Dynamic network sampling

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Dynamic network sampling

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- The **population** of interest has spatial structure, often has network structure and moves or changes over time.
- Designs for selecting a **sample** units use spatial and network relationships and progress dynamically.
Population and sample processes

**Population**: A stochastic process \( \{Y_t\} \).

**Sample**: A stochastic process \( \{S_t\} \).

Time \( t \) such as day, with \( t = 0, 1, 2, \ldots \).

Values \( Y_t \) of units such as locations, states, and relationships between units at time \( t \).

Sample \( S_t \) the set of units in the sample at time \( t \).
Spatial-temporal population model

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- clustering, mixing, migration—point process
- movements within and among groups—small random displacements, MCMC selections, autoregressive processes
- insertions and deletions of objects—birth and death process, immigration and emigration.
Dynamic network model

- builds on spatial temporal point process
- link probabilities dependent on distance between nodes, node characteristics, and current degree or target degree distribution
- renewal process for link formation, persistence, and dissolution
Sampling process

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- For the dynamic situation we use a sampling process that includes
  - an acquisition process by which units are added to the sample
  - an attrition process by which units are removed from the sample
Equilibrium distributions

Many properties of the population and sample process are ergodic and have stationary and limiting distributions.
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- Sample size tends to increase when acquisition rate exceeds attrition rate
- and decrease when attrition rate exceeds attrition rate
Uses of sampling designs

- **Inference** about population characteristics
- **Experiments** on sample units
- **Interventions** on sample units
Intervention strategy

- Select a sample of units from the population, make interventions on those units changing their values.
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- One strategy interacts with another
Effect of an intervention

- An **intervention strategy** consists of a sampling design for finding units in the population on which to make interventions, and a plan for the types of interventions to be made, which may depend on sample unit characteristics.

- A simple way to view the **effect** of a strategy is the difference in the resulting equilibrium distribution, compared with the equilibrium distribution without the strategy, or with a different strategy.
Natural sampling strategies

- virus selects a sample of people with a link-tracing design
- insects select a sample of plants with a temporal spatial distance design.
Dynamic network sampling

• Initially and at ongoing rate, units are selected using conventional or spatial design.
• New units are added through link tracing; the tracing rate may depend on unit and link values.
• Units are removed from the sample through removal probability or deletion from the population.
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Random walk in static network

The classic random walk in a graph starts with an arbitrary node and at each step selects at random one of the links out from the current node to reach the next node.
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- Connected components of networks form closed classes.
Random walk in dynamic network

- links between nodes change over time
- component structure changes
- a random walk temporarily stuck in one component can eventually reach nodes of other components
Random walk in dynamic network

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- component structure changes
- a random walk temporarily stuck in one component can eventually reach nodes of other components
- deletions and insertions of nodes can interrupt the walk, requiring reseeding
Random set designs

- current sample $S_t$ is a set of nodes
- acquisition of nodes includes tracing links out from sample
- attrition through removal of nodes from sample or deletion from population
Simple random set design

- with-replacement selection
- independent link tracing
- independent removals
Design options

- selection and removal probabilities depend on node and link values
- with or without replacment
- links followed from active sample units only
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- selection and removal probabilities depend on node and link values
- with or without replacment
- links followed from active sample units only
- replacement, activeness values between 0 and 1
Desired features

- trace rapidly at first; reseeding.
- have a target sample size distribution.
- find units with high degree or “interesting” values.
Epidemic example

- HIV virus spreads with dynamic network sampling design
- seek and treat designs for interventions to reduce incidence.
- combination of interventions and counter-responses leads to new equilibrium distribution.
What influences equilibrium distribution

- sample volume = number of nodes
- sample surface = number of links out
What influences equilibrium distribution

- sample volume = number of nodes
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- may be weighted by tracing probabilities
What influences equilibrium distribution

- sample volume = number of nodes
- sample surface = number of links out
- may be weighted by tracing probabilities
- surface to volume ratio tends to decrease as sample size increases
Also affecting equilibrium level

- new node entering sample (HIV) tends to have higher degree than average for population
- and higher proportion of links-out than average for sample
- especially in early stages of epidemic