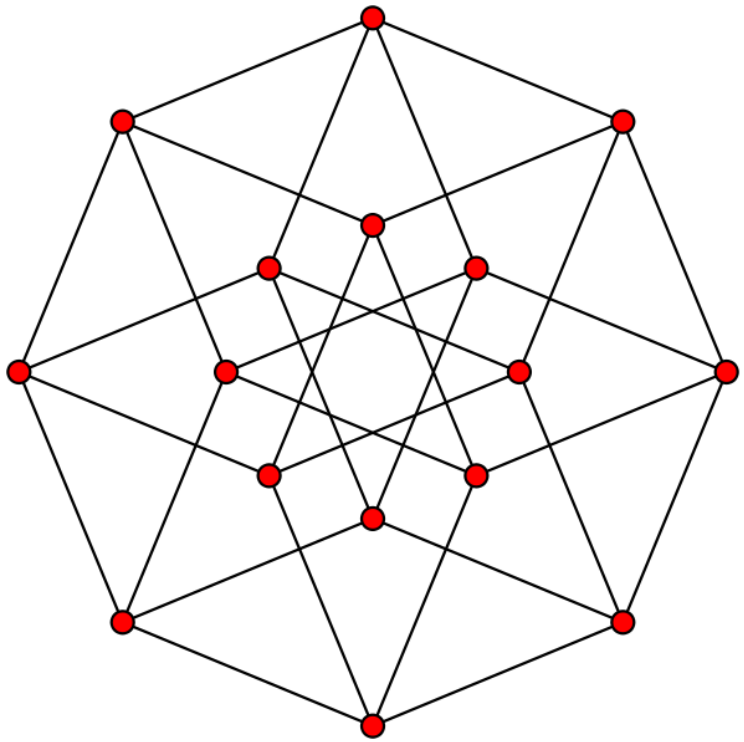
social connections



Combined analysis

Social overlap vs. k-index

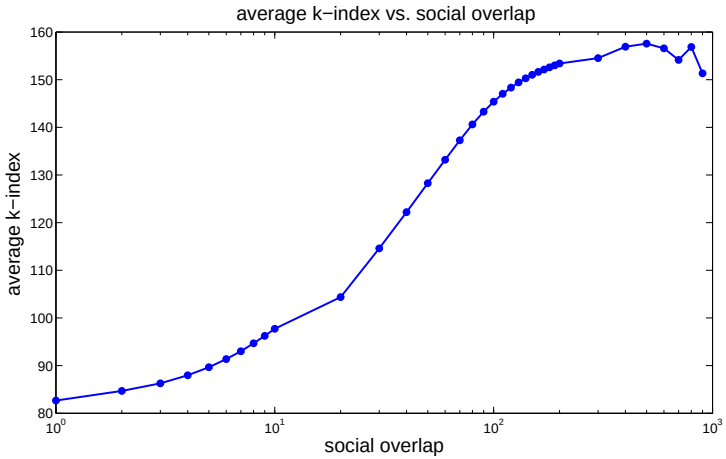
social overlap and *k*-index allow network scenarios where links may have high *k*-index and low overlap, or the other way round

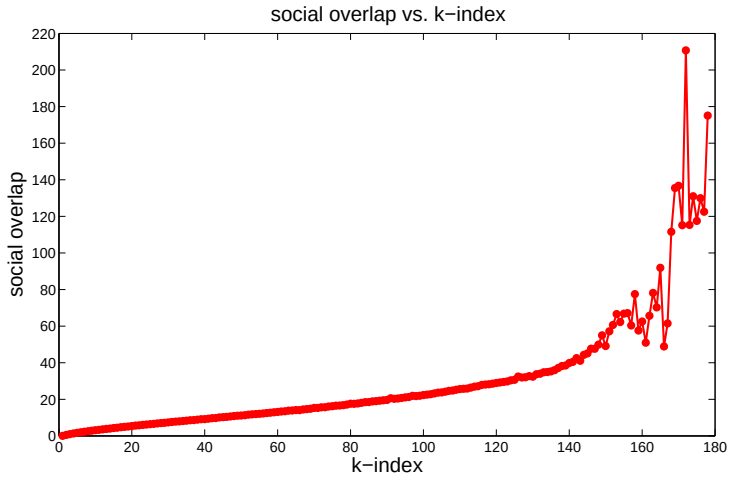


Combined analysis

Social overlap vs. k-index

- social overlap $\uparrow \Rightarrow$ *k*-index grows quickly
- *k*-index $\uparrow \Rightarrow$ the average social overlap grows slowly
- *there are inner cores where users are tightly connected to each other*
- *other parts of the network include more isolated users that tend to not belong to any community*

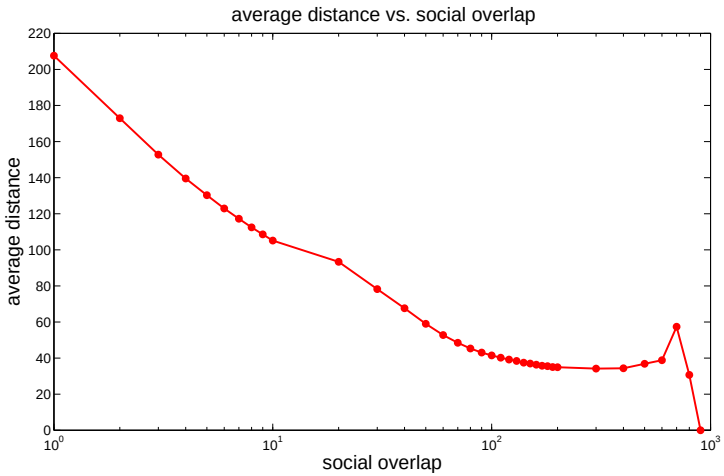


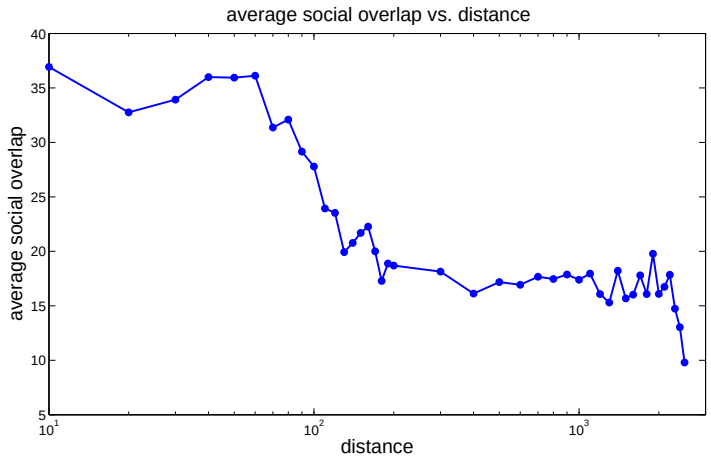


Combined analysis

Distance vs. social overlap

- the geographic distance between two connected users decreases as they share more and more friends
- social connections which span less than 60-80 km exhibit higher values of social overlap

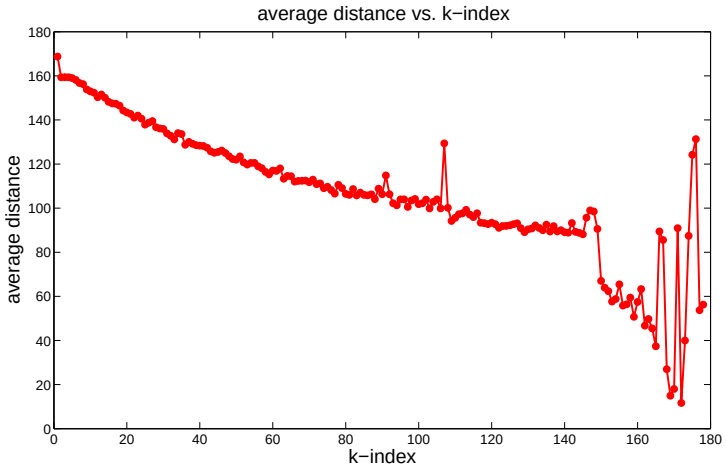


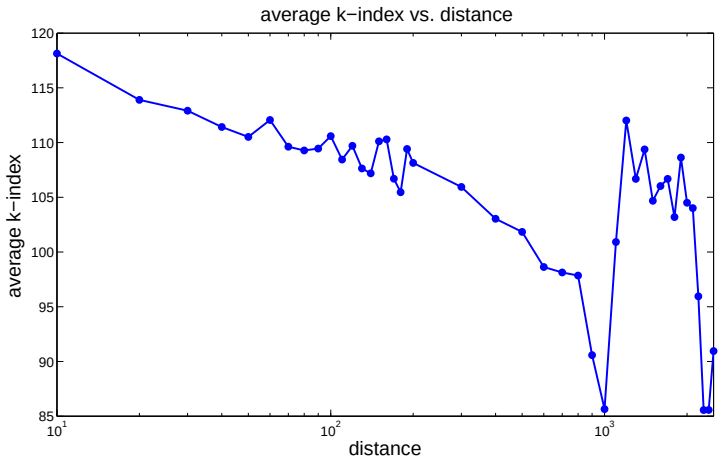


Combined analysis

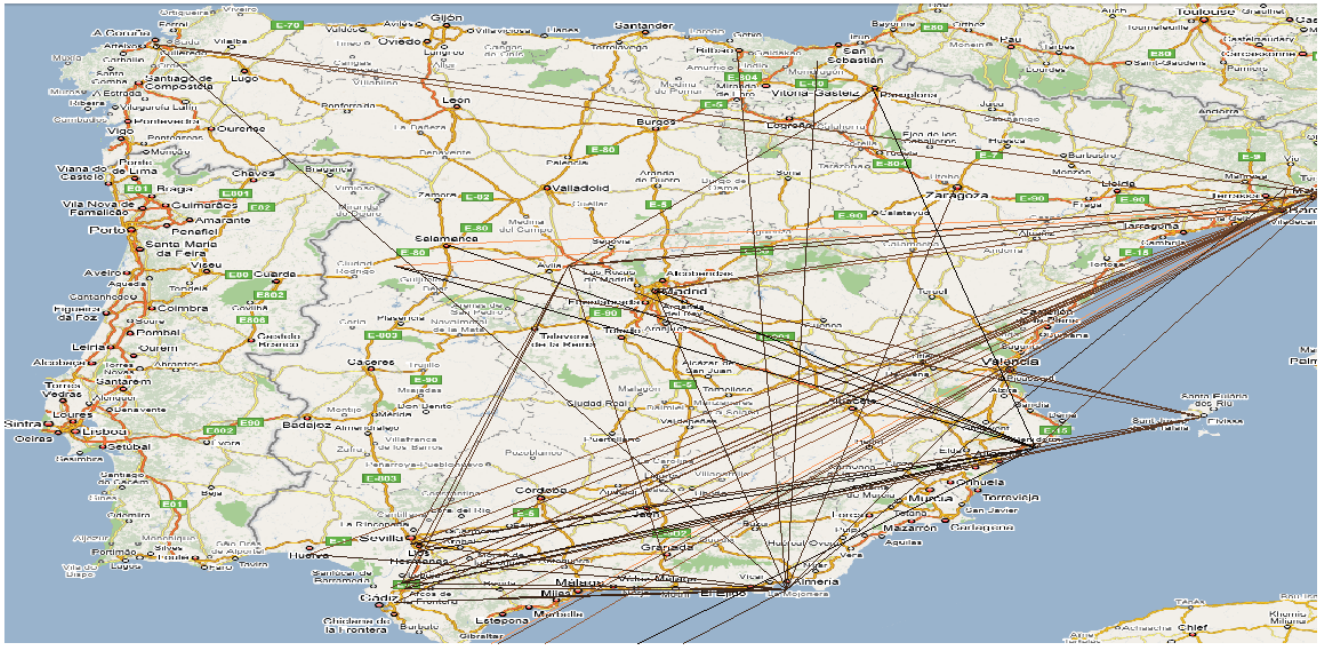
Distance vs. *k*-index

- the average spatial length of social links decreases as their *k*-index increases
- social links inside the core tend to be shorter than the ones reaching the periphery of the social network





k_{max}-core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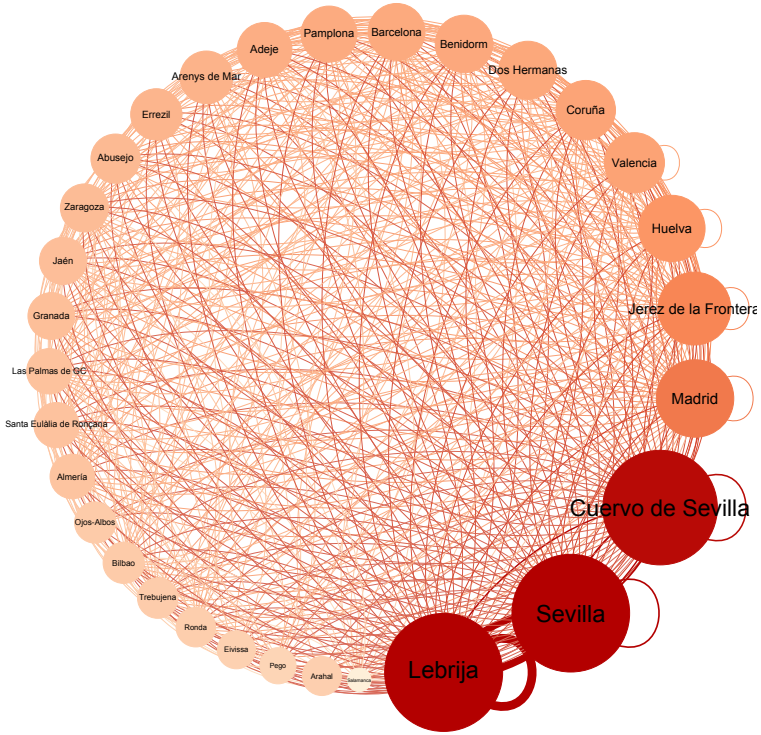
Toulouse

Combined analysis

Distance vs. *k*-index

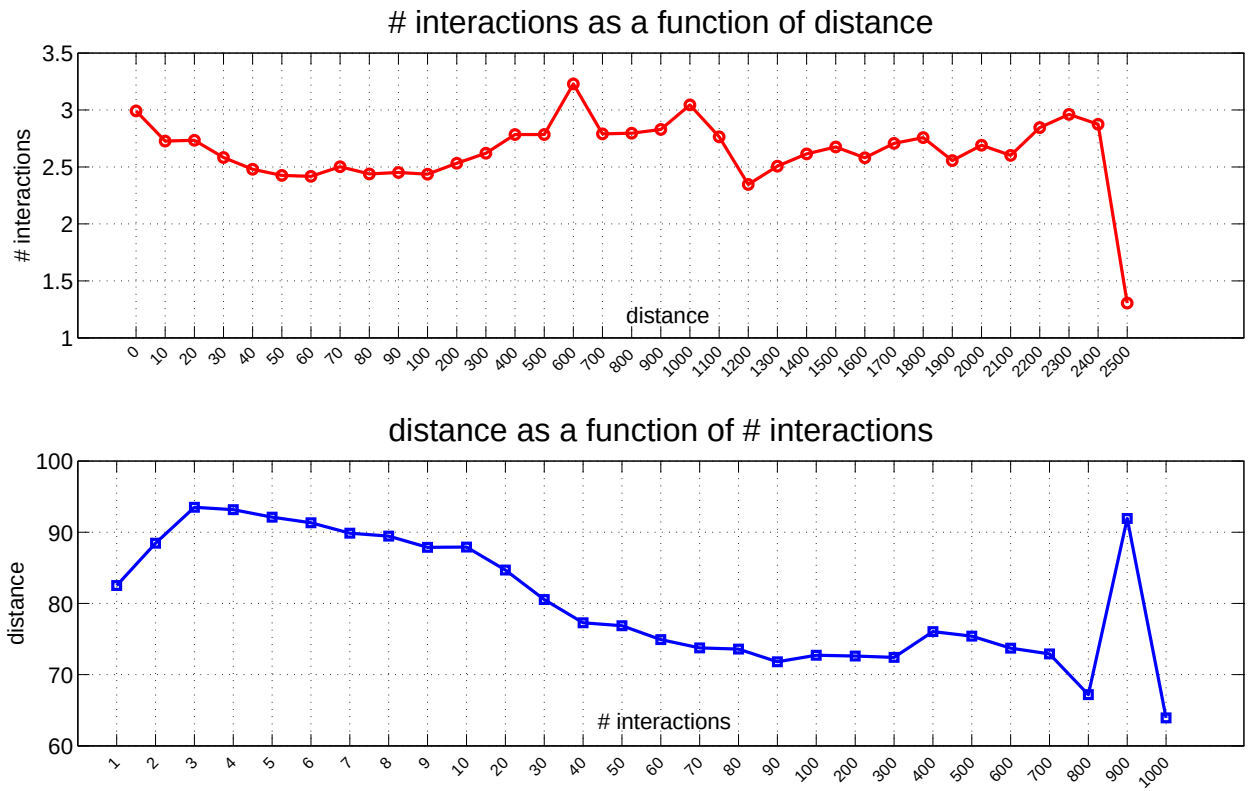
k_{max}-core



Combined analysis

Distance vs. interaction weight

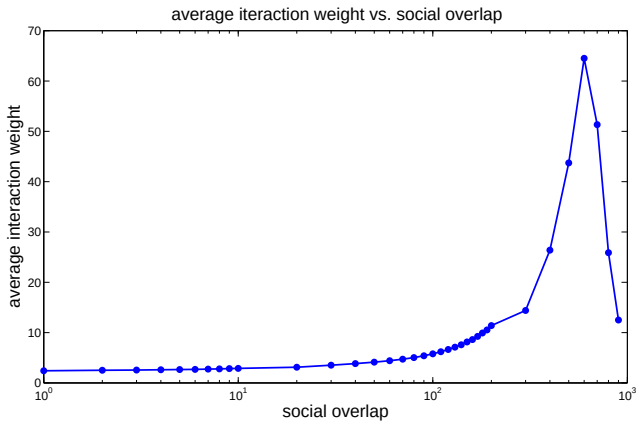
- *the amount of interaction is uncorrelated to spatial distance*
- note that the likelihood that two individuals are connected is heavily dependent on distance

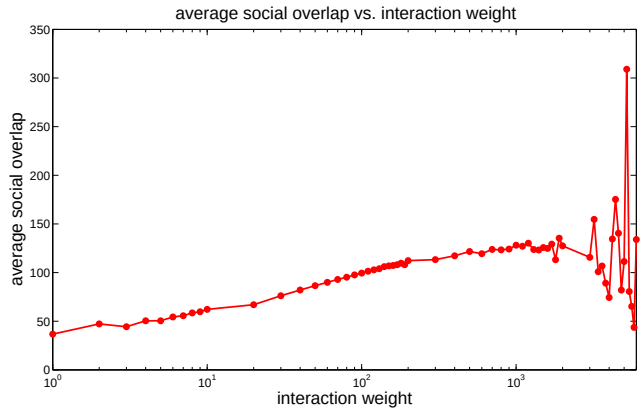


Combined analysis

Social overlap vs. interaction

- *the impact of social overlap remains fairly constant*
- the interaction weight only slowly increases the social overlap grows
- the extremely high levels of interaction mainly take place between users with several shared friends, which are likely to be in the network core

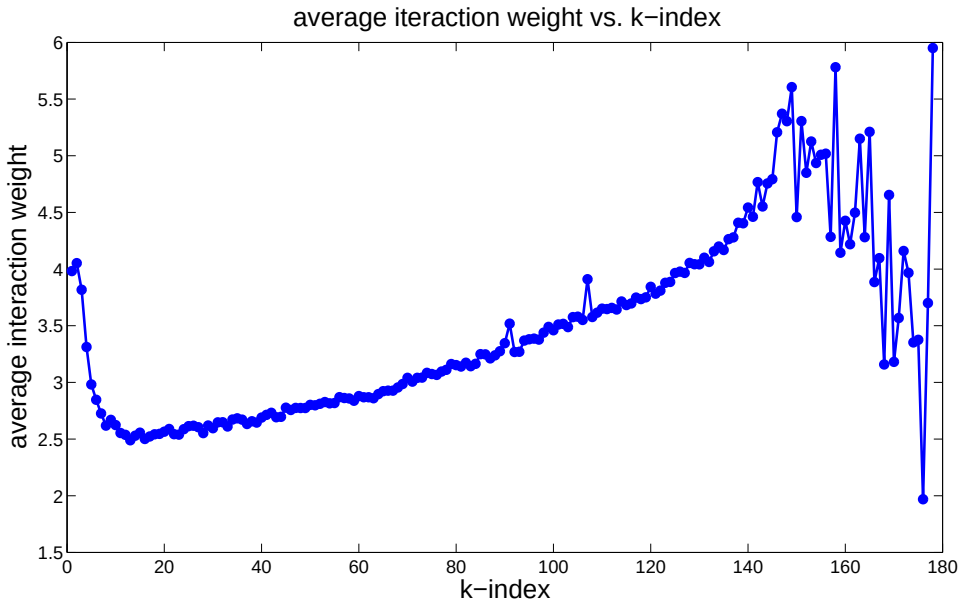




Combined analysis

k-index vs. interaction weight

- ties in the inner cores have the highest levels of interaction
- interaction weights are almost equally high for social ties with low *k*-index
- social ties with intermediate *k*-index, likely to bridge together different portions of the network, experience the lowest interaction levels



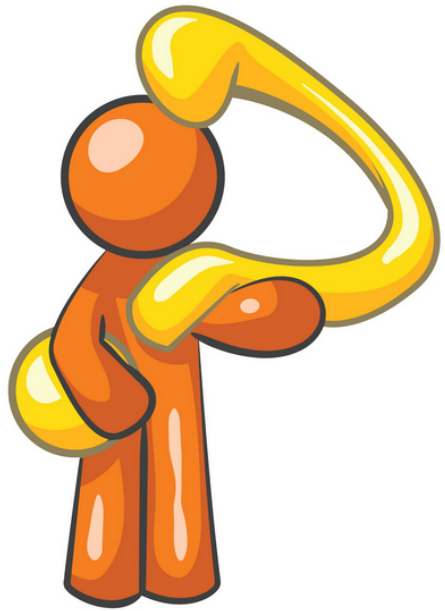
Conclusions

Conclusions

- social connections between users inside the core tend to have shorter geographic spans than connections stretching outside the core
- social ties outside the core tend to be much longer than the other links: the length of these bridge ties is thus creating not only network shortcuts, but also spatial shortcuts
- the amount of interactions appears independent of spatial distance
- interaction levels appear higher inside well-connected cores and on links connecting to the fringe of the network
- **edges could be more informative than nodes**

Questions

Questions



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