

# Learning Social Signals in Cyber-Physical Systems

## The Social Macroscope

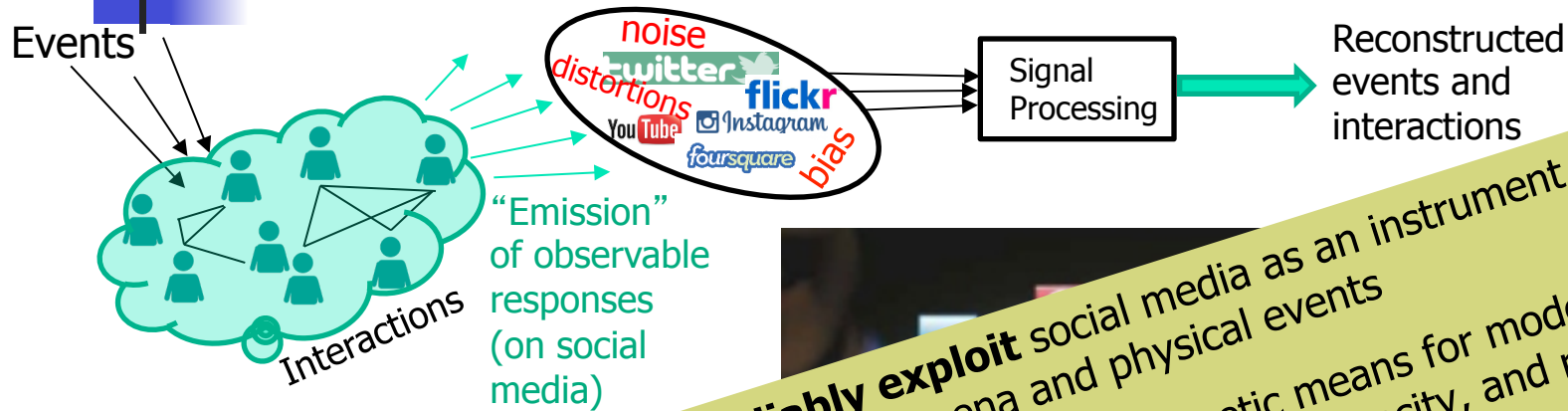
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# Research Goal

## The “Social Macroscope”

Towards a Science of Social Media as a Measuring Instrument



The goal: (Build the science to) **reliably exploit** social media as an instrument for understanding social phenomena and physical events

The innovation: Develop information-theoretic/estimation-theoretic means for modeling social noise, characterizing the signal, and optimizing (social channel) capacity, and reliability

An application: A learning system to reliably understand ongoing physical events and social phenomena by exploiting noisy social media.



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# Unleashing New Media

The rise of the social media command center

# A Physical Analogy

## Learning the Social Signal



Physical target

Response of physical propagation medium  
(e.g., acoustic, vibration, optical, ...)

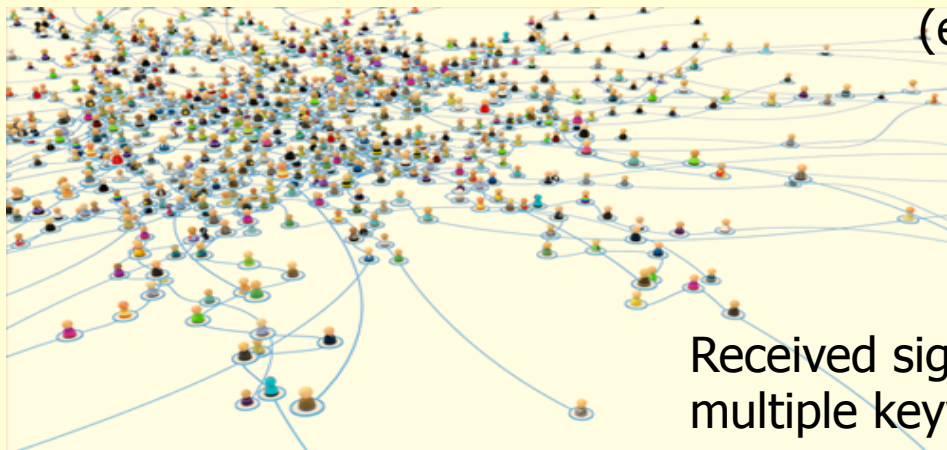


Received signature (energy in  
multiple signal frequency bands)



Physical event

Response of social propagation medium  
(e.g., tweets)



Received signature (energy in  
multiple keyword frequency bands)

# A Physical Analogy



Physical target

Response of physical propagation medium  
(e.g., acoustic, vibration, optical, ...)

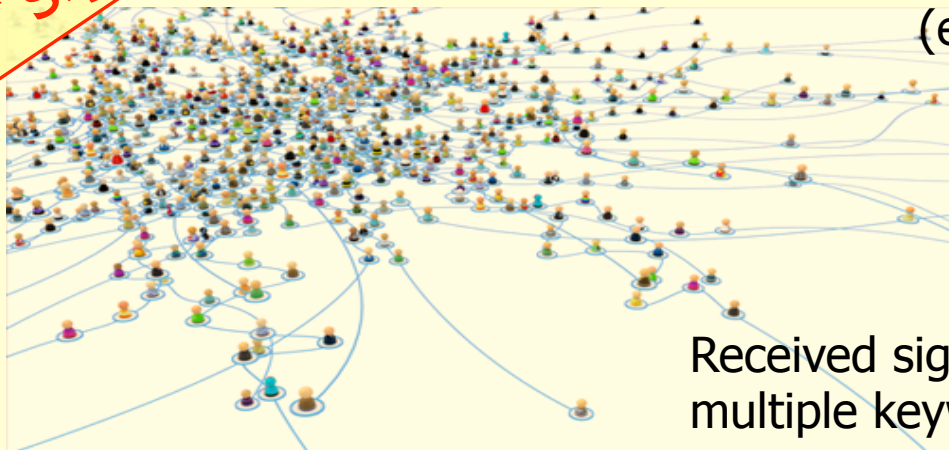


Received signature (energy in multiple signal frequency bands)



Social event

Response of social propagation medium  
(e.g., tweets)



Received signature (energy in multiple keyword frequency bands)

Received "signature" uncovers properties of target!



# A Physical Analogy



Physical target

Response of physical propagation medium  
(e.g., acoustic, vibrational, optical, ...)



Received signature (energy in multiple signal frequency bands)



Physical event

Response of social propagation medium  
(e.g., tweets)



Received signature (energy in multiple keyword frequency bands)

Received "signature" uncovers properties of target!

Propagation characteristics uncover properties of medium!

## Joint signal detection and channel estimation problem

# A Physical Analogy



Physical target

Response of physical propagation medium  
(e.g., acoustic, vibrational, optical, ...)



Received signature (energy in multiple signal frequency bands)



Response of social propagation medium  
(e.g., tweets)



Received signature (energy in multiple keyword frequency bands)

Received "signature" uncovers properties of target!  
Propagation characteristics uncover properties of medium!

# Application: Humans as Sensors

## A "Signal Detection" Problem

### Events



Traffic jams



Disasters



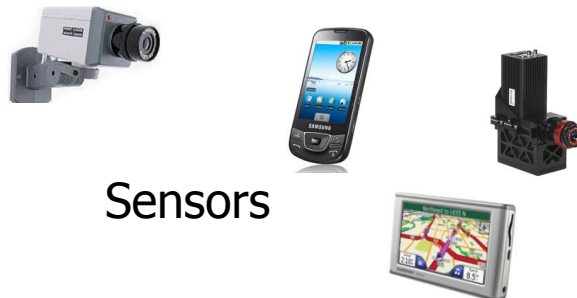
Civil unrest



News and Public Sources



People



Sensors

### Autonomic Service Stack



Data

### Reliable Fact-finding







# The Signal: Information “bits”

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- A binary signal model

Each observation is a “bit” of information: Either true or false

## Examples of Twitter “Sensing”

Crash blocking lanes on I-5S @ McBean Pkwy in Santa Clarita

BREAKING NEWS: Shots fired in Watertown; source says  
Boston Marathon terror bomb suspect has been pinned down

The police chief of Afghanistan’s southern Kandahar  
province has died in a suicide attack on his headquarters.

Yonkers mayor has lifted his gas rationing order. Fill it up!

# The Ground-truth State Estimator

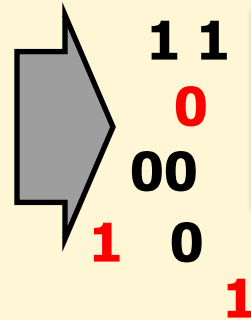
## The Social Sensing Subsystem

Observers of unknown reliability,  $S$



Crowd-sensing

Noisy reported observations (claims),  $SC$



State Estimator

Maximum likelihood estimation

Reconstructed state,  $z$

Decision Making

Error Bounds

10010... 11110... 11100... 00010...

State trajectories (time series),  $C$

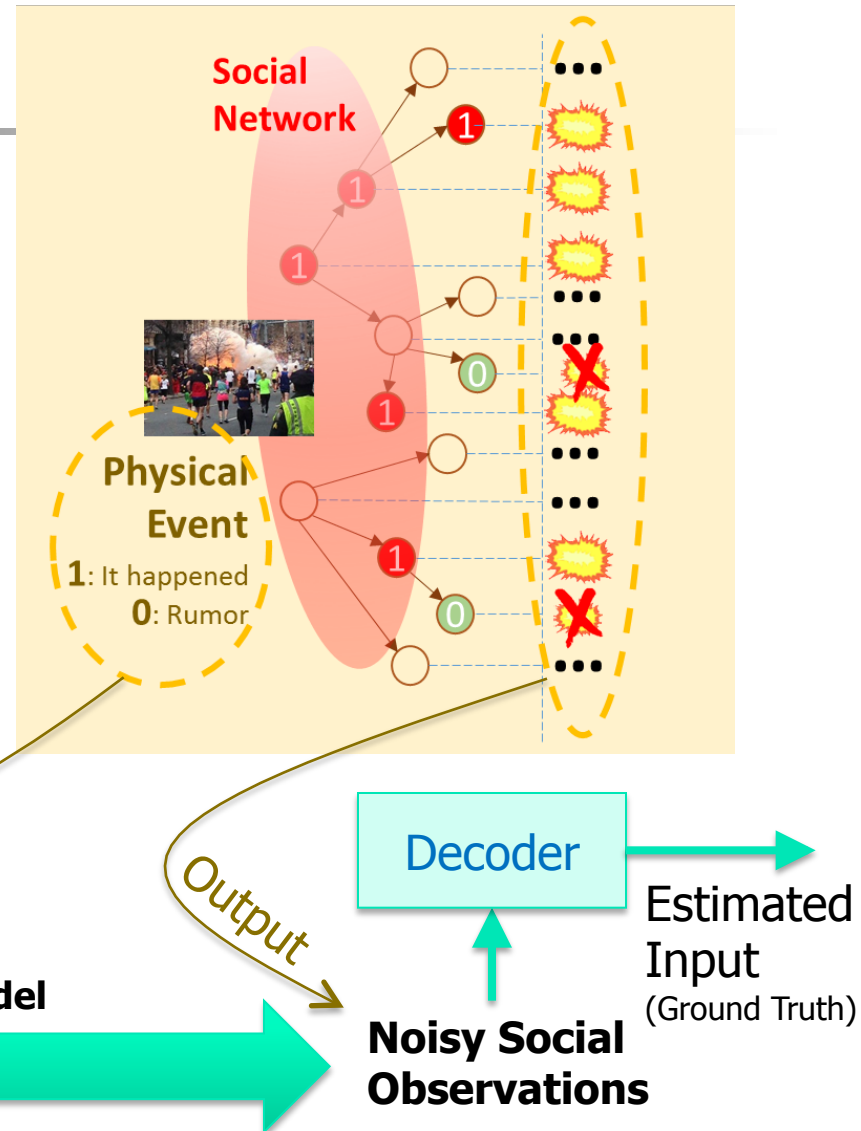


The Physical Environment

# Fundamental Information-theoretic Accuracy Bounds

## Approach:

- Model the social network as a noisy channel that transforms “ground truth” into noisy observations
- Compute accuracy bounds of optimal channel estimator and signal classifier





# Summary

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- An emerging area in CPS: Data services for decision support in Cyber-physical Systems
  - Talk focused on social sensing
- Challenge: understand the social sensing modality (acoustic, magnetic, optical, and now social)
  - Physical events impact the social medium which responds with a signature
  - Analyze signature to measure the event
- Challenge: Accurately detect and track physical events (matching an application's interest)
- Challenge: Accurately assess data veracity
- Challenge: Automatically explain measured phenomena of interest