Multi-agent Negotiation Mechanisms for Statistical Target Classification in Wireless Multimedia Sensor Networks

JIHOON YUN

References

- X. Wang, D. Bi, L. Ding, and S. Wang, "Multi-agent Negotiation Mechanisms for Statistical Target Classification in Wireless Multimedia Sensor Networks", Sensors 2007, 7, 2201-2237

Outline

- Introduction
  - WSNs and WMSNs
- Target classification in WMSNs
- Hierarchical Multi-agent Architecture
- Belief-Desire-Intention(BDI) Model
- One Shot Dummy Multi-Item Auction (OSDMIA)
- Combination of Individual Decisions
- Committee Decision
- Conclusion
- Praises
- Critiques

Wireless Sensor Networks

- Tiny, low-cost and low-power
- Composed of large number of sensor nodes
- Monitors the environment
- Sensing + Processing + Communication

Wireless Multimedia Sensor Networks

- Newly Emerging type of WSNs
- Equipped with cameras, microphones, and other sensors retrieving audio, video and other scalar data
- WSNs vs. WMSNs
  - Decreasing energy consumption to extend network longevity under resource constraints -WSNs
  - Efficient delivery of application level quality of service (QoS) – WMSNs

Target classification in WMSNs

- Statistical methods
  - Power spectrum analysis - extracted features from raw audio data
  - Principal component analysis – compressed features
  - Gaussian process classification - classification
    - Complement memory and bandwidth limitations
- Multi-agent negotiation mechanisms
  - Combine individual decisions in a committee manner
    - Extend network longevity
    - Accomplish efficient collaborative multimedia in-network processing

Hierarchical Multi-agent Architecture

- Front-end interface agent
  - Accept user requests, provide feedbacks of images, video, or audio.
- Regional agent
  - Based on geographical or similar criteria
  - Manage several regions
- Cluster agent
  - Several sub-regions
  - Reduce communication load
  - Improve in-network processing efficiency
- Query agent
  - Audio and video information acquisition and processing

Belief-Desire-Intention(BDI) Model

- Beliefs
  - In WMSN, the environment is dynamic
  - Past events need to be remembered
- Desires
  - Such objectives as the agent to accomplish
- Intentions
  - What the agent has chosen to do

Two Phase negotiation mechanisms

Purpose

Target Classification in WMSNs

Requirements

Efficient resource usage,
Reliable classification accuracy,
Real-time manner for WMSN

Decision

Statistical methods			Multi-agent negotiation	
PSA	PCA	GPC	Phase 1: task allocation	Phase2:combination of individual decision

Phase 1

The agent should engage in a classification task that necessitates usage of these resources

The value of individual decision, weight

Phase 2

The most reliable and accurate decision from individual decisions

Phase 1: Task Allocation

Requirements

Efficient resource usage, Reliable classification accuracy, Real-time manner for WMSN

Design objectives

Bounded by time	complete within a predefined time window
Fast	finish quickly
Kept short	the minimized number of iterations
Kept short the negotiation-related messages	reduce loss and improve communication speed

The auction based negotiation mechanism for collaborative target classification

Task allocation problem

Only one item (classification task)	Several agents may win the bidding simultaneously
Several rounds	Time consuming, undesirable for real-time processing

OSDMIA

One Shot Dummy Multi-Item Auction (OSDMIA)

- Single bidding round
- Sell several dummy duplicates of the item to several buyers

Auctioneer : supervising the auction

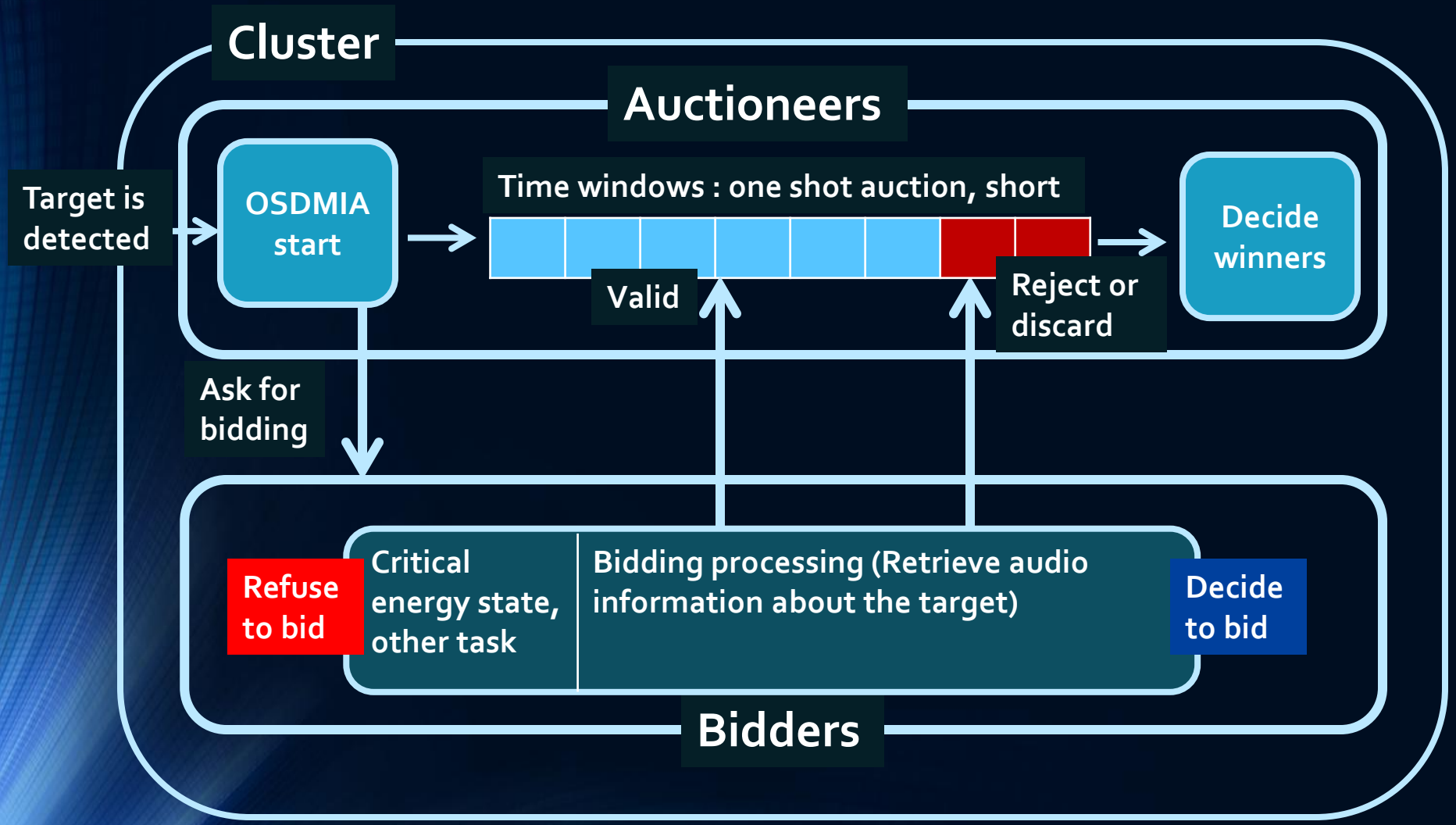
Items : N_i dummy classification tasks

$$OSDMIA = \{ a_{Auc}, A \backslash \{a_{Auc}\}, \{T_1, T_2, .., T_{N_i}\}\}$$

Bidders : agents trying to get involved in the classification task

- Determination of N_i
  - Larger N_i -> increase accuracy
  - Smaller N_i -> decrease resource usage
  - In this paper, set N_i as 3

One Shot Dummy Multi-Item Auction (OSDMIA)



One Shot Dummy Multi-Item Auction (OSDMIA)

- Bidding Price

$$Bidding = \{C_a, A_r, S_s\}$$

C_a : priori classification accuracy

A_r : available resources

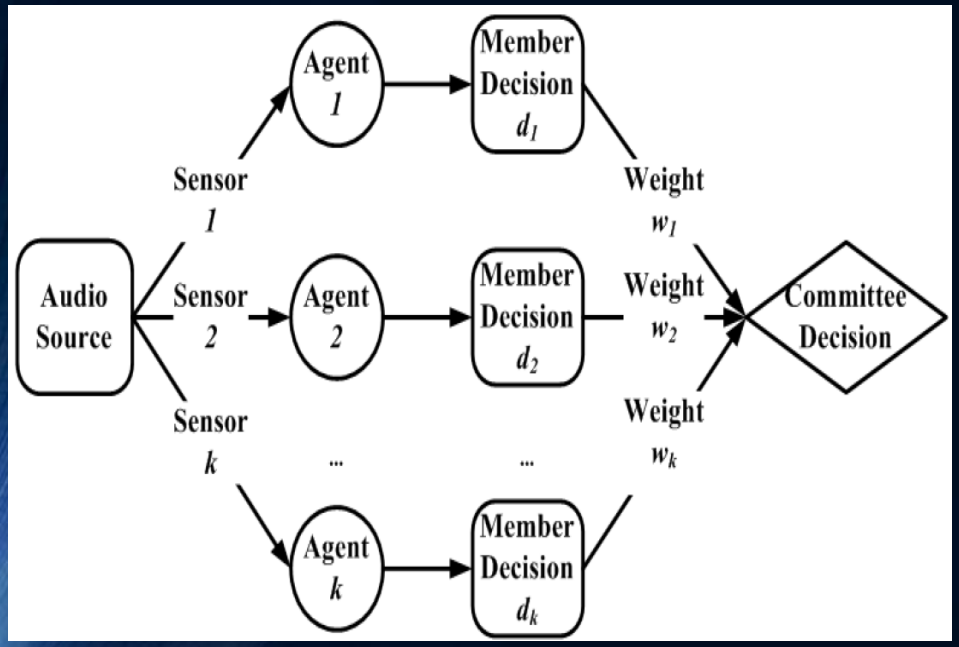
S_s : the strength of the observed signals

- The auctioneer is obtained the price by the utility function

$$U_{Auc}(C_a, A_r, S_s) = C_r^2 A_r (S_s / S_{s\,max})^2$$

Phase 2 : Combination of Individual Decisions

- Uncertainties related to audio signal acquisition
- The predictions the classifiers
- If decision error of the individual committee members, cancel out

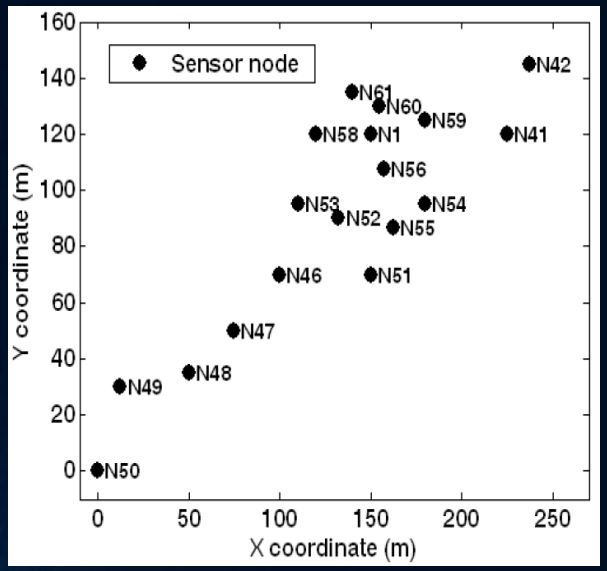


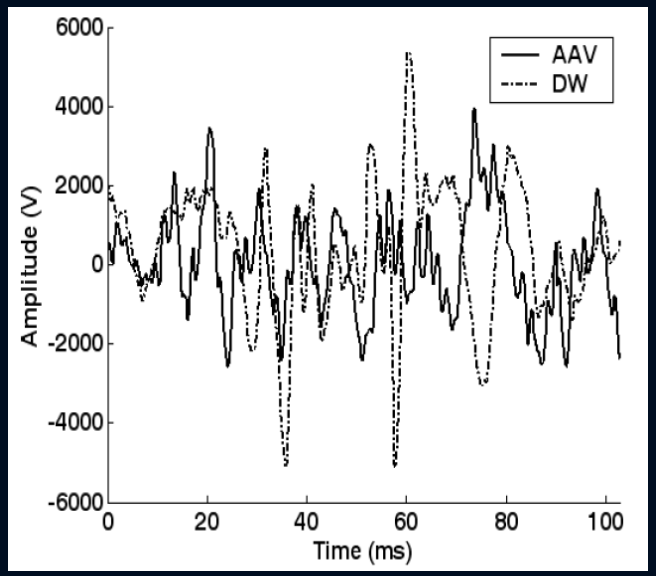
$$w = C_a S_s / \hat{S}_{s\,max}$$

C_a : priori classification accuracy
S_s : the strength of the observed signals

$$D = \frac{\sum w_i d_i}{\sum w_i}$$

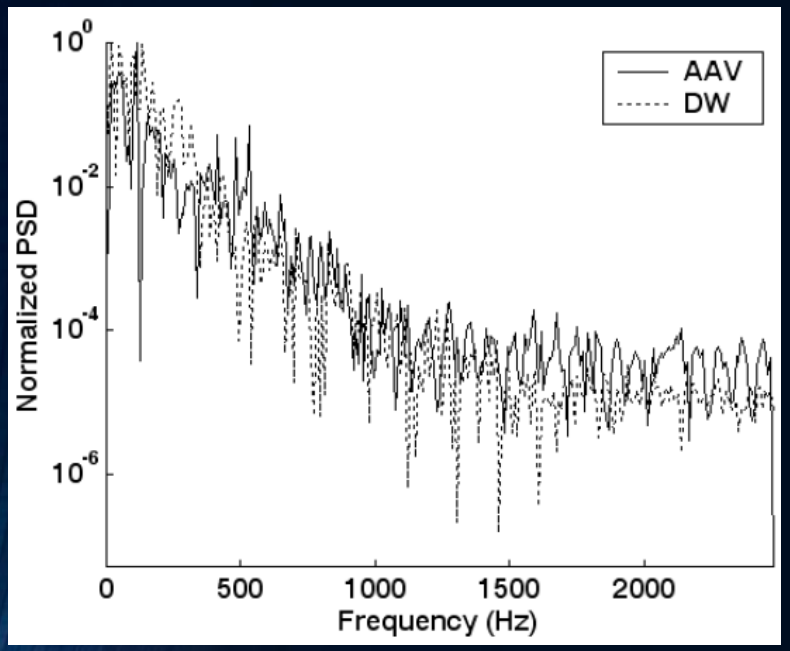
Experiment Setup

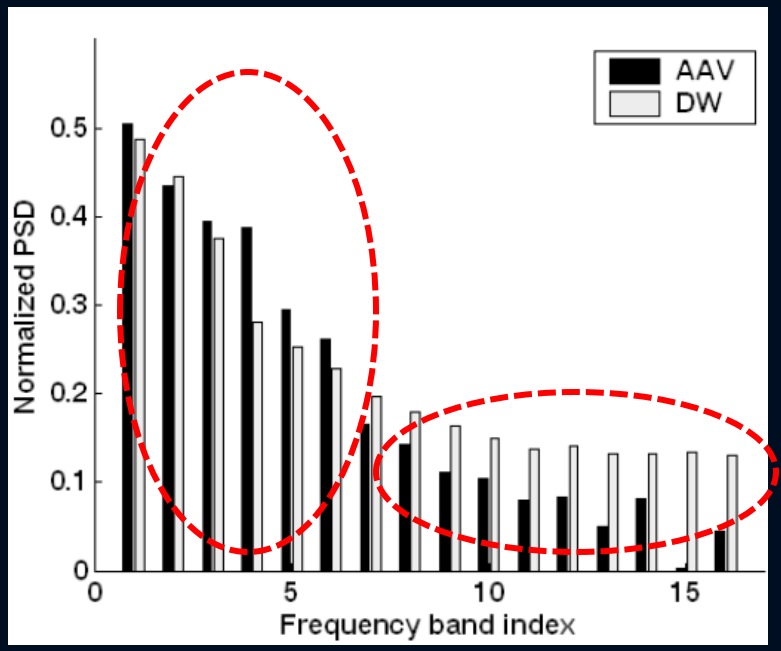




- Signals of AAV and DW observed by the sensor node N49
- Assault Amphibian Vehicle (AAV)
- Dragon Wagon (DW)

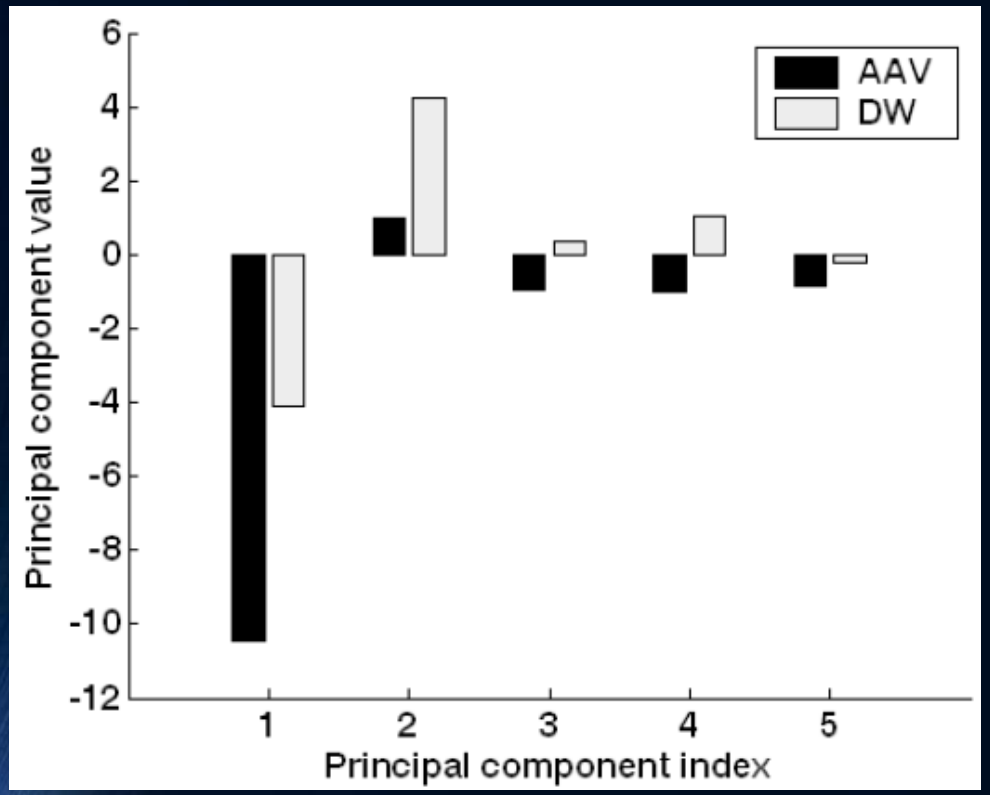
Power Spectrum Analysis (PSA)





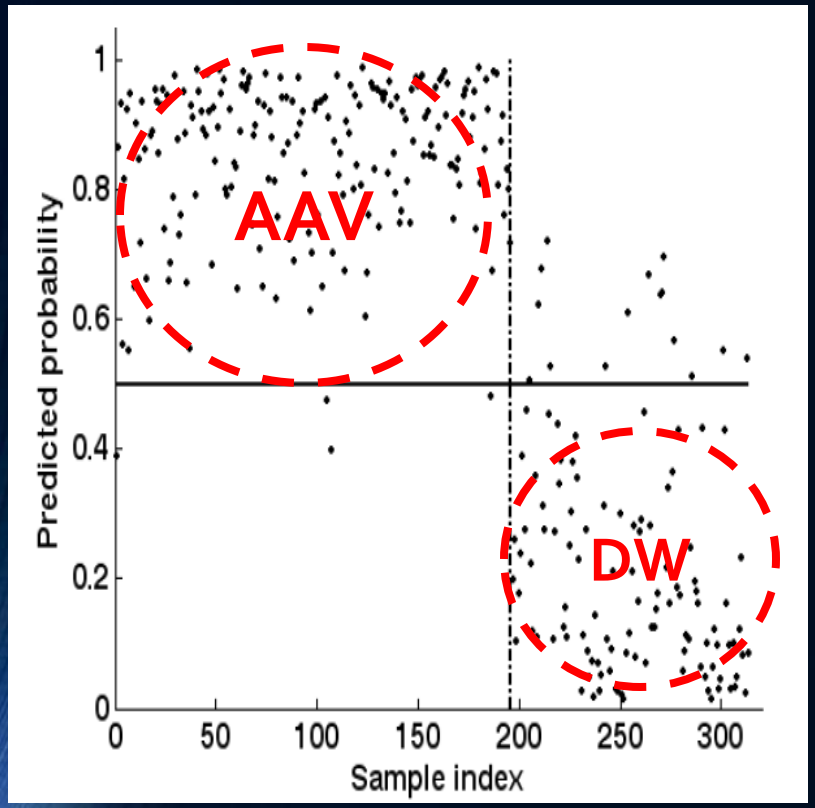
- Normalized power spectral density of the acoustic signals
- Features extracted from the PSD (distribution in the 16 frequency bandwidths)

Principal Component Analysis (PCA)



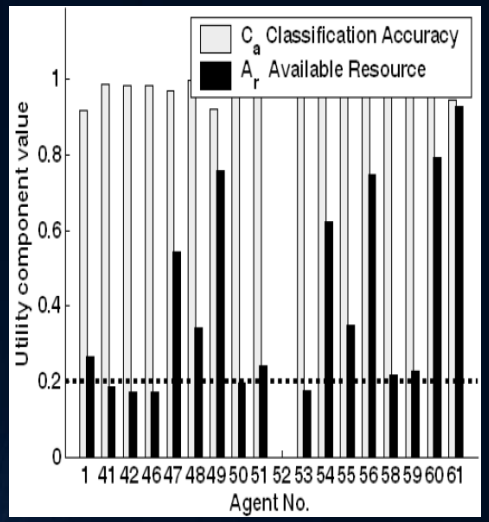
- Compressed to 5 elements

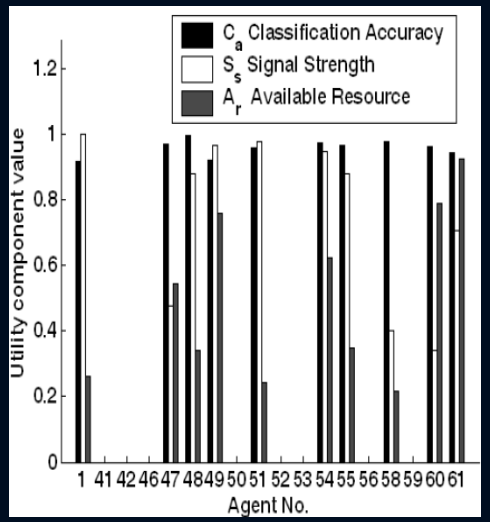
Training and test of GPC

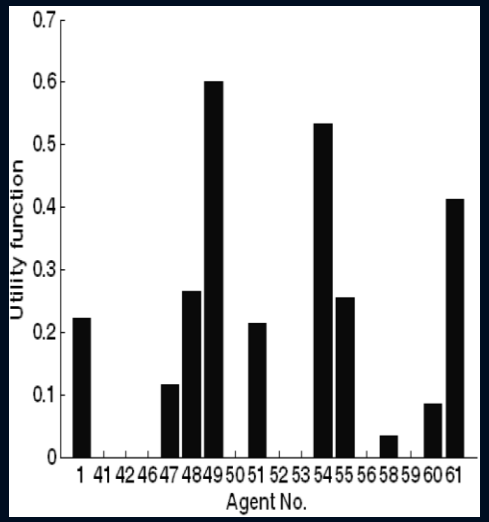


- AAV : 294 samples (98 for training, 196 for testing)
- DW : 178 samples (60 for training, 118 for testing)

Phase 1: Task Allocation (Bidding)







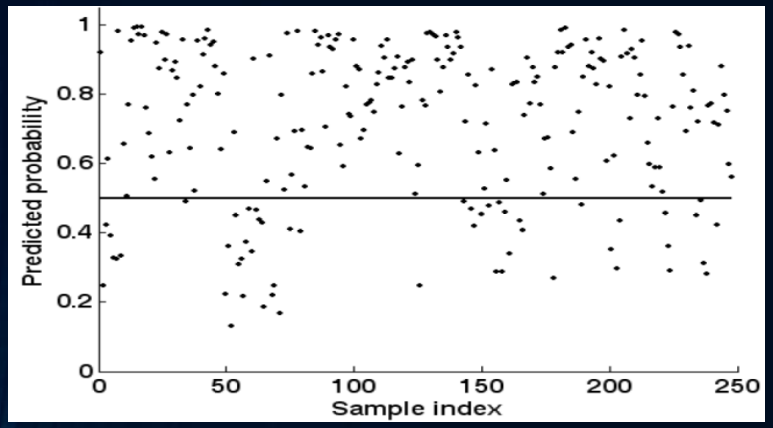
- N41, N42, N46, N53 : Deny -> critical energy level (0.2)
- The auctioneer calculates the utility functions
- N49, N54, N61 : Decided -> largest utility functions

Phase 2: Committee Decision

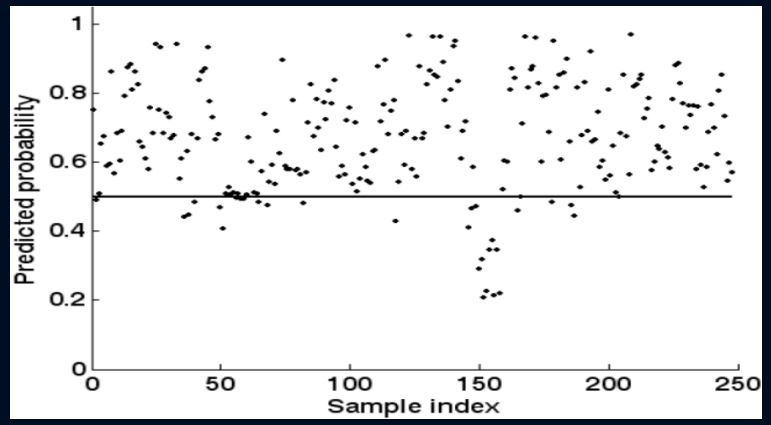
Committee Member	Member Decision d_i	Weight Component C_a	Weight Component S_s	Member Weight $C_a S_s$	Committee Decision D
N49	0.3911	0.9204	1.0000	0.9204	
N54	0.6750	0.9746	0.9824	0.9574	0.6293
N61	0.8837	0.9440	0.7310	0.6900	

- The committee decision made by three committee members
- N49 : misclassification (below 0.5 -> DW) -> cancel out
- N54, N61 : committee decision

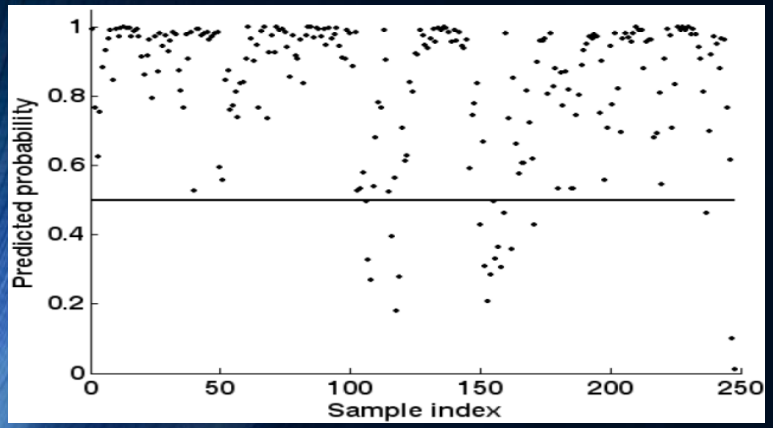
Phase 2: Committee Decision



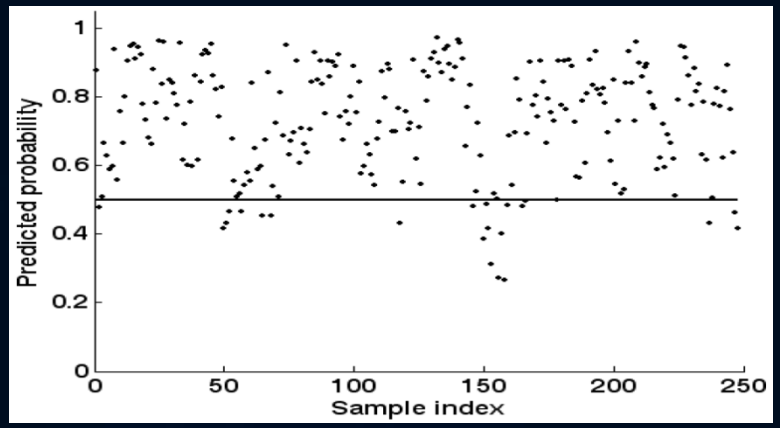
N49 – 79.03%



N54 -87.50 %



N61 – 91.93%



Committee decision – 90.73%

Conclusion

- This paper proposed target classification in WMSNs
- Verified by the simulation experiments
  - Proposed statistical processing
    - PCA, PSD, GPC
  - The negotiation mechanism
    - OSDMIA, committee decision

Praises

- Robustness in terms of misclassification
- PSD, PCA, GPC reduce memory and computation capability requirements
- Reach a compromise between resource consumption and accuracy
- Reduce the uncertainty of individual classifier prediction
- Enhance the overall classification reliability

Critiques

- Simulation - no real experiment
- Still need many tasks and resources – Acoustic signals, Training
- Limited experiment
  - Only compared two vehicles
  - If the noise is strong?