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Protecting Patients through Dynamic Network Analysis of Hospital Department Relationships

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(Joint work with Bradley Malin and Steve Nyemba)



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[\[In HIPAA / State Privacy Regulations \]](#) Jul 15, 2010
[New HIPAA/HITECH Rules Announced:](#)

[California Hospitals Fined \\$675,000 For Privacy Violations:](#) Jun 11, 2010

[What Every Risk Manager Needs To Know About Copy Machines:](#) May 8, 2010 CBS exposes the risks to healthcare and other entities for possible data breach violations, financial privacy laws violations, HIPAA violations, and makes them vulnerable to being targeted by criminals for theft or other crimes. The video also shows an example of how they can be exploited by terrorists. Of course, that is in addition to the risks posed by improper use and distribution of copies themselves. [View Here.](#)

[Be Prepared To Deal With Exploding Medical ID Theft And Privacy Issues In Healthcare:](#) May 3, 2010 Medical ID Theft is hitting the headlines as organized crime and ID thieves grab millions in false claims and leave innocent patients and healthcare providers with the bills. By Stephen A. Frew JD.

[Hospital Employee Gets Jail Time For HIPAA Violation:](#) Apr 29, 2010 Hospital employee sentenced to federal prison for 3-week long medical records spree.

[UCLA Employee Indicted For Celebrity Privacy Violations:](#) May 8, 2008 Hospital employee sells celebrity medical info to tabloids.

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**\$675,000 for
Privacy Violation**

**Jail Time for
Malicious Accesses**

Patient information needs to be protected from insiders

- Traditional security practices (e.g., role-based access control) are insufficient to ensure EMR security
 - Common for >100 employees to access a patient's medical record during their visit
 - Often difficult to determine who the members of a care team are and who will need access to what information at which time

EHRs have adopted collaborative capabilities to facilitate interaction between teammates and coordinate care

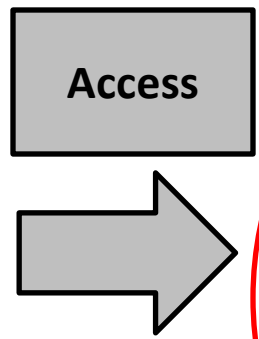
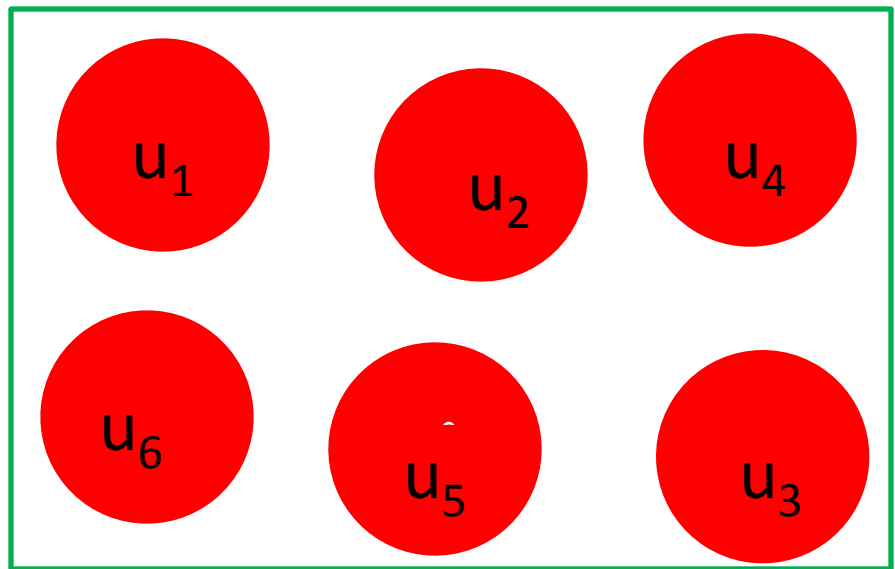
- We hypothesize that HCO departments will exhibit predictable interaction behavior
- Our goals:
 1. Investigate if such behavior exists
 2. If so, determine if it is stable
 - If stable interactions become unstable → associated patients will be anomalous

The dependent relations between green departments and red departments are very low

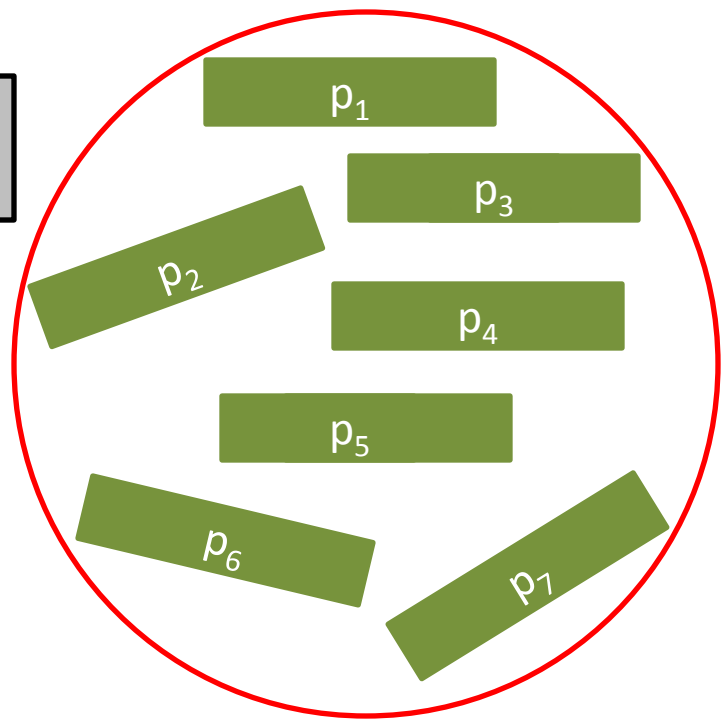
Our goal is to retrieve the dependent relations of departments and determine whether the dependencies among departments touching that patient are expected?

Two general objects of EHR access logs

U(sers)



P(atients)



Departments, job titles, roles...

Diagnosis codes, location...

Auditing Models on EHRs systems

Supervised

Logic regression
and SVM

require adjudication
from privacy experts
and pre-existing
knowledge of what
constitutes a suspicious
access

Unsupervised

CADS, MetaCADs

SNAD

Access
Explanation

Relational Analysis

Users
Communication

Departments
Communication

Our works will investigate whether the relations of departments are stable or not and how the dynamic characteristics could be applied to assess if the set of specific accesses associated with a particular patient record were anomalous

Boxwala A, Kim J, Grillo J and Ohno-Machado L. JAMIA, 2011

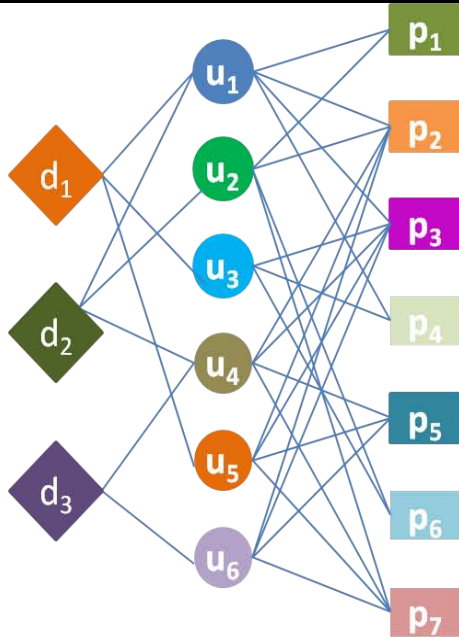
Chen Y, Nyemba S, Zhang W, and Malin B. Security Informatics, 2012

Malin B, Nyemba S, Paulett J. JBI, 2011.

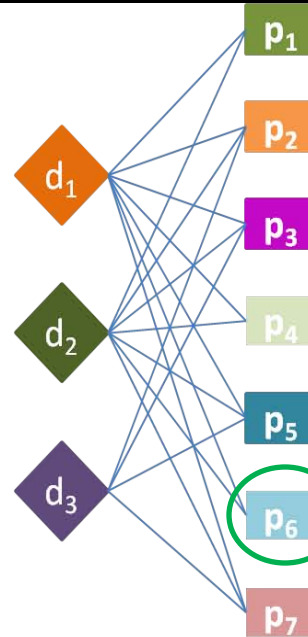
Fabbri D and LeFevre K. VLDB Endowment, 2011.

Healthcare Interaction Networks

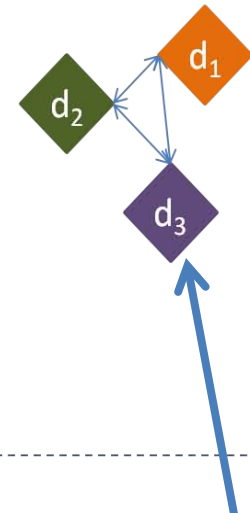
Tripartite graph of departments, users and patients



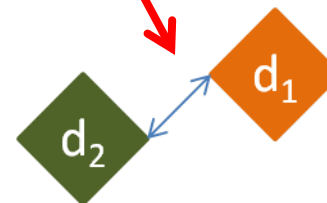
Bipartite graph of departments and patients



Health interaction network



Local view for p₆



Global view

Where are We Going?

A Global Network of Departments

Two metrics: certainty and reciprocity

Stable status in terms of the two metrics

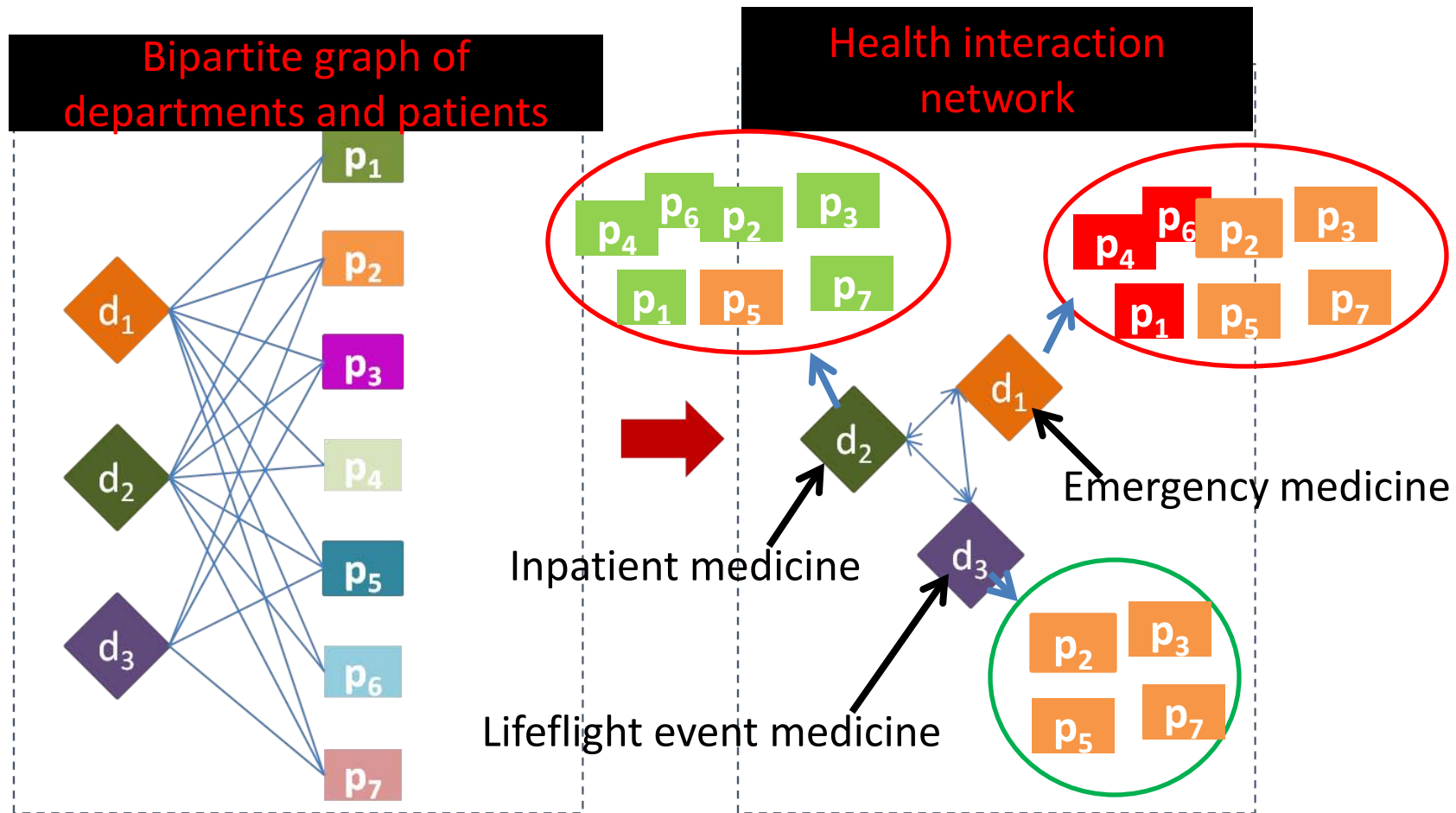
Local Network-for a specific patient

Two metrics: local network score and reciprocity

Application of the Networks

Detecting patients with anomalous medical records accesses

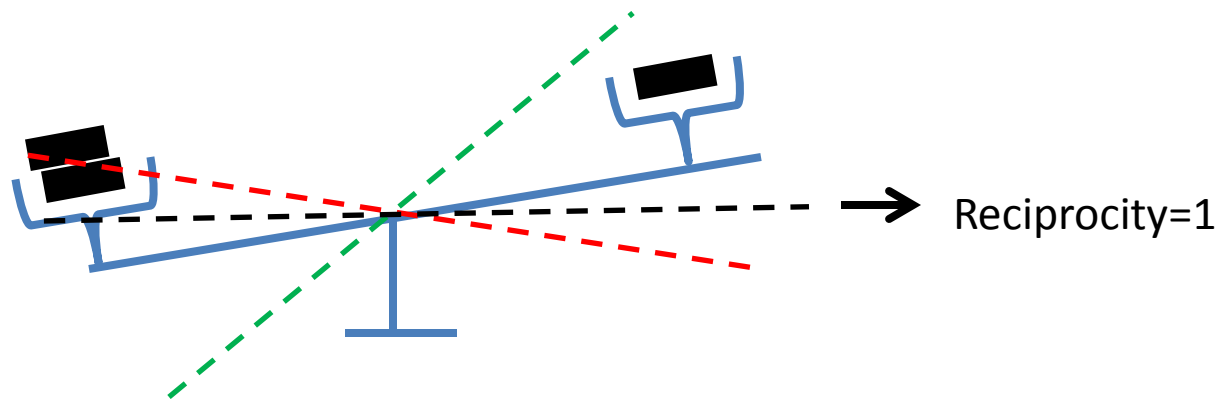
Certainty to Model Relationship of Global Network



$\text{Cert}(\text{Lifelight event medicine } (d_3) \rightarrow \text{Emergency medicine } (d_1)) = 4/4$

$\text{Cert}(\text{Inpatient medicine } (d_2) \rightarrow \text{Inpatient medicine } (d_2)) = 6/7$

Using reciprocity to characterize the mutual interaction between all pairs of departments in the global network



Pediatric Emergency Dept \rightarrow Peds Respiratory Care = 0.57

Peds Respiratory Care \rightarrow Pediatric Emergency Dept = 0.037

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Dataset used for this study

- Vanderbilt University Medical Center “StarPanel”
- 3 months in 2010
- Arbitrary Week
 - ≈ 9,200 users
 - ≈ 99,000 patient records
 - ≈ 400,000 accesses
 - ≈ 450 departments

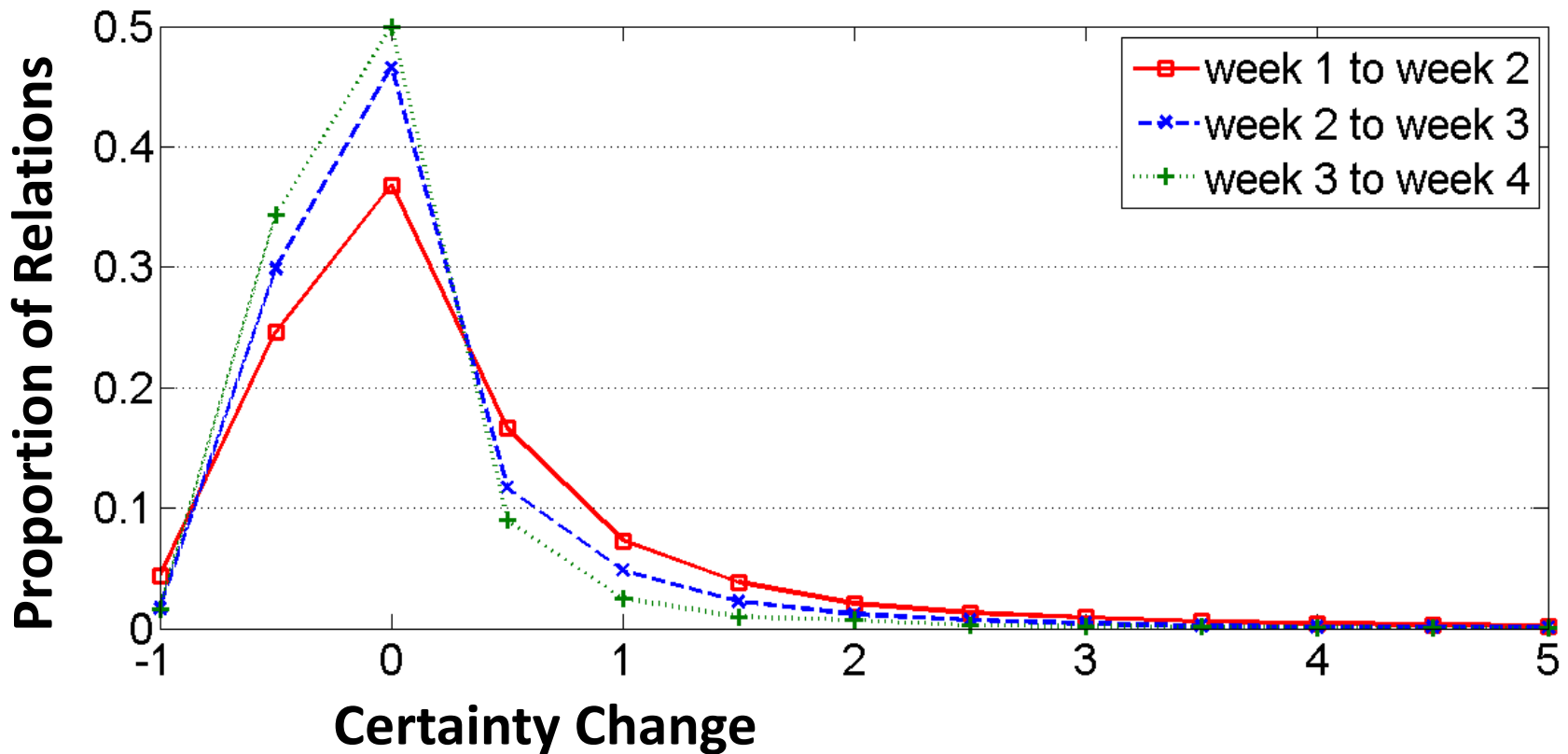
Although the relations of the network are very unbalanced, the unbalance is stable over time

Time	Week 1	Week 2	Week 3	Week 4
Reciprocity	0.267	0.2814	0.2858	0.2871

$$(0.2814 - 0.267) / 0.267 = 0.05$$

Week 1 to week 2

The changes become smaller over time (centralization: green > blue > red)



Degree of relations between departments changes little over time
>82.5% of the change resides in [-0.25, 0.25]

Strong relations between VUMC departments over a four week period

Department (d_i)	Department (d_j)	Min Certainty	Max Certainty
<i>Intradepartmental Relations</i>			
4East OB/GYN	4East OB/GYN	0.74319	0.7669
Adult Emergency Medicine	Adult Emergency Medicine	0.74024	0.78453
Cancer Infusion Center	Cancer Infusion Center	0.73171	0.844
8N Inpatient Medicine	8N Inpatient Medicine	0.7197	0.80909
Newborn Nursery	Newborn Nursery	0.70406	0.72727
<i>Interdepartmental Relations</i>			
DOT Radiology	Orthopaedics	0.99621	1
Nursing Education and Development	Medical Information Services	0.95833	1
Main OR - Trauma/Renal	Medical Information Services	0.94444	1
Life Flight Event Medicine	Emergency Medicine	0.90805	1
Emergency Medicine Admin	Adult Emergency Medicine	0.91489	0.94186

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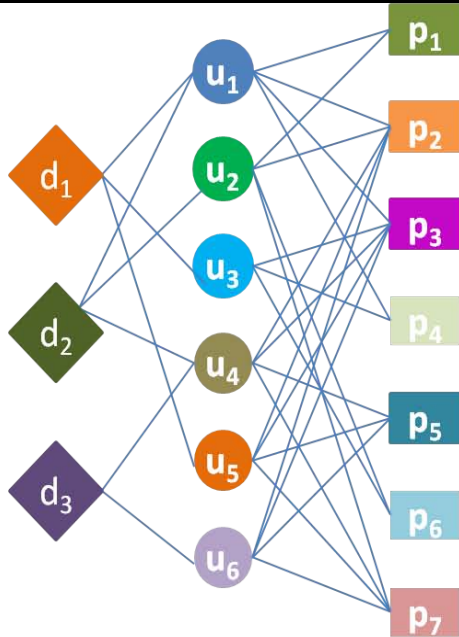
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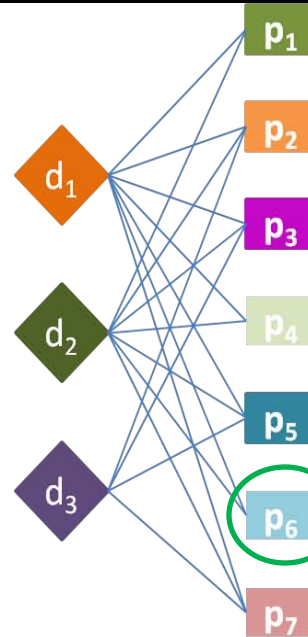
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Healthcare Interaction Networks

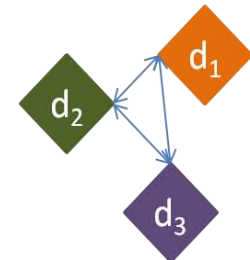
Tripartite graph of departments, users and patients



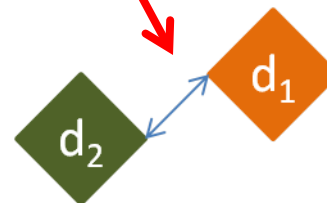
Bipartite graph of departments and patients



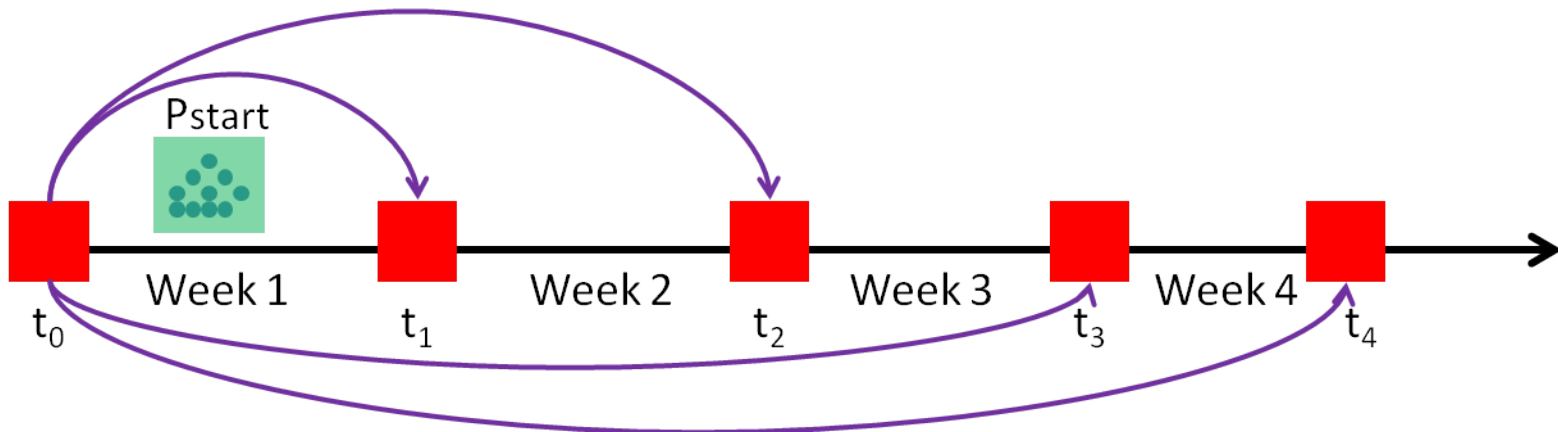
Health interaction network



Local view for p₆

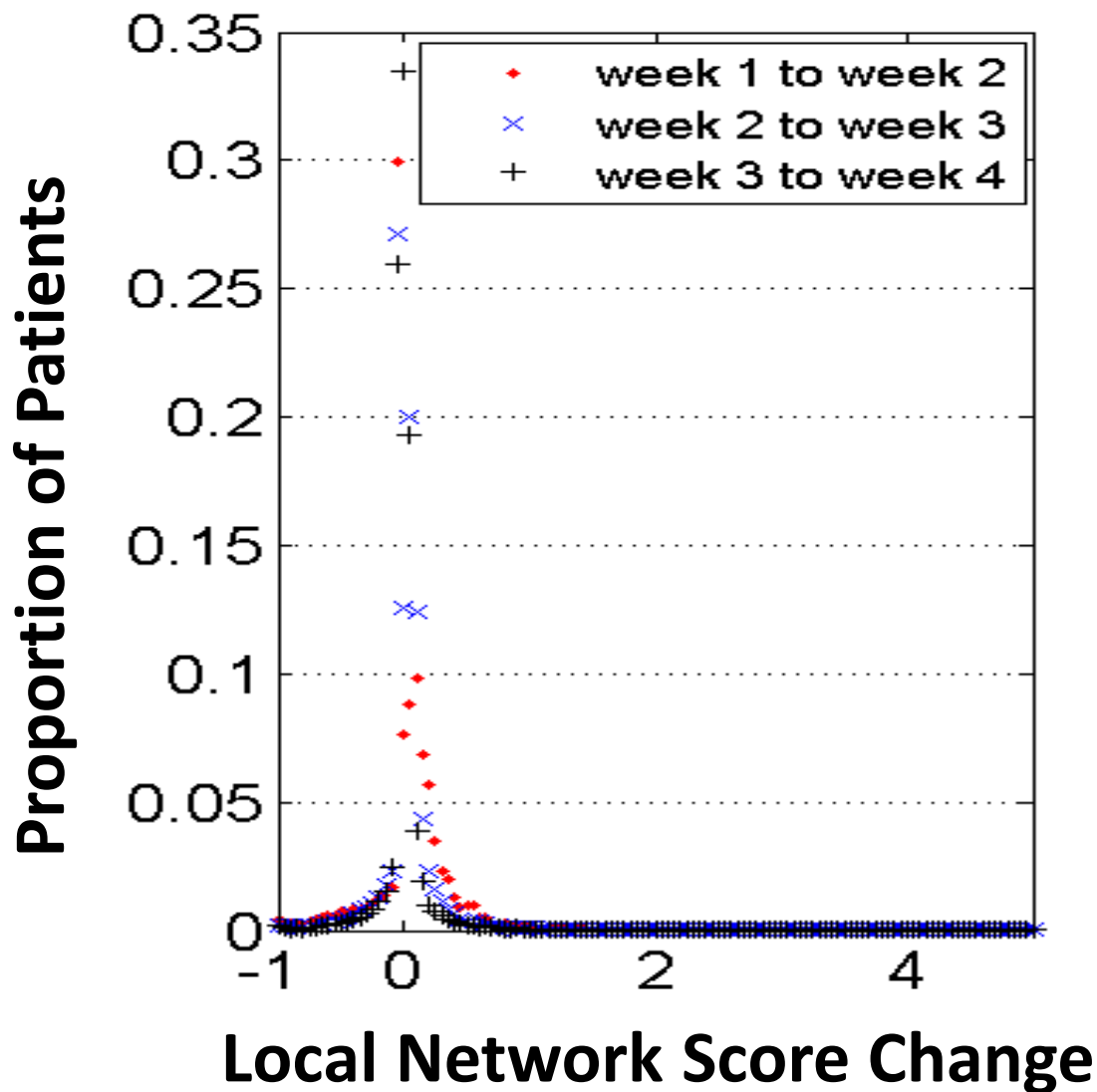


Evolution of Local Networks in Terms of Local Network Score and Local Network Reciprocity

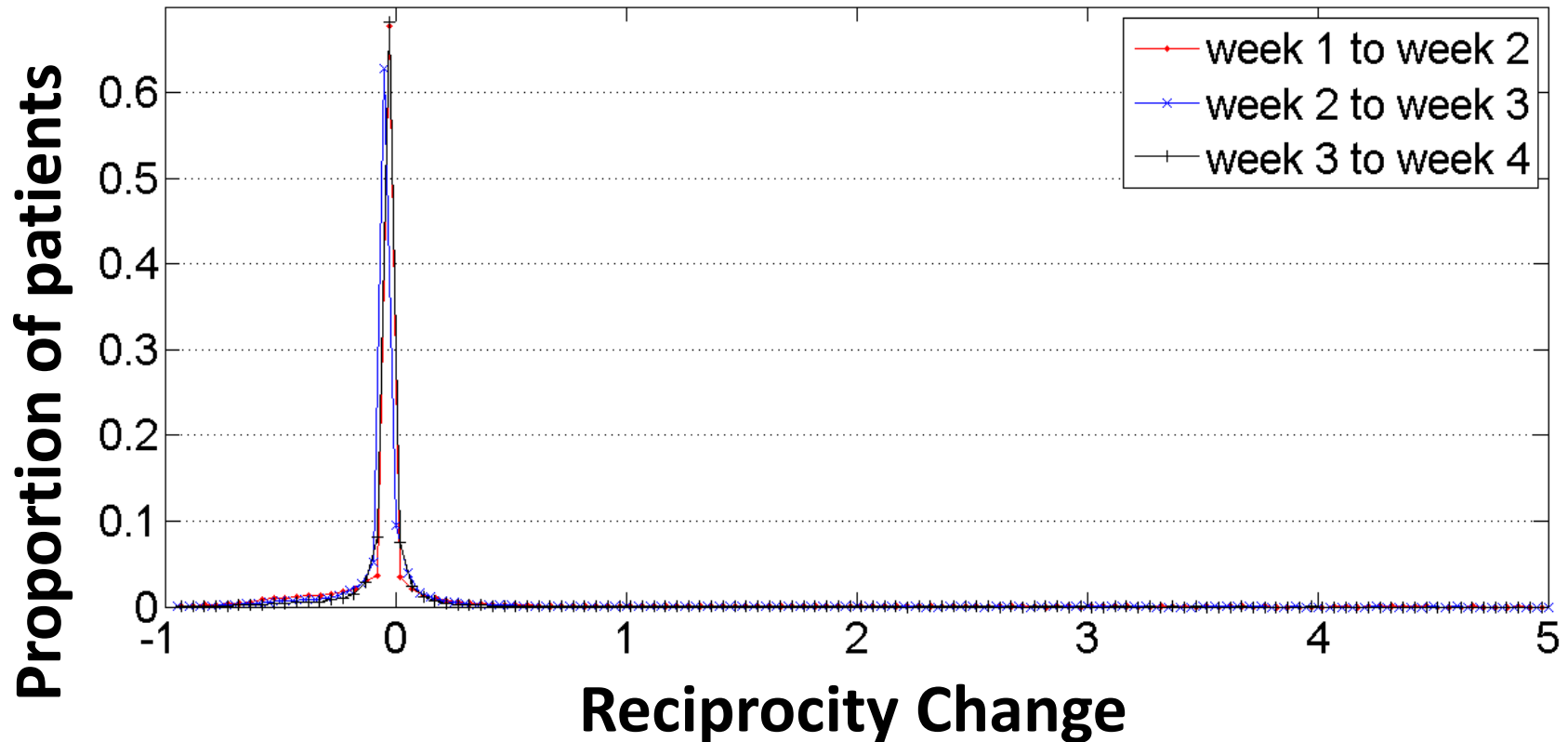


Each point in P_{start} corresponds to a local network

Over 98% of patients are normal because they exhibit a score change <0.05



Approximately 99% of patients are normal because they have a change of reciprocity < 0.1



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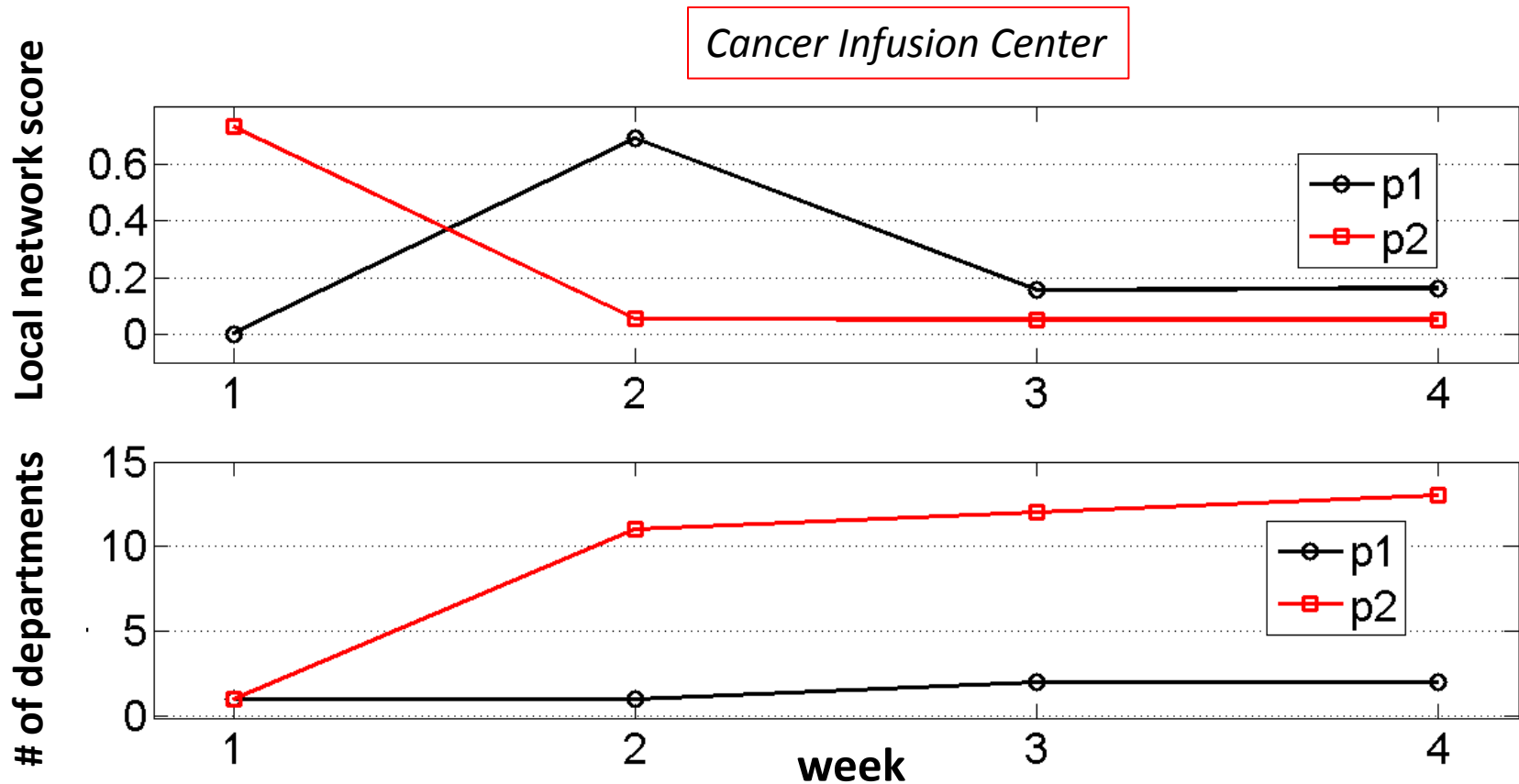
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accesses

p2 has -0.93 change of local network score and -0.79 change of local reciprocity from the 1st to the 2nd week



Breast Center, [Anonymized Street Location], Care/Eskind Diab Acces, Disease Management Service, Eskind Diabetes - Adult, Free Stipends, Internal Medicine, VIM, VMG Physician Billing Services, Vanderbilt Home Care Primary

Conclusions

- We hypothesized an HCO would exhibit strong stability
→ **confirmed by our experiments**
- We can characterize how strange a patient's local network appears
 - **Two groups of patients**; those with **small changes** in local network score and reciprocity score and those with **significant changes**
 - The changes in the latter group do not justify the claim that the patient has been intruded upon, but may provide a reason for an investigation that incorporates more nuanced domain knowledge

Some Limitations

- Global and local networks appear to represent the business processes of HCO departments
 - however, such claims must be confirmed with employees knowledge about the working of the medical center and its affiliated clinics
- Need to specialize tool to account for semantics of patients
 - Patient: {Diagnosis, Procedure, Demographics, Residence, physical location in a hospital}
 - Incorporating semantics about the patient, p_2 in the last figure may have no intrusion; rather it is likely a complex cancer patient, which could be confirmed by inspection of clinical documents in the medical record

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Questions? Comments?

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Health Information Privacy Lab:

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