The Sociometer: A Wearable Device for Understanding Human Networks

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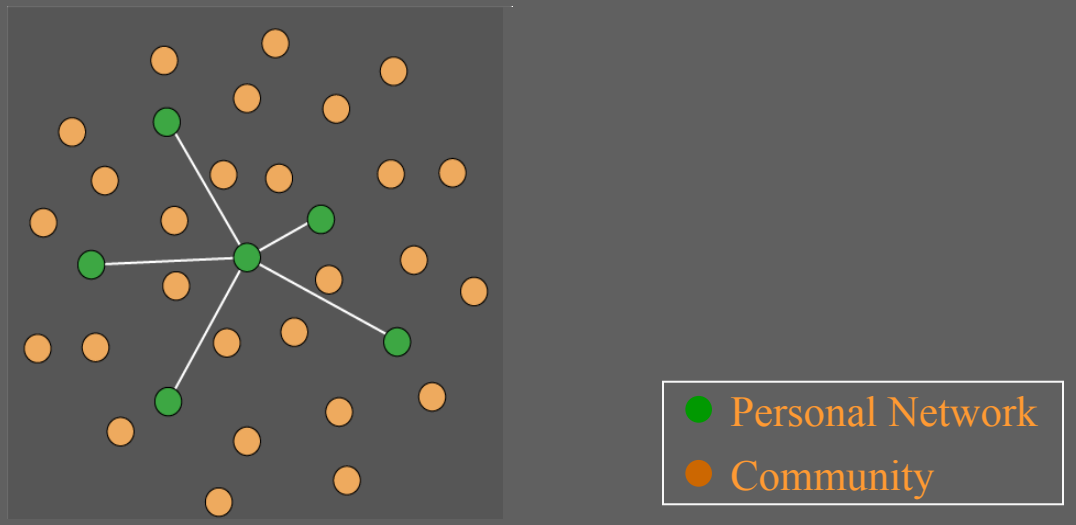
What is a Human Network ?

A *human network* is the pattern of communication, advice or support which exists among the members of a social system.



Sensors NOT Surveys

We want to take a data driven approach to modeling human networks – i.e. use sensors to collect data about people's interactions

- Need to overcome or deal with uncertainty in sensor measurements
- Needs to be acceptable and comfortable enough for users to wear regularly
- Privacy concerns

Why is it important to understand interactions?

- In any social/work situation our decision making is influenced by others around us –

  - Who are the people we talk to
  - For how long and how often ?
  - How actively do we participate in the conversation ?

Why is it important to understand interactions?

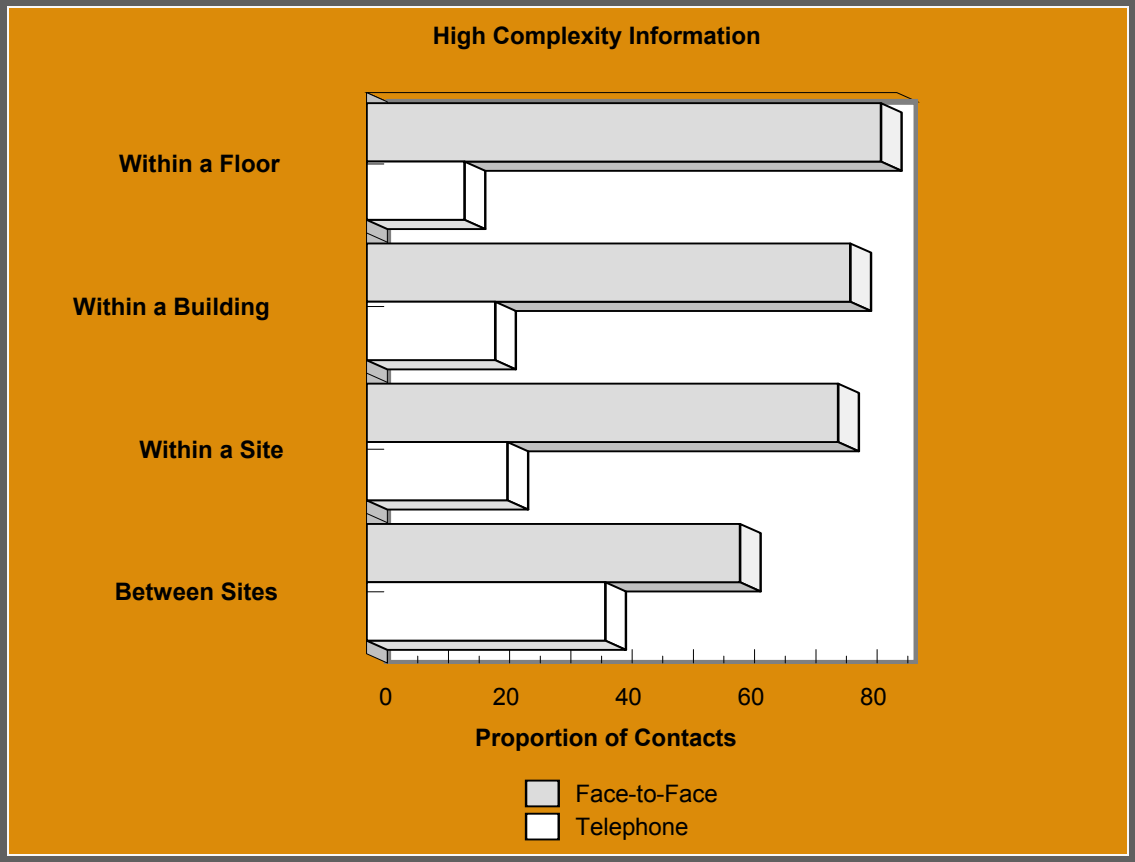
Connection structure and nature of communication among people are important in trying to understand –

- Diffusion of information
- Group problem solving
- Consensus building
- Coalition formation

What can we do by learning group interactions?

Identify Leaders	Can we identify the leaders or connectors? Who is the leader influencing the most?
Diffusion of innovation	Who do we have connections with ? Who are the people influencing us ?
Effective methods of intervention	Can we target the most influential node ?

Why face-to-face interactions ?



Allen, T., *Architecture and Communication Among Product Development Engineers*. 1997, Sloan School of Management, MIT: Cambridge.

How do we measure group interactions ?

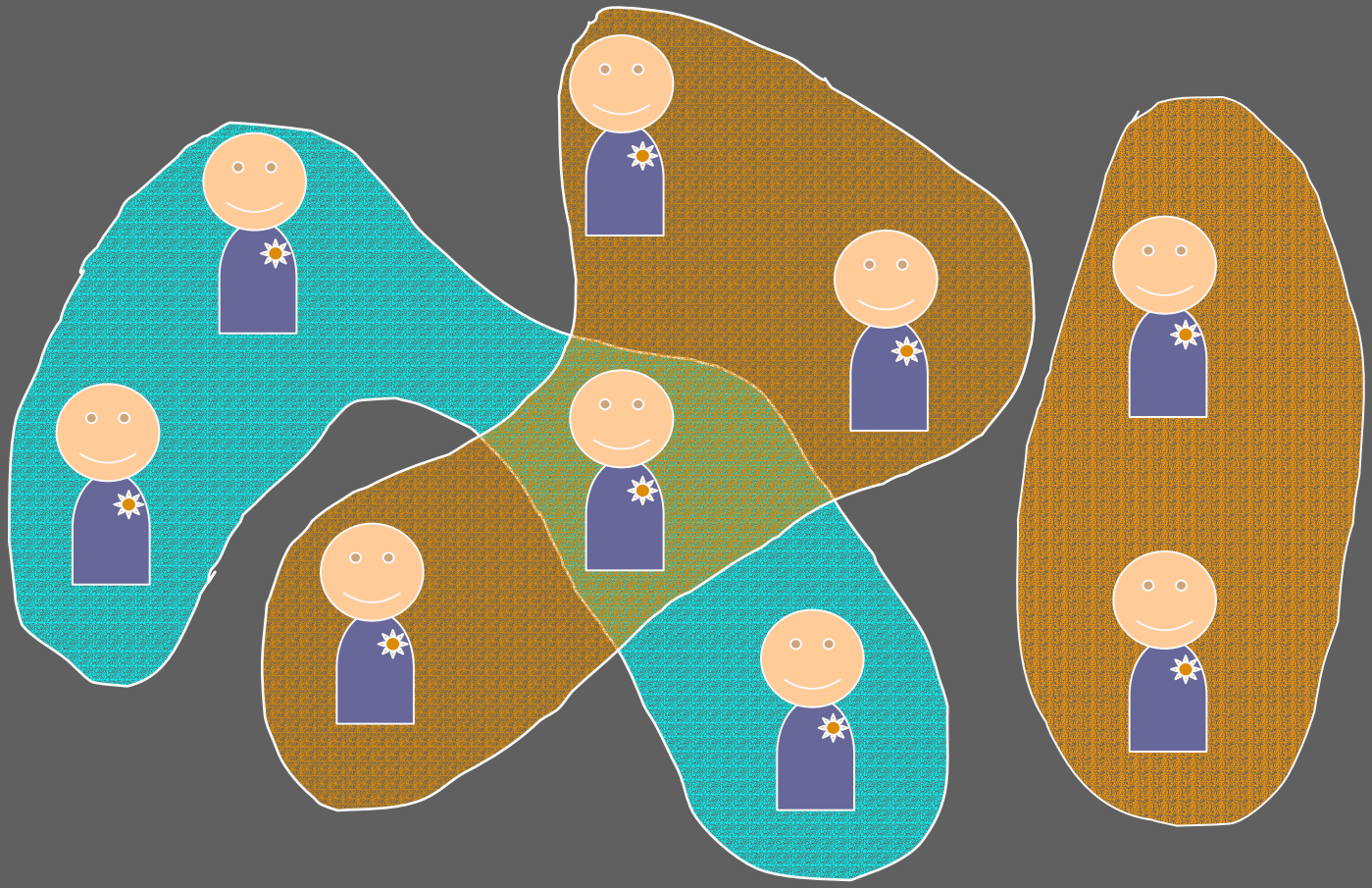
Can we learn the structure of groups in a community ?

Outline of experiment

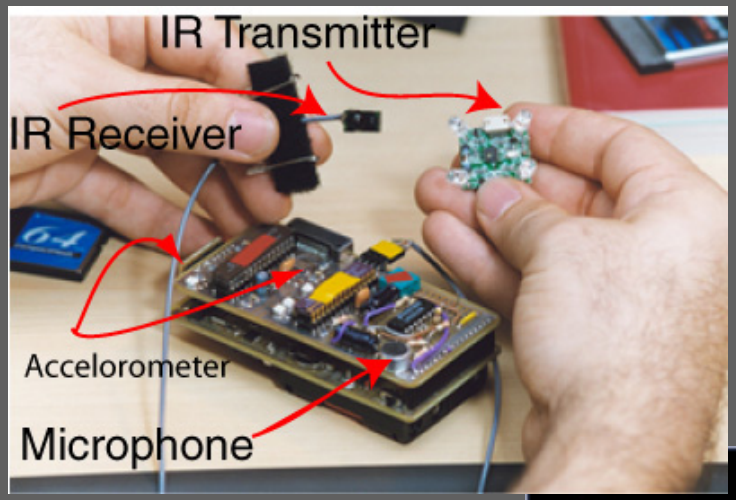
- A group of people who agree to wear sensors
- We collect information over certain period of time
- Can we learn the types of groups and the communication structure that exists within the group?

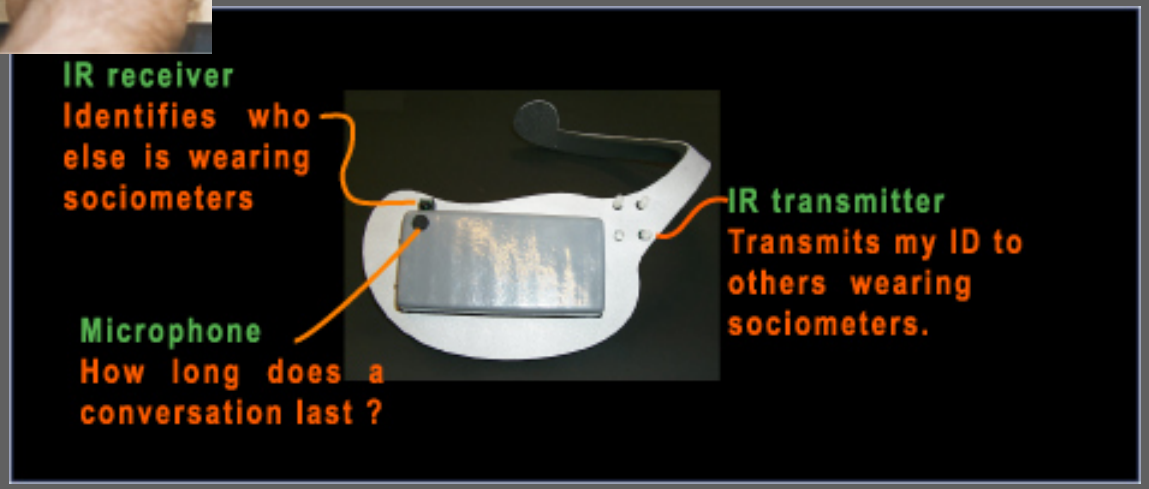
M Gladwell, *The Tipping Point: How little things make can make a big difference*. 2000, New York: Little Brown.Thomas W. Valente, "Social Network Thresholds in the Diffusion of Innovations", *Social Networks*, Vol. 18, 1996, pp 69-89.
M. Granovetter. "The strength of weak ties", American Journal of Sociology, 78(6), 1360-1380 (1973).

How do we measure group interactions ?



The Sociometer





The Sociometer

The sociometer stores the following information for each individual

- Information about people nearby (sampling rate 17Hz – sensor IR)
- Speech information (8KHz - microphone)
- Motion information (50Hz - accelerometer)

Other sensors (e.g. light sensors, GPS etc.) can also be added in the future using the extension board.

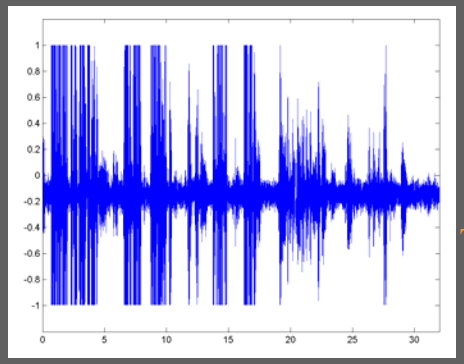
What do we want to learn ?

Who talks to whom ?	Detect people in proximity Segment speakers Identify conversations Estimate conversation duration
Who are the connectors, experts? How does information flow ?	Build model of the communication link structure Build model of influence between people

The Experiment

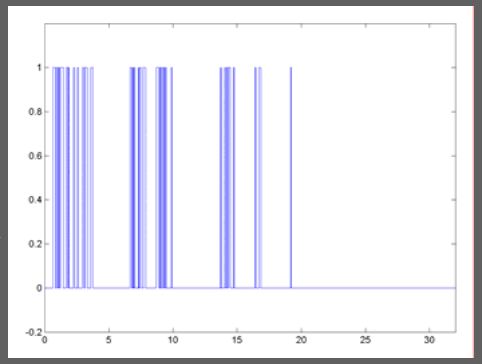
- 23 subjects wore sociometers for 2 weeks – 6 hours everyday
- 60 hours of data per subject – total 1518 hours of interaction data

Speaker Segmentation

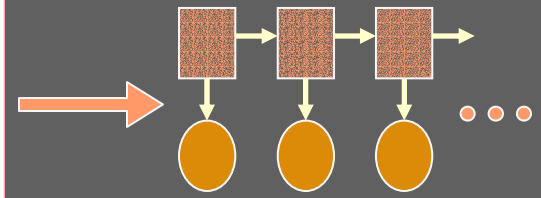


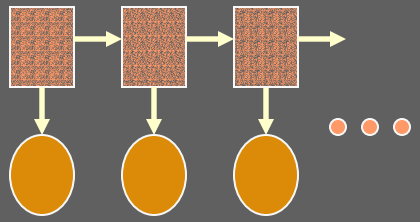
Raw speech signal

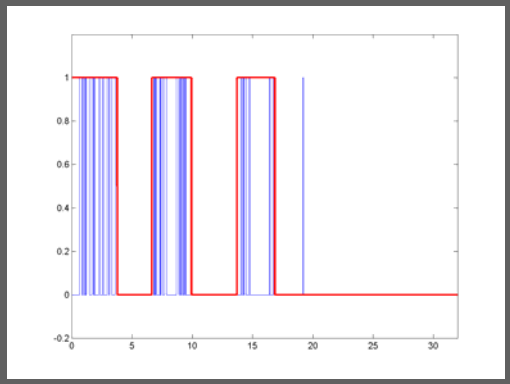
Threshold Energy



Output of energy threshold

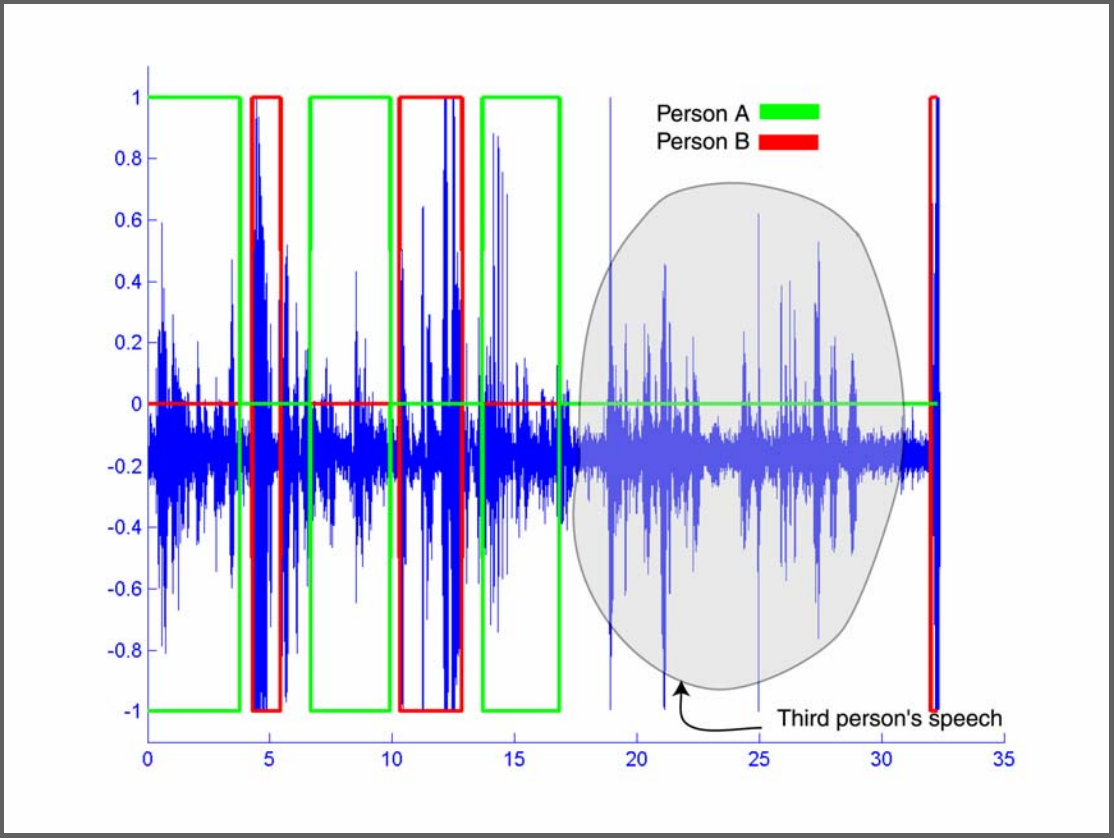






Output of HMM

Speaker Segmentation



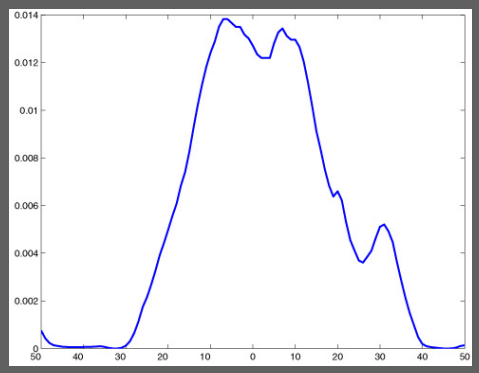
Finding Conversations (Basu 2002)

Consider two voice segment streams

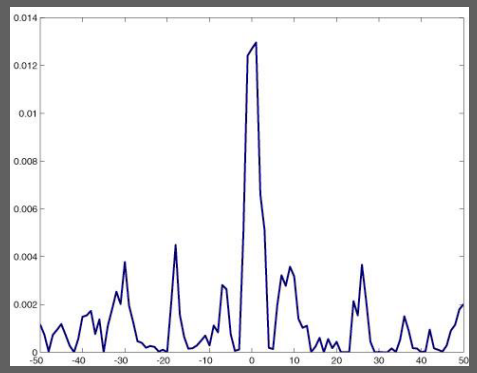
- How tightly synchronized are they?
- Alignment measure based on Mutual Information

$$a[k] = I(v_1[t], v_2[t-k])$$

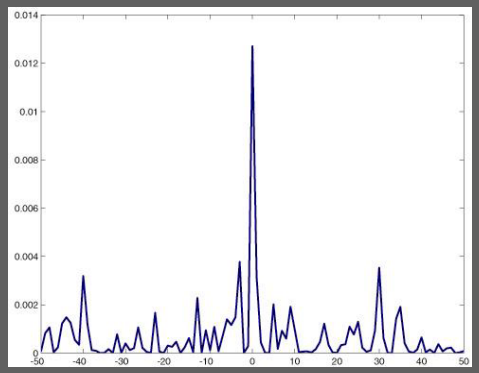
$$= \sum_{i,j} p(v_1[t] = i, v_2[t-k] = j) \log \frac{p(v_1[t] = i, v_2[t-k] = j)}{p(v_1[t] = i)\, p(v_2[t-k] = j)}$$



1.6 seconds



16 seconds

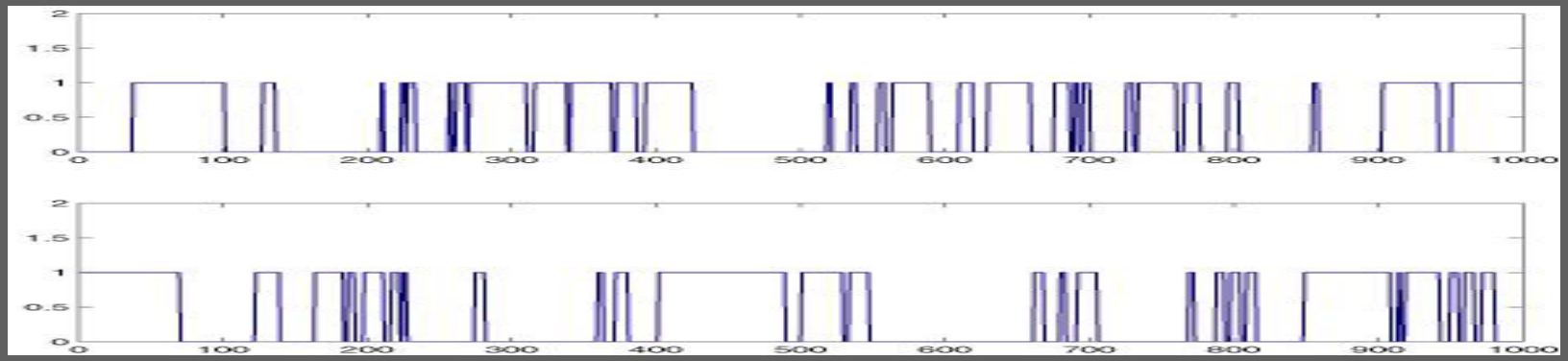


2.5 minutes

Why Does It Work So Well? (Basu 2002)

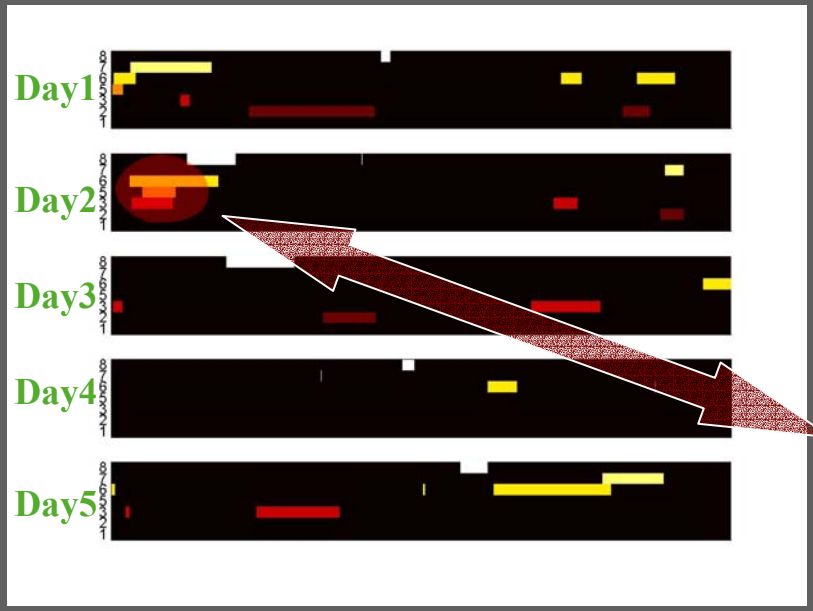
Voicing segs: pseudorandom bit sequence

- The conversational partner is a **noisy** complement



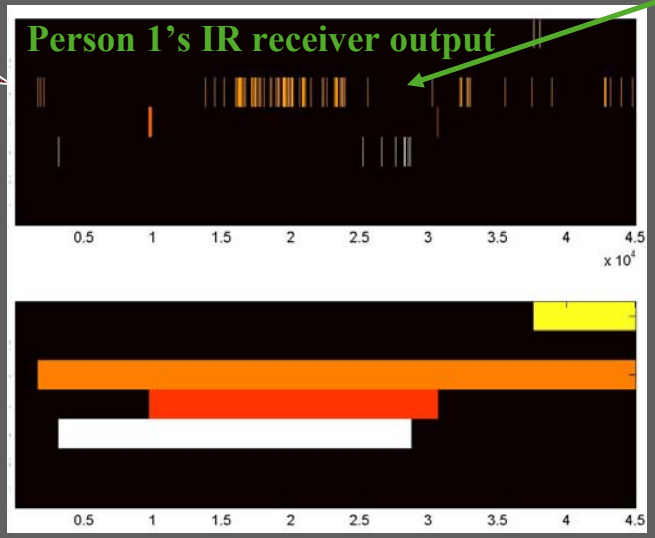

Views Selection Label Options
MyAudio

Identifying People in Face-to-Face Proximity



IR output for person 1

Signal received from person 3



From Features to Network Models

We have features but still need to do -

- Transcription of the sensor data into descriptive labels (such as conversation duration and types).
- Characterization of the communication network i.e. the network structure/map
- Participation types and dynamic models of interactions
- Prediction of future interactions

The Influence Model

•The "Influence Model" is a generative model for describing the connections between many Markov chains with a simple parameterization in terms of the “influence” each chain has on the others.

•Computationally tractable

The parts of the model:

•Each node represents an individual as a full-fledged Markov Process.

•Each arrow represents some form of influence that one individual has on another.

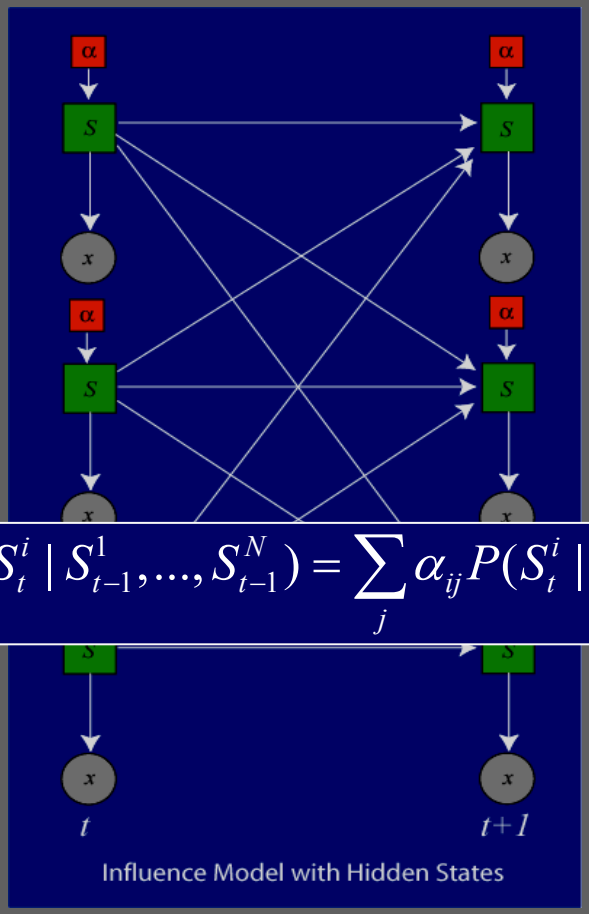
Reference:
C. Asavathiratham, "The Influence Model: A Tractable Representation for the Dynamics of Networked Markov Chains," in Dept. of EECS. Cambridge: MIT, 2000, pp. 188.

Inside the Influence Model

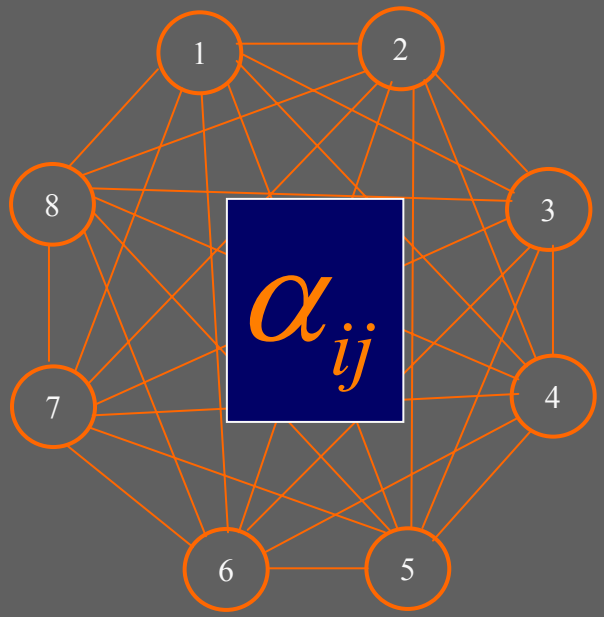
Inside each node is one or more Markov Processes that can represent:

- the state of the individual
- the dynamics of the individuals state-changing behavior

Influence Parameters: $\{\alpha_{ij}\}$



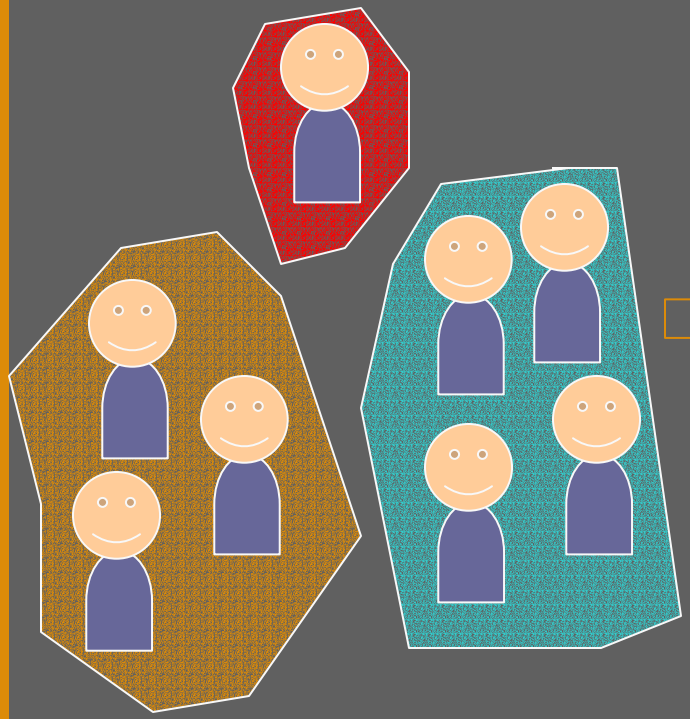
$$P(S_t^i \mid S_{t-1}^1, \ldots, S_{t-1}^N) = \sum_j \alpha_{ij} P(S_t^i \mid S_{t-1}^j)$$

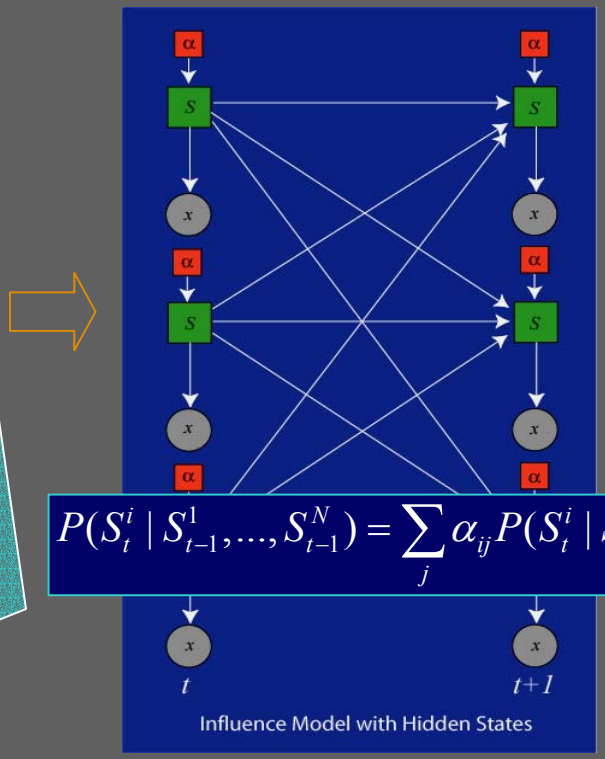


$\{\alpha_{ij}\}$: Amount of influence that person i has on person j

$P(S_t^i \mid S_{t-1}^j)$: How person i is influenced by person j

Basic Approach





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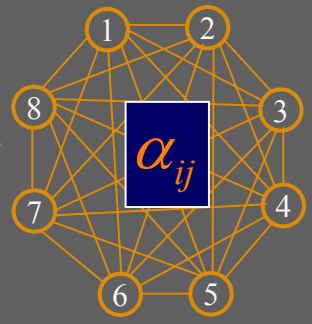
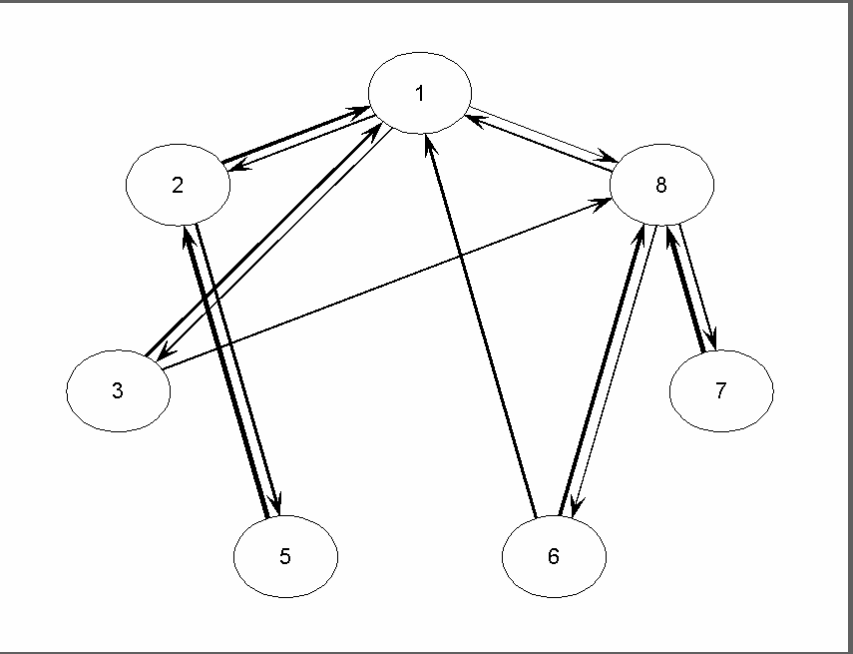


Take Sensor Measurements of individuals as they interact

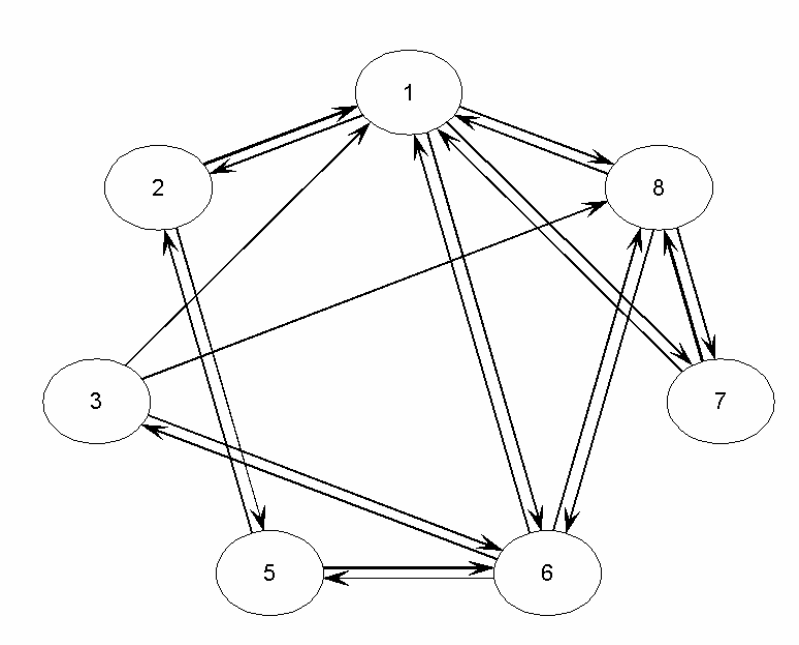
Represent the Interaction Dynamics With a Dynamic Bayes' Net (DBN)

Link Structure of the Group Duration vs. Frequency

Interaction structure based on duration



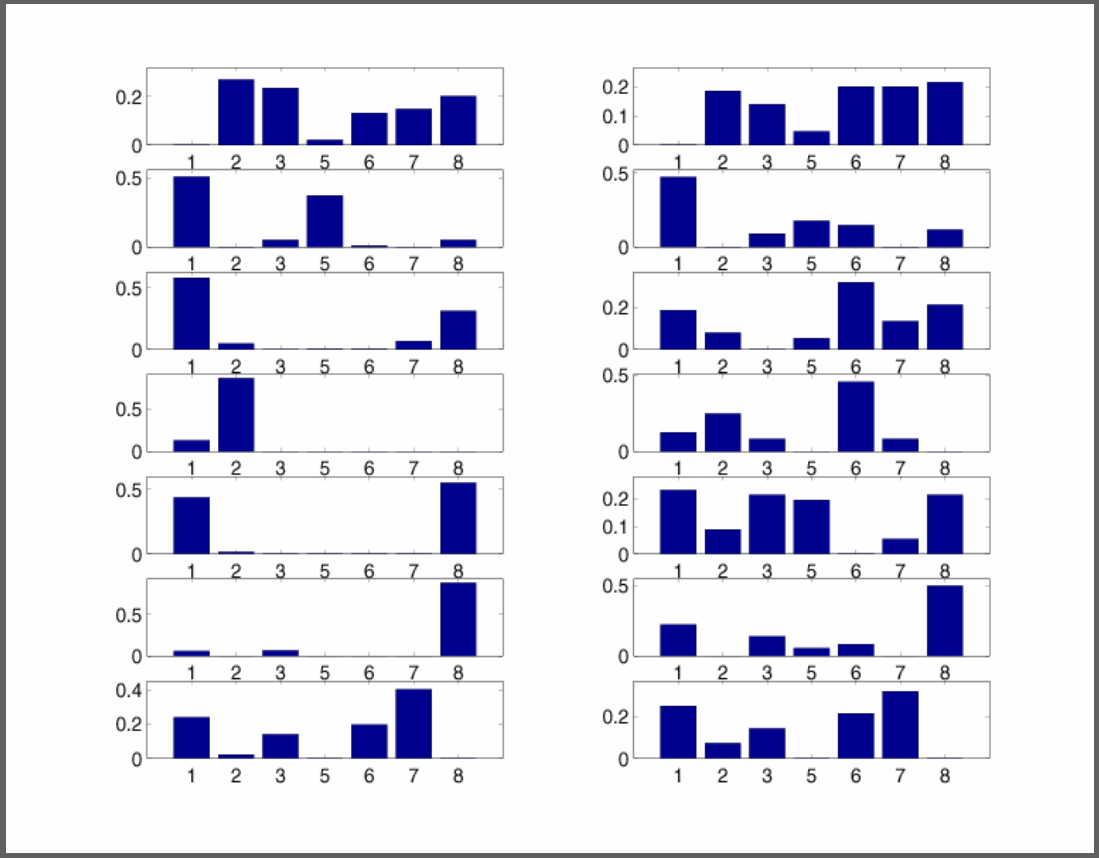
Interaction structure based on frequency



Interaction Distribution

Fraction of interaction based on duration

Fraction of interaction based on frequency



Conclusions

- Sensor-based models of human communication networks
- Continuous sensing on interaction without relying on personal recall or surveys
- Models of communication links structure
- Inter/intra group interactions
- Influence model for group interactions

http://www.media.mit.edu/~tanzeem/shortcuts

Acknowledgements

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