U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

Uncertainty-Aware AI&ML for Effective Decision Making

Dr. Lance Kaplan

Team Leader

US Army Research Laboratory

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APPROVED FOR PUBLIC RELEASE

RESEARCH CONTEXT

Multi Domain Battle → Prevailing in a Complex World

Large-scale, cluttered, contested urban environment

Highly-dispersed team of human & robot agents accessing highly heterogeneous information sources

Dynamic in-flight learning & re-planning at the Speed of the Fight

Learning in new environments with deception from persistent threats

Research outcomes address CSA Priorities:
(i) Next Gen Combat Vehicles (primary) and (ii) Networks/C3I (secondary)

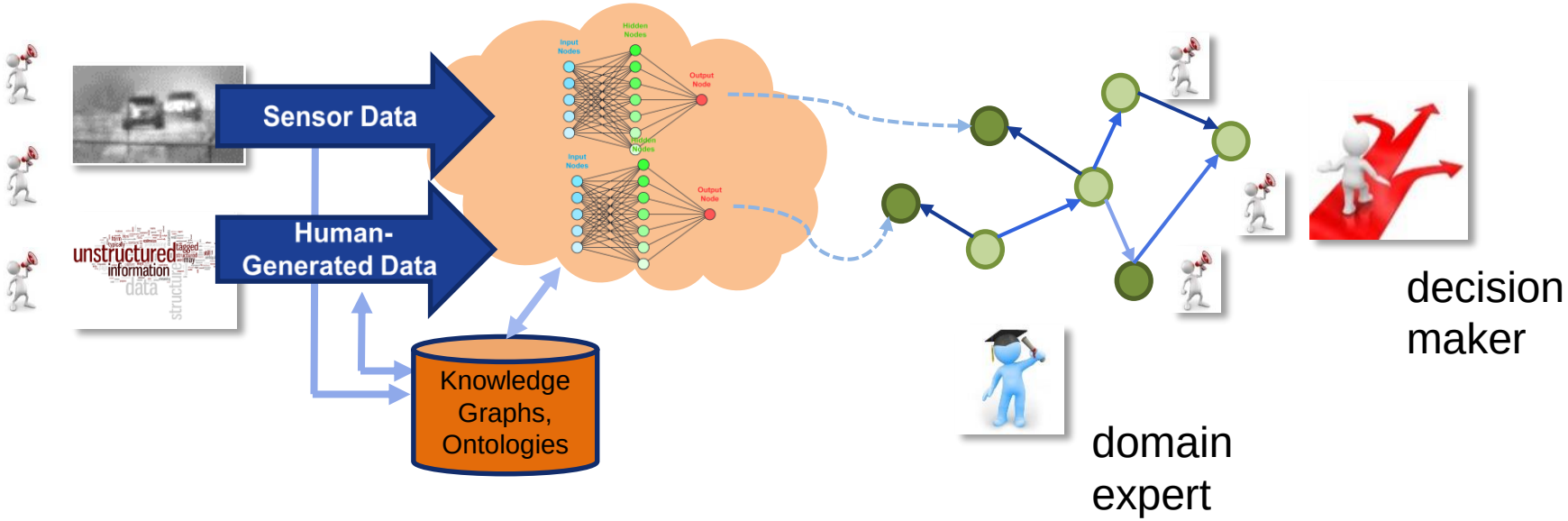
AI & ML RESEARCH CHALLENGES

AI & ML Research Gaps

Learning in Complex Data Environments	→ AI & ML with small samples, dirty data, high clutter → AI & ML with highly heterogeneous data → Adversarial AI & ML in contested, deceptive environment
Resource-constrained AI Processing at the Point-of-Need	→ Distributed AI & ML with limited communications → AI & ML computing with extremely low size, weight, and power, time available (SWaPT)
Generalizable & Predictable AI	→ Explainability & programmability for AI & ML → AI & ML with integrated quantitative models

Goal: To research and develop artificially intelligent agents (heterogeneous & distributed) that rapidly learn, adapt, reason & act in contested, austere & congested environments

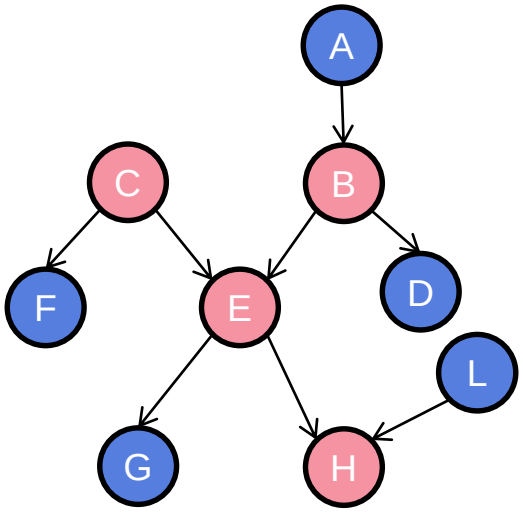
AI&ML SYSTEM



- **Limited training data**
- **Training and observational data can come from unreliable sources**

- **Reasoning with limited training data**
- **Characterization of uncertainty**
- **Explanations of uncertainty for the user**

SUBJECTIVE BAYESIAN NETWORKS

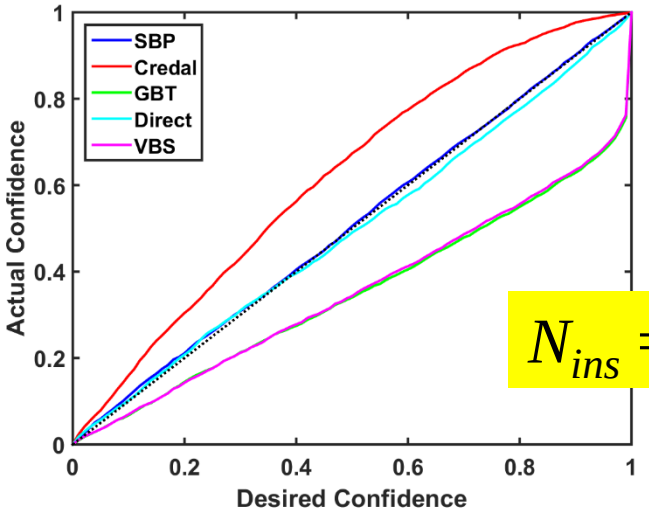


- Uncertain Bayesian networks due to sparse training data
- Efficient inference methods that generalize belief propagations

Accuracy
(Root Mean Squared Error)

	SBP	Credal	GBT	Direct	VBS
Act.	0.112	0.121	0.124	0.256	0.123
Pred.	0.110	0.155	0.098	0.247	0.098

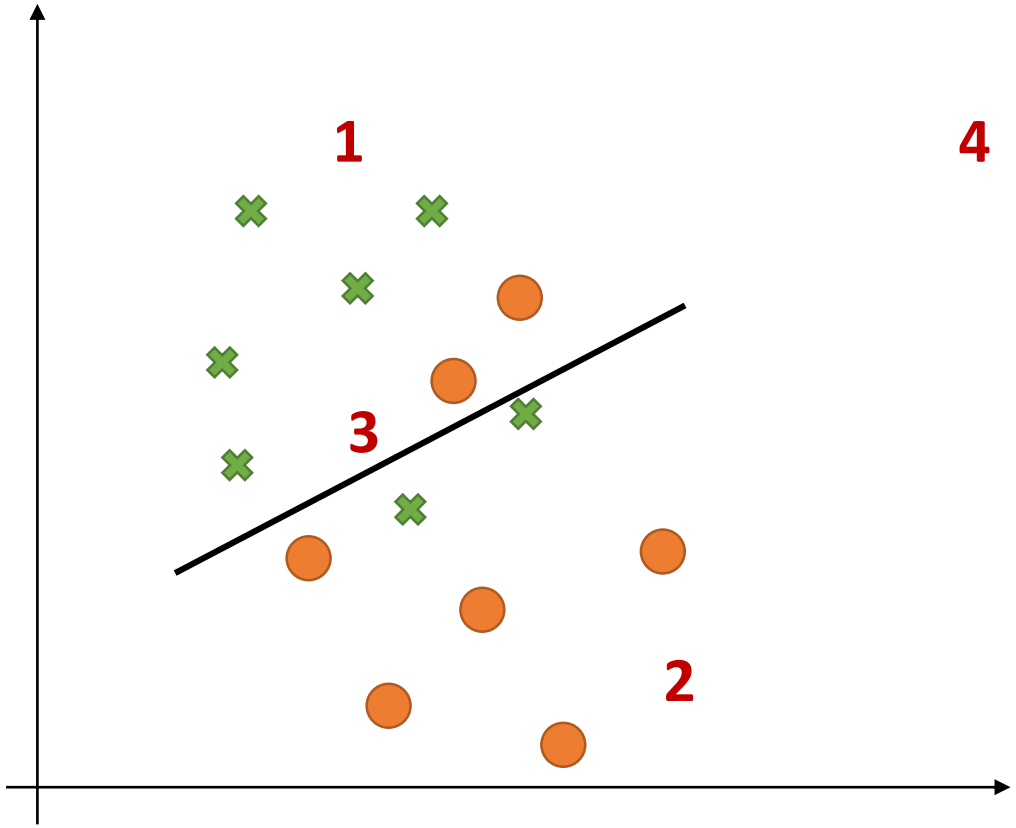
Uncertainty Characterization
(Desired Confidence Bound Divergence)



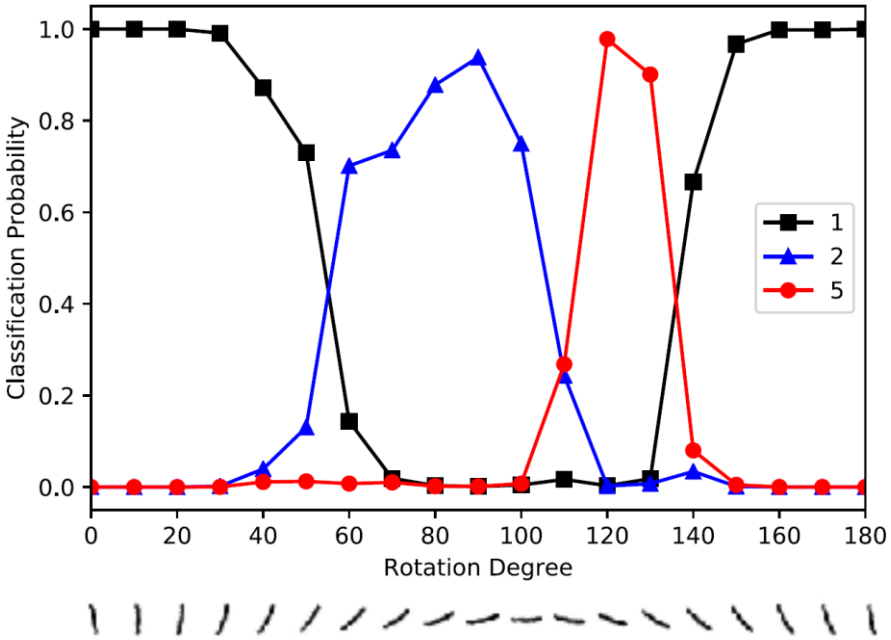
$N_{ins} = 50$

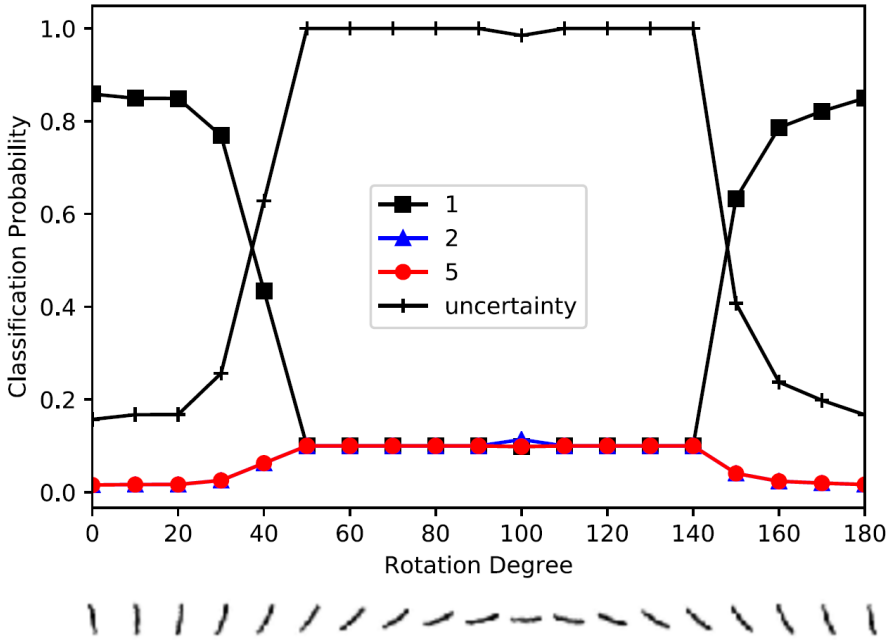
Ivanovska, Kaplan, Int. Jour of Approx. Reasoning, 2018

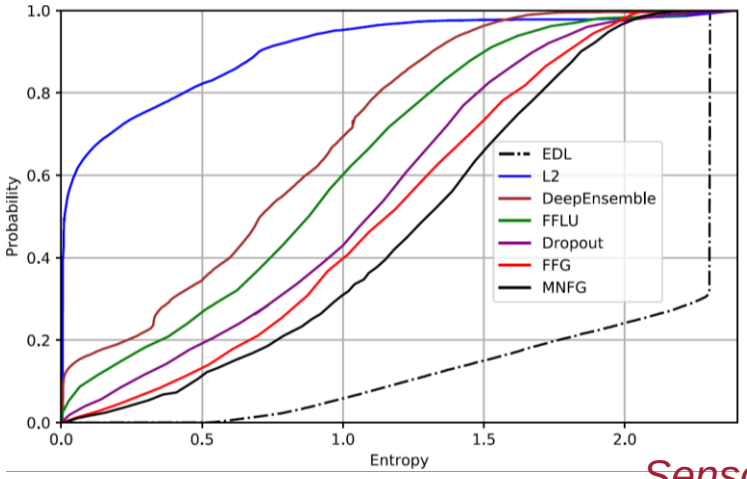
UNCERTAIN-AWARE MACHINE LEARNING



EVIDENTIAL NEURAL NETWORKS



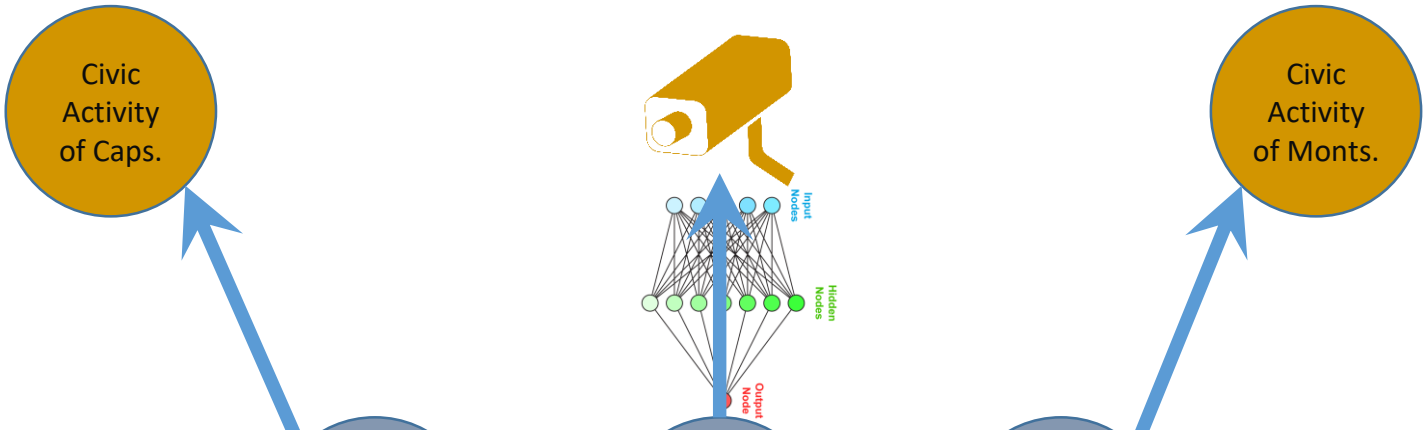




Trained on digits
but tested on letters

Sensoy, Kaplan, et al., submitted to NIPS 2018

ROUTE PLANNING EXAMPLE

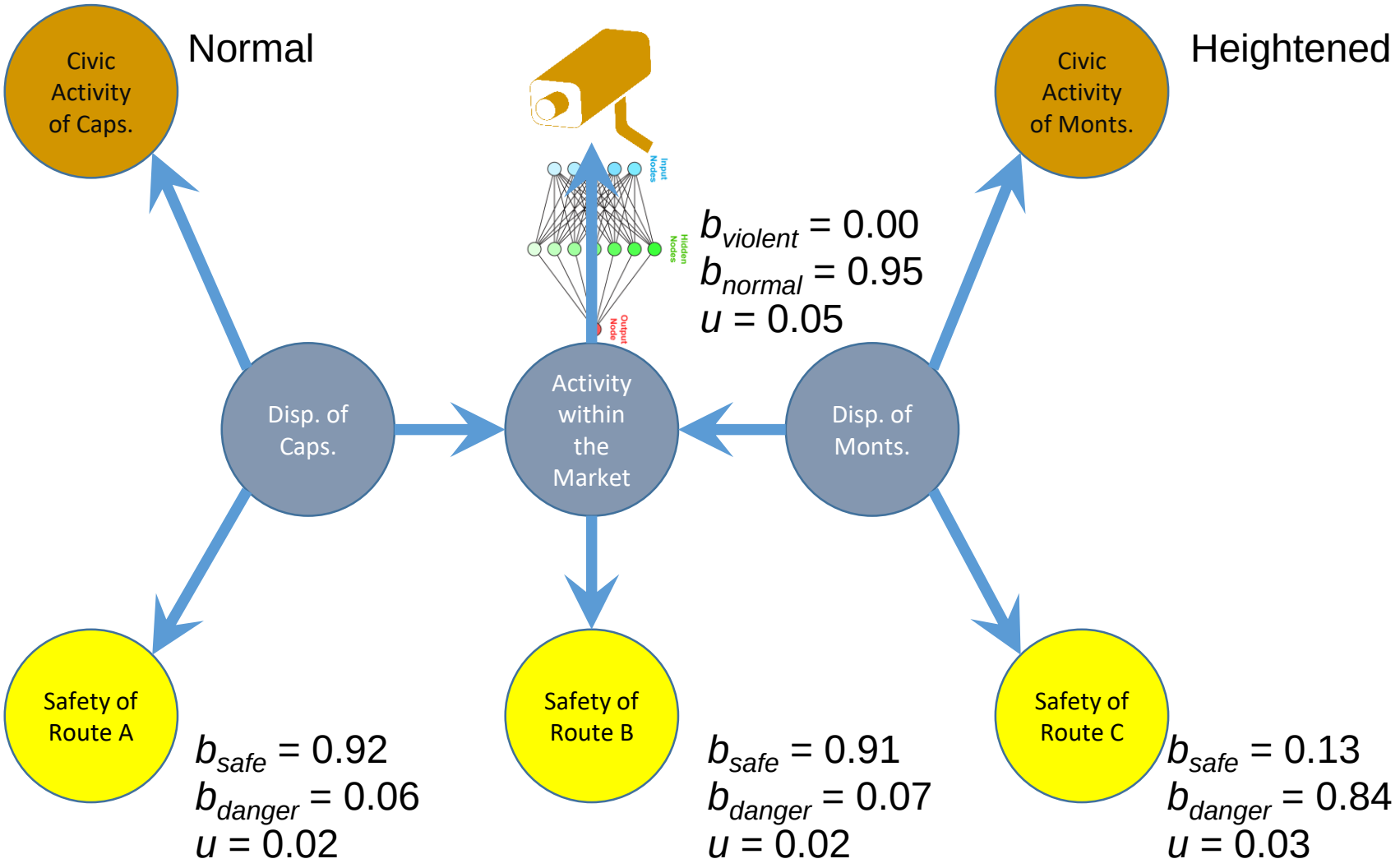


$b_{safe} = 0.78$
$b_{danger} = 0.20$
$u = 0.02$

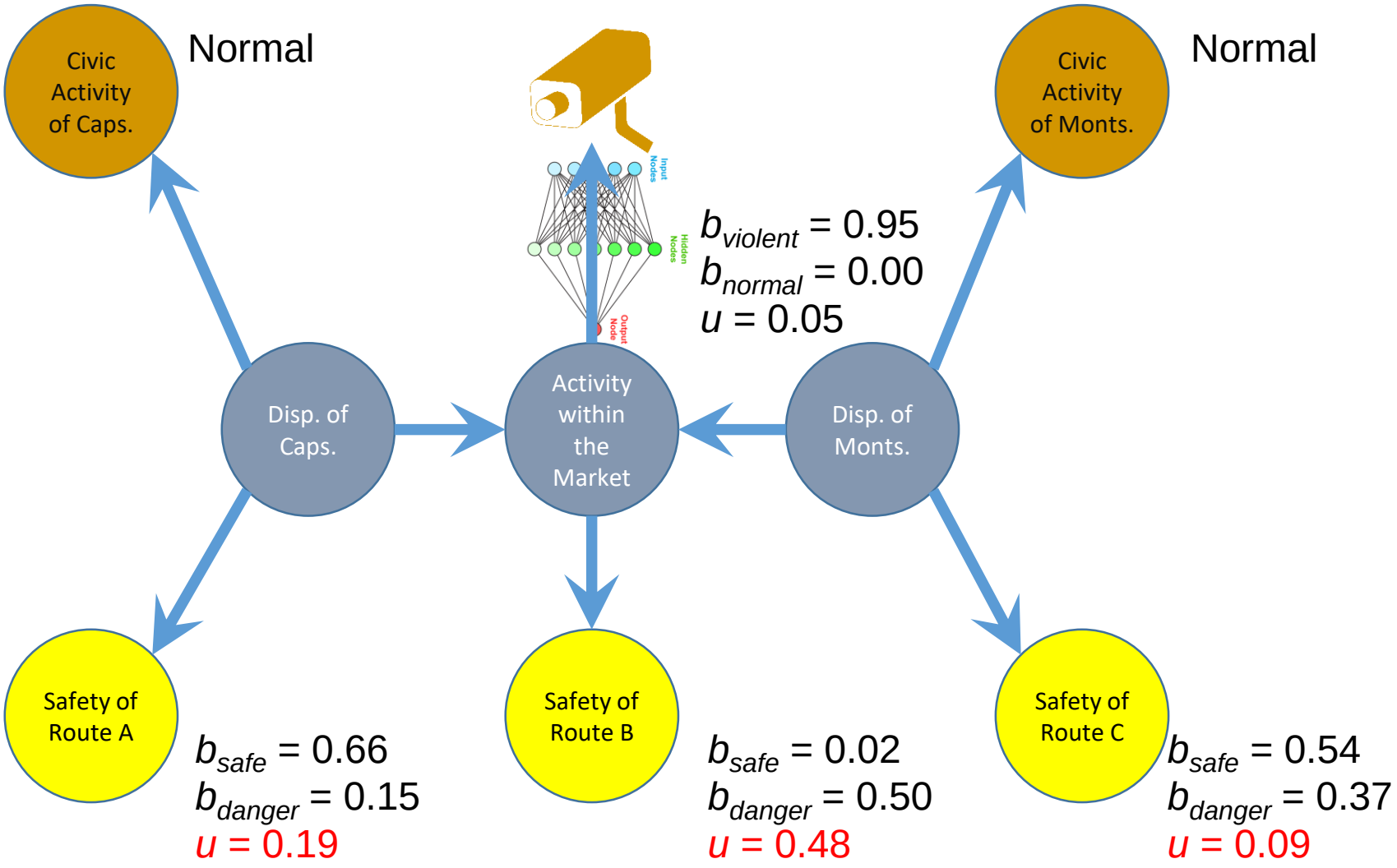
$b_{safe} = 0.77$
$b_{danger} = 0.21$
$u = 0.02$

$b_{safe} = 0.21$
$b_{danger} = 0.77$
$u = 0.02$

ROUTE PLANNING EXAMPLE



ROUTE PLANNING EXAMPLE



ROUTE PLANNING EXAMPLE