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Modelling Dynamics of Energy Choices on Social Networks

updated: April 18, 2011

Focus of the Pilot Study

- Study interventions related to adoption of new technology or energy use strategies,
    - mediated by social contacts between individuals (as well as through the media).
- This dissemination of technology or ideas can be studied using models of diffusion on networks,
    - often studied in the context of complexity science or dynamical systems.
- Theoretical/computational results can then be put into the context of energy technology/use,
    - particular schemes may be considered by public or private bodies.

Schemes Under Consideration

- Green Deal provider covers upfront costs of EE tech, paid back from the savings in energy bills;
    - householder has to trust the provider would deliver the savings (also depends on the householder's behaviour).
- Subsidy for installing EE out of LA budget;
    - word-of-mouth about savings achieved,
    - further incentives such as "recommend a friend and get 5% off" or "10 friends get 10% reduction" etc.
- Smart meters installed;
    - effects of seeing personal use compared to neighbours' average.

Scenarios to Consider

Comparisons can be made between various strategies, e.g.:

1. street-by street targeting for installation,
2. focusing on communities to induce a "critical mass" of adopters,
    - may then propagate outwards on the network,
3. 'random' installation
    - e.g. via advertising campaign.
4. 'word-of-mouth' propagated installation
    - e.g. incentive to "recommend to a friend"

Scenarios to Consider

5. strengthening network ties to improve communication.

- In each case the strength of influences could be different,
  - e.g. if two households have simultaneous installation they may be more likely to discuss the new technology with each other due to its novelty value.
- In this way they may reinforce “correct” use of the technology.

Real-World Social Networks

- Different types of social connection exist; these include:
  - neighbours, distant friendships, family trees, communities.

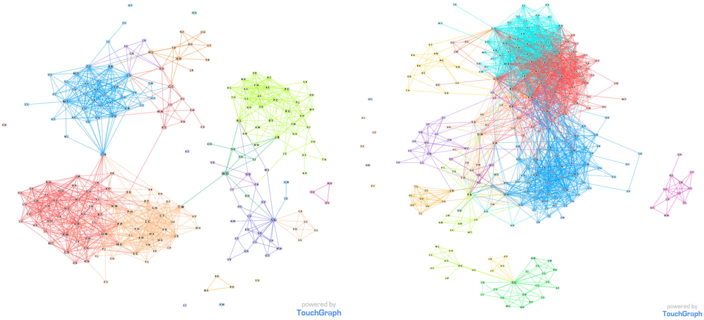


Figure: From *TouchGraph* on the *Facebook* website.

Communities

- **Communities** are sets of individuals which are more well connected internally than to the rest of the network [**?**].
    - communities have a distribution over a range of sizes,
    - communities have varying degrees of overlap [**?**].
- Individual membership characterised by knowing a high degree of the other members.
- Most individuals will be connected to more than one group;
    - work, leisure, children's school etc.
- Often more than one individual connecting various groups.
- Sometimes even large overlaps exist.
- This creates the cobweb of highly inter-connected groups which exists in the real world.

Using Data to Construct Models

- Individuals are often surveyed about their own personal social network [**?**].
  - *Egocentric* networks studied by asking an individual (the *ego*) about contacts (the *alters*) and interconnections.
- In overall network most individuals will be connected to multiple communities.
- Also more structured links such as family trees or local neighbourhoods.
- The surveys will give insight into which of these potential lines of communication exist
- Appropriate network models can be composed to give representative model of the network structure.

Models of Complex Networks

- Firstly we need to define the topology of our network,
  - the structure of links between individual units (here, households).
- Network models mostly constructed to reproduce some statistical feature found on real networks,
  - construction based on reasonable hypothesised principles rather than real social behaviour [**?**, **?**].
- Properties include
  - **degree distribution**: number of connections per node,
  - **shortest path** between nodes: seen in so called *small-world* networks.
- Networks are often modelled using *random networks*,
  - so called due to the probabilistic way they are generated and their statistical properties.

Types of Model Network

- Various ways of constructing a random graph,
    - give qualitatively different networks, exhibiting different real-world phenomena.

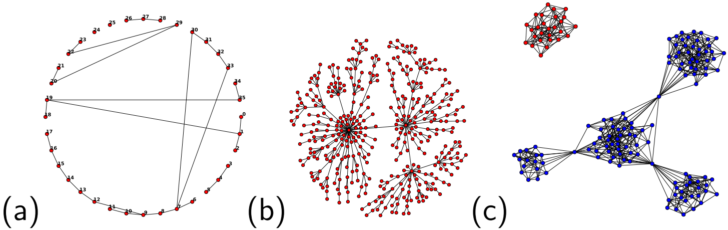


Figure: (a): A *small world* network with 20% rewiring of a regular lattice. (b): A preferential attachment graph which has a *scale-free* degree distribution. (c): A simple model of inter-connected communities.

Combining Network Models

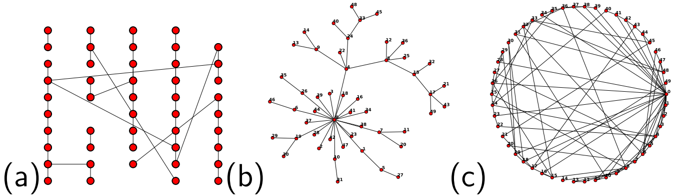


Figure: Graphs constructed summing links from networks generated by both methods. Local and rewired features are combined with hubs.

Dynamical Models

- Once the network topology is established the behaviour of the individuals and interactions are modelled.

Modelling considerations:

- Do all entities interact continuously with each other or at intervals as discrete events?
- Are internal dynamics of nodes changing continuously or at discrete intervals?
- The types of decision rules on which to base these internal dynamics must be determined from data.

Dynamical Models

Internal Dynamics could include the following factors:

- Rational cost-benefit analysis;
  - dynamical system on nodes,
  - defined decision criteria.
- Fixed number of friends/proportion of contacts;
  - decision based on influence crossing some threshold.
- Could be probabilistic.
- Would likely have multiple parameters.

Aspects to Include in Models

- Weight links of different types
    - diffuse effect of system average
- small group interactions
- distributions of behaviour archetypes
    - bell curve of thresholds for early/mid/late adopters
    - probability distribution of adoption around threshold

Social Dynamics Models

Many models exist for social dynamics[**?**].

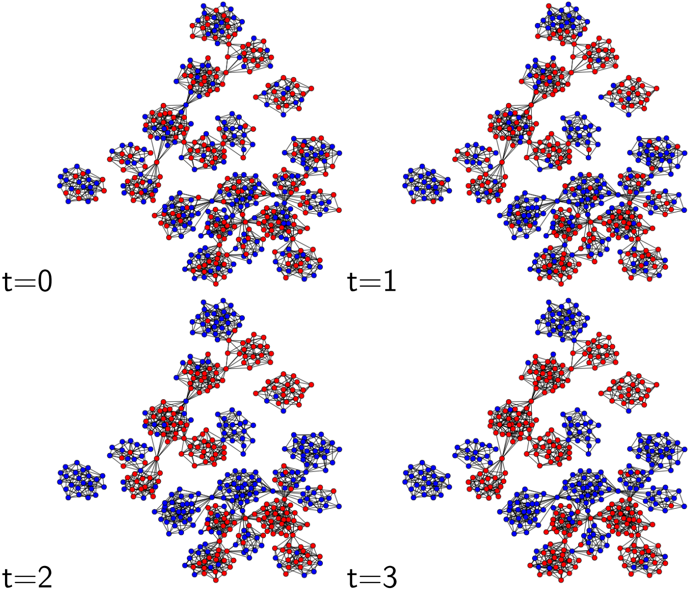
- Very simple: *Voter Model*,
    - individuals take one of two opinions which depend on an average value of the local neighbours' opinions.
- more complicated: *Axelrod Model*,
    - individuals may only vary their opinion in response to others with sufficiently similar opinions to their own,
    - individuals interact considering multiple factors.

Technology Adoption/Diffusion Models

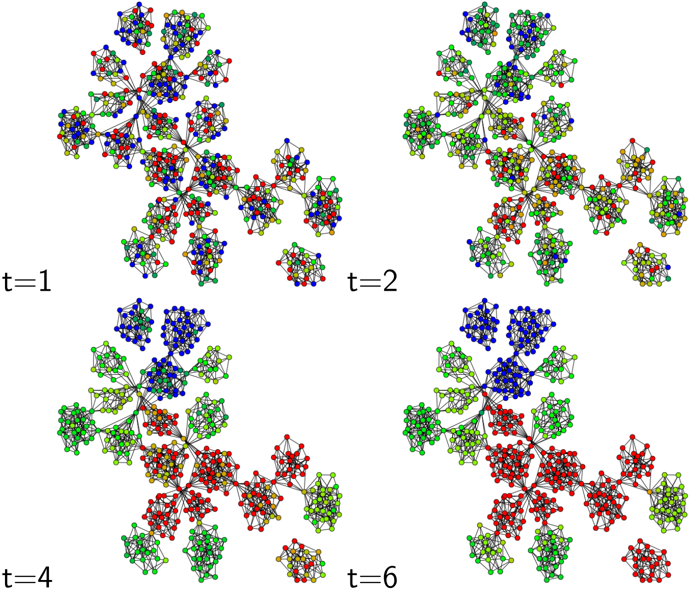
We are more interested in technology adoption models,

- once a household has an energy efficiency (**EE**) technology they don't return to the pre-installed state.
- Often used are threshold models,
  - individuals use the technology if a certain number or proportion of the neighbours are using it [**?**].
- Can consider the communities as the nodes of a higher-level network model:
  - members of the communities considered as populations,
  - average state taken as a continuous dynamical variable,
  - links defined by community overlaps.

Opinion Dynamics Model (binary Voter type).



Additional Subtleties Included (indecision).



Other Decision/Adoption Models

A simple model scheme using the following rules on various networks:

- Threshold model where:
  1. Opinion is changed based on average neighbours' opinion at current time,
  2. technology is adopted when an individual's own opinion exceeds some threshold,
  3. the consumers who have already purchased are given a more heavily weighted influence.
- Can quantify system "effectiveness" counting both:
  - number of individuals who have technology,
  - average opinion of technology.

Threshold Adoption Model (with random purchases).

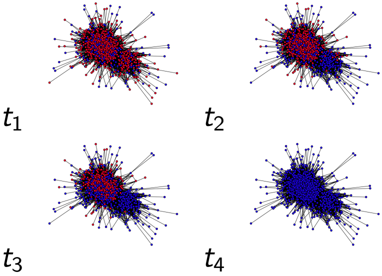


Figure: t_1=50, t_2=75, t_3=85, t_4=95

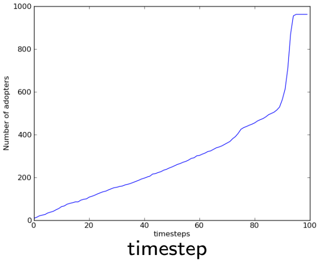
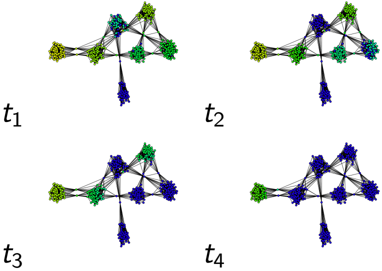


Figure: Number of Adopters

Using Simple Community Model Network



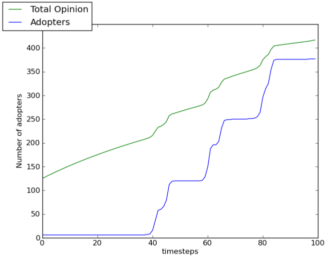


Figure: t_1=45, t_2=60, t_3=75, t_4=90

Comparing Different Transitions

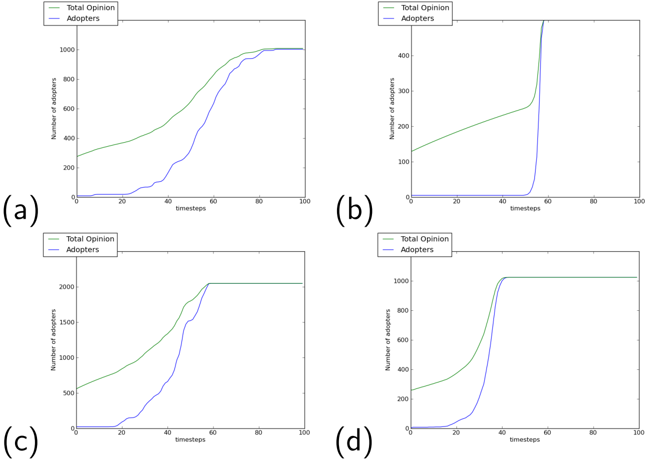


Figure: **(a)**: Weakly connected communities. **(b)**: Inter-community *bridges*. **(c)**: Large, weakly bound groups. **(d)**: Distributions of thresholds.

Possible Conclusions

In this simple example:

- fast transitions are seen wherever tightly bound communities interact with more than a few others.
- Transition to technology adoption can be slowed when:
    - communities are not tightly bound,
    - communities do not interact strongly,
    - a lot of individuals have high resistance to uptake.
- To ensure a fast transition increase:
    - strength of links,
    - inter-community ties,
    - information about whole system.

Potential Recommendations

- Increase network ties for swift transition;
  - incentivise people to spread the word, e.g. by:
    - money back for recommending a friend,
    - money off for groups investing together.
- Make energy more visible to consumers, e.g.:
  - Smart meters, inc. local neighbourhood averages, time-averaged individual (monthly/weekly) spend
  - Potential savings from EE measures
  - show prevalence of EE measures in society to encourage people into the ‘trend’,
  - attract *early adopters* by predicting future trends.