Online Construction of Analytical Prediction Models for Physical Environments: Application to Traffic Scene Modeling

Anurag Umbarkar, Shreyas K Rajagopal and Alex Doboli

Department of Electrical and Computer Engineering

State University of New York, Stony Brook, NY 11794

Email: adoboli@ece.sunysb.edu

Presentation Outline

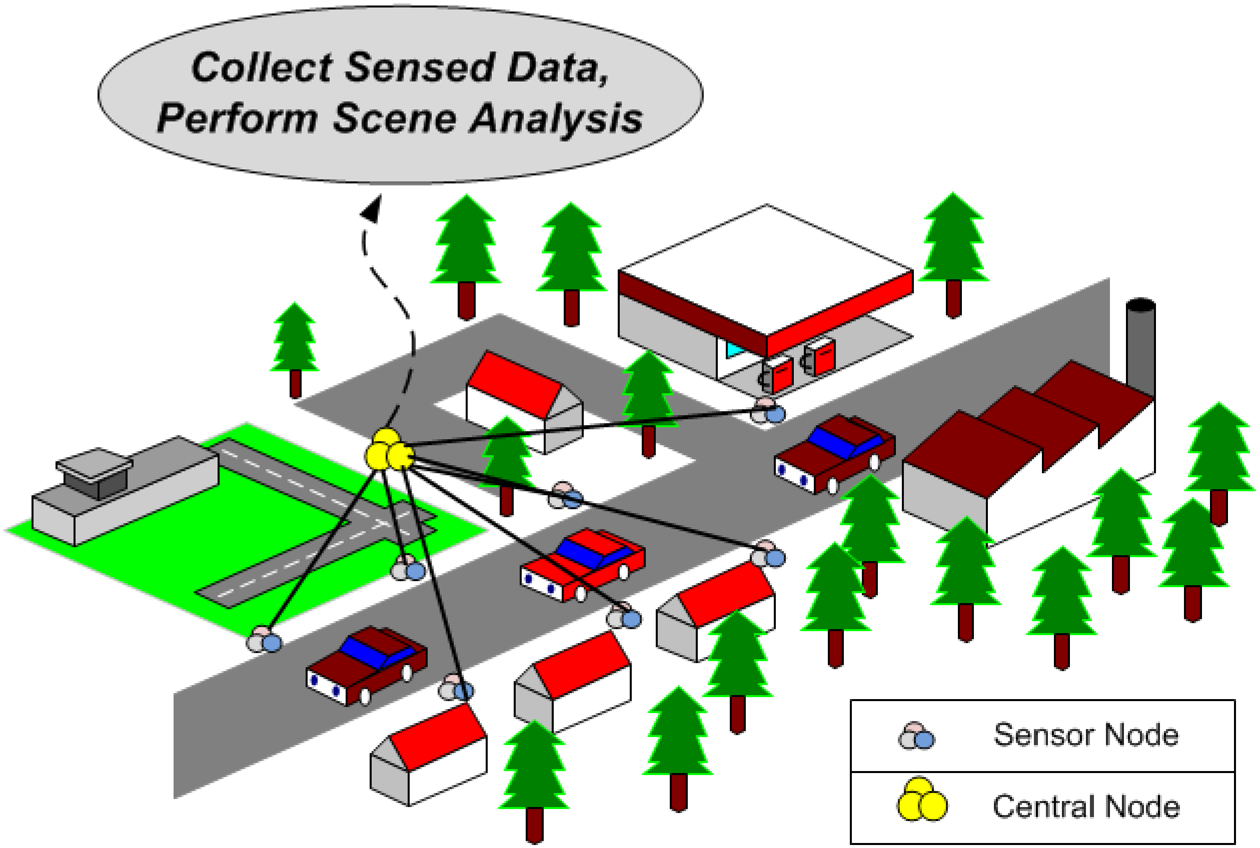
- Introduction
- Main Challenges
- Problem Description
- Modeling Methodology
- Experimental Results
- Conclusions

Introduction

- **Cyber Physical Systems are distributed systems-of-systems that perform reliable data acquisition in order to build efficient data models.**
- **Modeling natural enviroments vs engineered systems**
- **These models can be used for monitoring, tracking and predicting the dynamics of the physical phenomenon**
- **Data models aid decision-making procedures under resource constraints.**

Introduction

- **Example: Traffic Scene Modeling**



Main Challenges

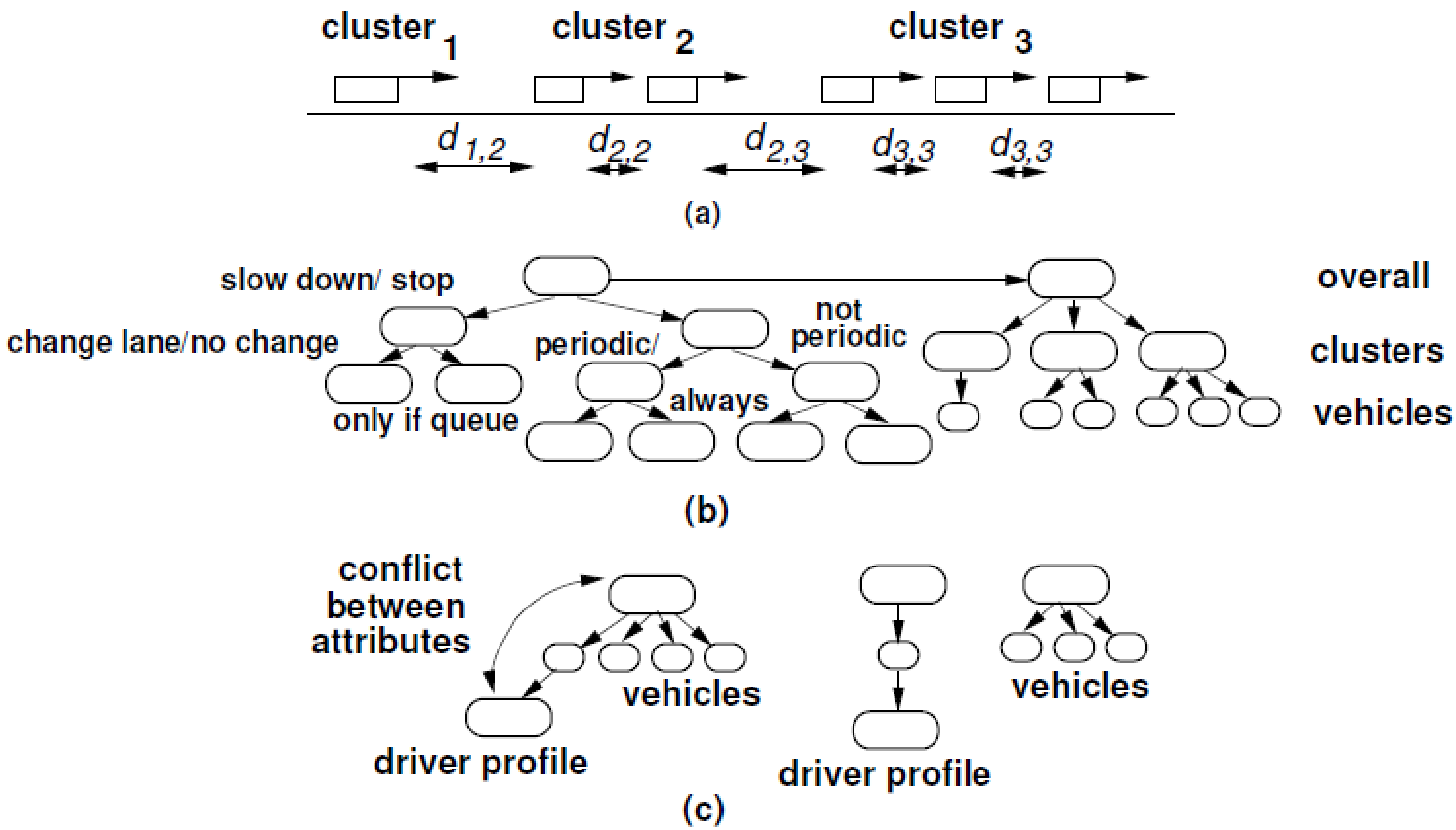
- **Incomplete sensing**
- **Algorithmic limitations**
- **Human and social dimension**

Problem Description

- Finding components of a scene
- Understanding the relations between components in a scene
  - Insight into cause of existing relations
  - Disambiguation
- Predicting the evolution of a scene

Problem Description

- **Example: Simple traffic situation**



Modeling Methodology

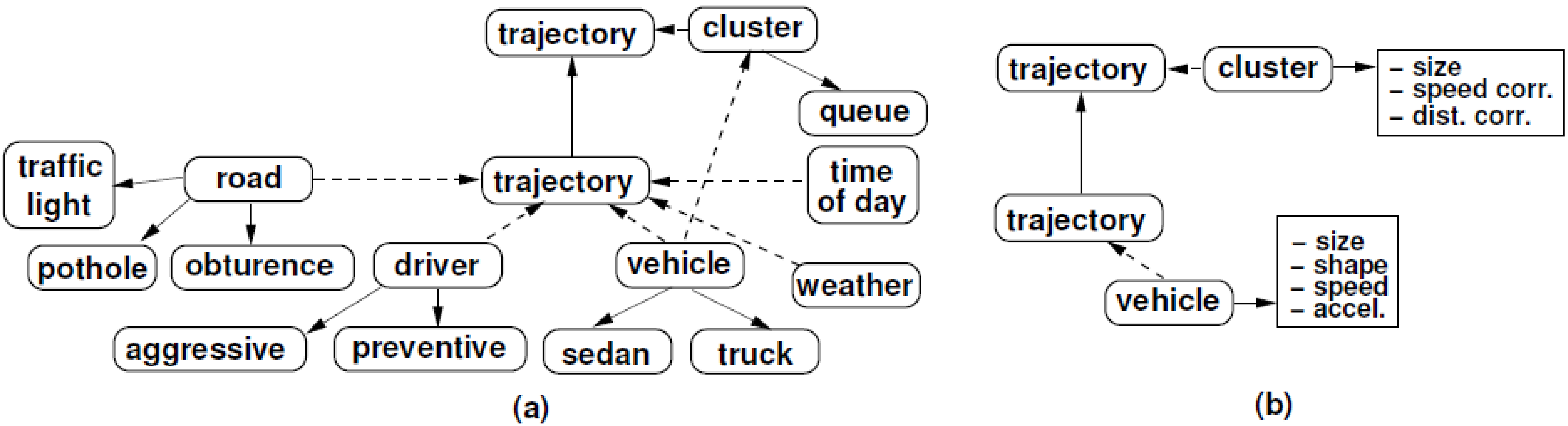
- Constructing ontology description for vehicular traffic applications
- Constructing traffic scene representation
- Predicting traffic dynamics

Ontology Description

- Concepts
- Attributes
- Basic Semantic Elements:
  - Vehicle attributes
  - Driver’s driving profile
  - Cluster of vehicles
  - Cluster attributes
  - Cluster-level, social behavior
  - Cluster dynamics
  - Road conditions
  - Weather conditions

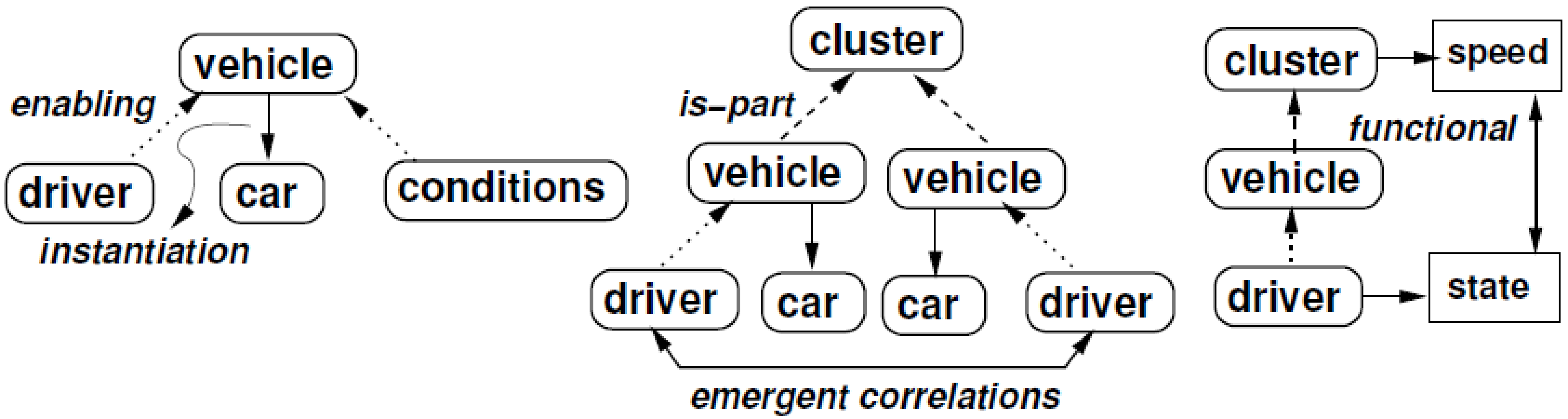
Ontology Description

- **Example: Simple ontology for traffic applications**



Ontology Description

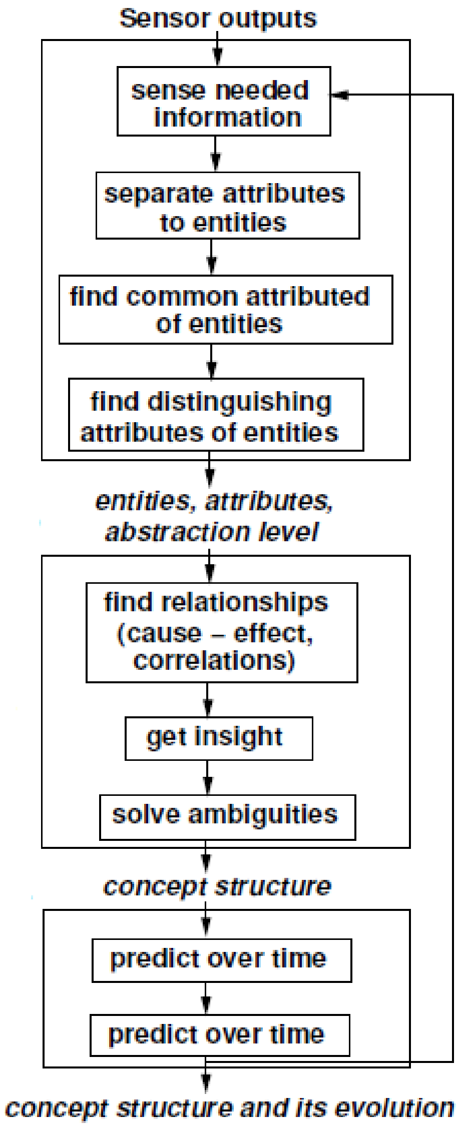
- **Relations in ontologies for traffic applications**
  - Enabling relation
  - Is-part relation



(a) (b) (c)

Traffic Scene Representation

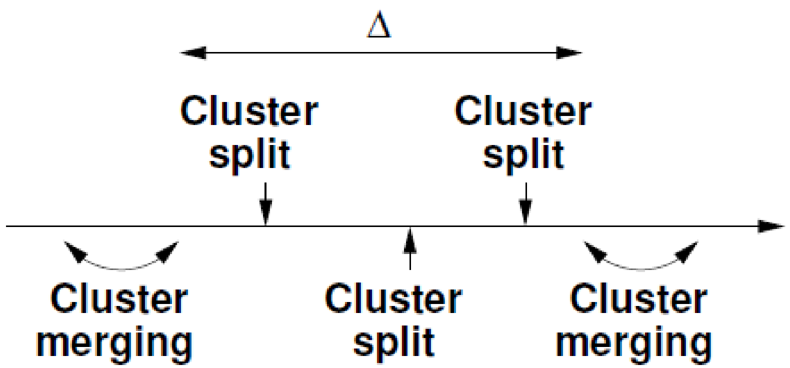
- **Entity Identification**
- **Relationship Understanding**
- **Scene Evolution**



Predicting traffic dynamics

```
while (events are possible) {
 event = select next event;
 time = expected time of event;
 S = set of clusters that could participate to event;
 for (all consecutive pairs i,j in set S) {
   for (all speed vi of cluster i) {
     for (all speed vj of cluster j) {
       if (vi < vj) {
         p = probability of merging Cvi and Cvj;
         if (p > pthresh) {
           T = time of merging event of Cvi and Cvj;
           add new splitting events at time Tj and with probability p;
           for (all speed vii < vi)
             Tii = time of splitting Cvi for speed vii;
             add new event at time Tii and with probability p;
           }
           for (all speed vjj < vj) {
             Tjj = time of splitting Cvj for speed vjj;
             add new event at time Tjj and with probability p;
```

Predicting traffic dynamics



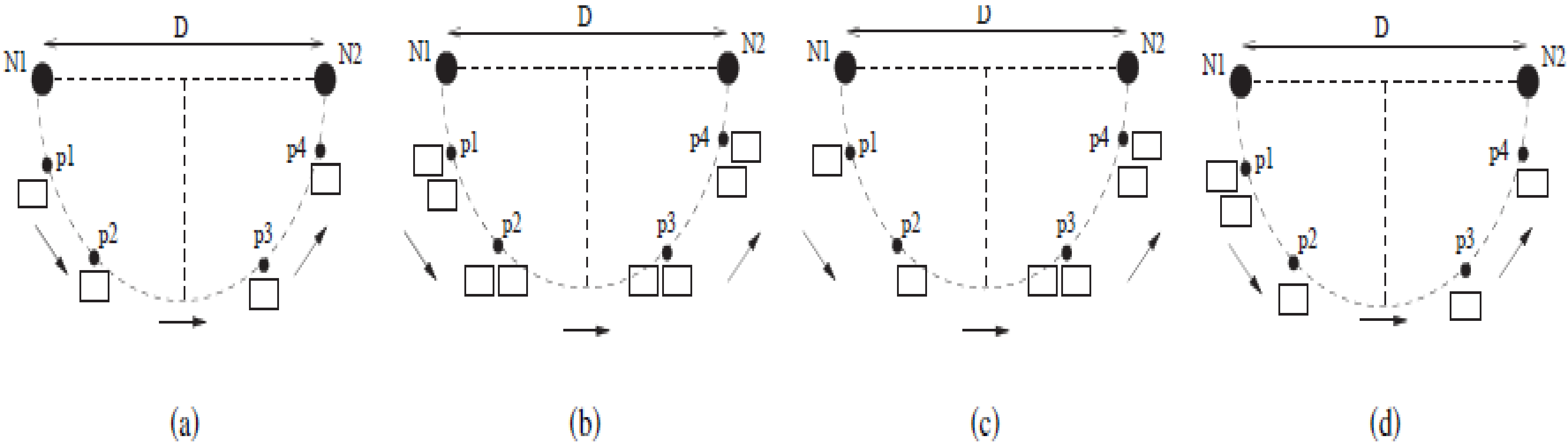
- **Time of separation** $$t_{split,C_I,C_{I_1},C_{I_2}} = \frac{D_{Lim}}{v_j - v_{C_I}} + t_r$$

  where, $$t_r = \frac{1}{p(C_I, C_{I,1}, C_{I,2})} t_{r0}$$

- **Time of merging** $$t_{merging,C_1,C_2} = \frac{D_{1,2}}{|v_{C,2} - v_{C,1}|}$$

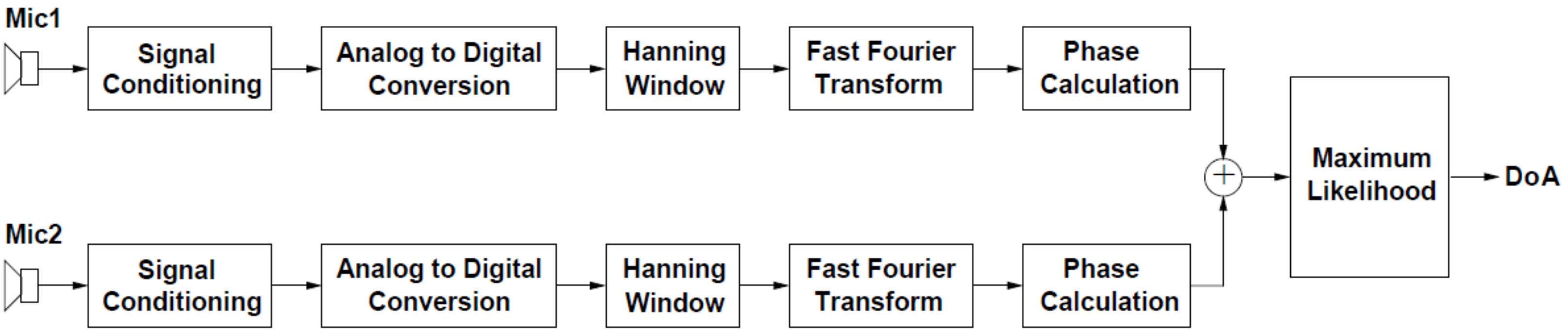
Experimental Results

- **Experiments with six scenarios:**
  - Single vehicle: Good/Bad driving conditions
  - Cluster of vehicles: Good/Bad driving conditions
  - A vehicle joining a cluster
  - A vehicle splitting from a cluster



Experimental Results

- **Extract scene elements:**
  - **Sound Sensing and Localization**



  - **SVM-based Clustering**

Experimental Results

- **Spatial Coordinates extracted from DoA estimates**

		Position 1		Position 2		Position 3		Position 4	
		X	Y	X	Y	X	Y	X	Y
CS1	V1	4.07	52.68	14.30	67.77	34.14	60.32	54.25	49.53
CS2	V1	6.14	47.14	14.26	67.58	38.41	59.35	55.88	47.04
	V2	22.44	60.31	26.26	72.89	52.31	57.47	69.92	39.87
CS3	V1	4.37	47.87	15.08	66.85	35.12	63.08	55.88	47.04
	V2	12.40	58.76	22.73	66.32	42.78	57.58	64.43	41.19
	V3	21.19	61.84	27.60	74.16	51.05	53.97	70.31	40.09

- **Sources of Error in Experimental setup, sound source**
- **Clustering accuracy: 87.5%**
- **Classification accuracy: 100%**

Conclusions

- The proposed methodology models the dynamics of traffic scenes, including the participating vehicles, vehicle clusters, attributes and relations of all scene elements, and related events, like cluster merging and splitting.
- The main steps of the methodology find the elements of a scene, identify the relations among the elements, and construct analytical prediction models for the traffic scene dynamics.
- Compared to other methods, this methodology constructs the models online using data from embedded sensors.

Questions? Comments?