Optimising partner matching for microsimulations of the HIV epidemic

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% Optimising partner matching for microsimulations of the HIV epidemic % Nathan Geffen % SACEMA Research Day, 24 March 2015

Website for this talk

http://nathangeffen.webfactional.com/partnermatching/partnermatching.html

- Too much to cover in 10 minutes
- This presentation is bird's eye view
- Webpage has details
- Perhaps seminar

Aim

- Microsimulation of HIV epidemic gives rich insights
- We want:
  - Monte Carlo simulation to calculate confidence intervals
  - Convenient high-level language programming
  - Visualisations on the web using Javascript
- BUT: It is too slow
- Partner matching is the bottle-neck
- **Find faster ways of doing partner matching**

Methodology

- Define three partner matching algorithms
- Define two reference algorithms to compare these with:
    - Quality: One very slow producing nearly ideal matches
    - Speed: One very fast producing random matches
- Define measure of quality
- Analyse mathematically
- Compare empirically in multiple tests

Typical discrete time microsimulation

```
for each time-step
    ----------------
    for each event E
        for each agent A
            if E should be applied to A
                apply E to A
    -----------------
```

Algorithm efficiency

- $O(n)$ vs $O(n^2)$

Number of agents (n)	n	(n2-n)/2
10	10	45
100	100	4,950
1,000	1,000	499,500
10,000	10,000	49,995,000
100,000	100,000	4,999,950,000
1,000,000	1,000,000	499,999,500,000

Graphically depicted

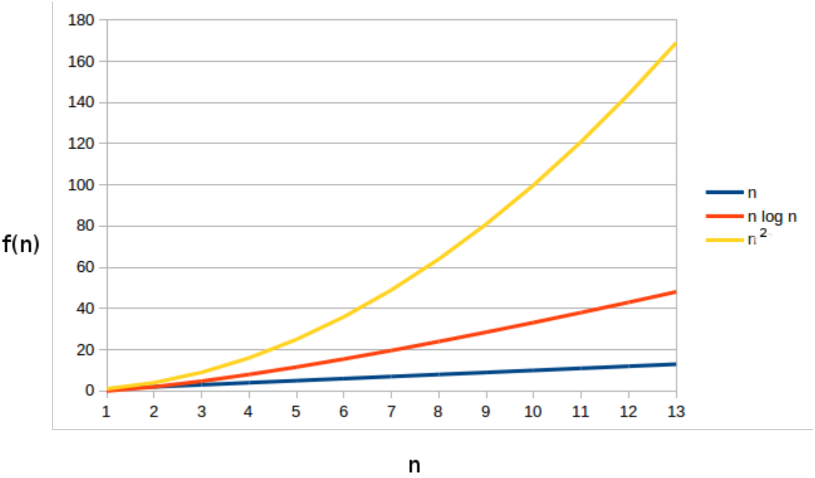


Figure : Three efficiency classes

Typical agent attributes for partner matching

- age
- sex
- desire for new partnership
- riskiness (including whether agent is a sex worker)
- relationship status (including whether agent is married)

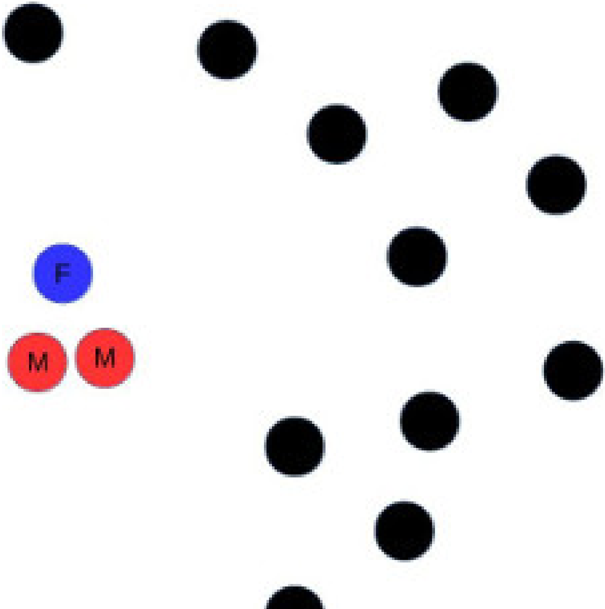
Typical simulation details

- Time-scale: 1 week
- All agents examined to see who is forming new partnerships.
- Agents can acquire new high or low risk partner
- Marriage affects partner selection

Euclidean plane

- Mapping agents to Euclidean plane would help
- Efficient nearest neighbour approximation algorithms
  - Locality-sensitive hashing
  - Best bin first
  - Balanced box decomposition

Euclidean space doesn't work for us



Distance function

- Example of distance function on webpage
- Extract from this a **cluster** function

Algorithms

- Brute force (reference: too slow)
- Random match (reference: too hopeless)
- Random match k
- Weighted shuffling
- Cluster shuffling

Brute force

```
brute_force_match(Agents):
// Agents is an array of agents
    shuffle(Agents)
    best = infinity
    for each agent, a, in Agents
        for each unmatched agent, b, after a in Agents
            d = distance(a, b)
            if d < best
                best = d
                best_partner = b
        make a and best_partner partners
```

This is $O(n^2)$.

Cluster shuffle match

```
cluster_shuffle_match(Agents, c, k)
// Agents is an array of agents
// c is the number of clusters
// k is the number of neighbours to search
// cluster_size = number of agents / c

    calculate cluster values for all agents

    sort agents in cluster_value order

    shuffle each cluster

    for each agent
        find best partner from k neighbours
```

This is $O(n \log n)$.