Multi-agent Cognitive Sensing for Behavioral Biometrics

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Outline

• Cognitive Sensor
• Heterogeneous Sensor System
• Agent-oriented Programming
• Multi-agent System Architecture
• Behavioral Biometrics
• Cognitive Sensing for Behavioral Biometrics
Machine Intelligence

• Perception: detection, fusion/aggregation
  – Analog to Information (A2I)

• Cognition:
  – Pre-conceptualization (prior knowledge)
  – Conceptualization (context/situation awareness, pattern modeling)
  – Predication & Decision (across-scale/modal)

• Action: presentation, fission/de-aggregation
  – Information to Analog (I2A)
Human Brain

- Power Consumption: 20 ~40 W
- Number of Neurons: 100 billion

Axon: send information
Dendrites: receive information
Synapse: point of connection

visual, auditory, gustatory, olfactory
haptic, thermal sensors
Biological Sensing

[Image of a diagram showing the process of biological sensing, labeled A and B, with steps from visual field to location map, summation clusters, and numerosity detector neurons.]

[Text citation: Mainen and Sejnowski, 1996]
Neuron Excitation

A

Pre area

Post area


B

Pre area

Post neuron
Cognitive Geometry Sensing

Target Geometry

Sampling Geometry

Random Projection

Information Aggregation

Sensing Layer

e-Projection

Information Layer

m-Projection
Heterogeneous Sensors

Thermal Sensors  Optical-fiber Pressure Sensor  Laser Sensor

Photonic Sensors  Acoustic Sensors
Novel Sampling Geometries

Signal Signature: [0 0 0 1 0 1], [1 0 0 0 1 0]
Agile Sensing Protocol

Probabilistic Medium Access Controller

Bernoulli Encoder

Pseudorandom number generator

ICA

$\Sigma f_s / N$

PCA

multinomial distribution

HMM
Cognitive Sensor

- **Spatial Awareness**
  - Understanding its geometric relation to targets and peer sensors
- **Data Awareness**
  - Using sparse representation of information
- **Group Awareness**
  - Understanding activities of other sensors
- **Context Awareness**
  - Understanding its operational situation
Agent Oriented Programming

- IBM – ebXML, tpaXML
- XbML
- DARPA Agent Mark Up Language (DAML)

- Embedded in the programming language
- Awareness of environment
- Learning capability
- Collaborations of agents of different purposes
Object- v.s. Agent-Oriented

• Object
  – Public/private data
  – Communication: message
  – Initialization/instantiation, deconstruction

• Agent
  – Beliefs, commitments, choices
  – Communication: inform, request, decline, promise
  – Mental state: evolving and learning
Type of Agents

- **Sensing Agent**
  - Contains various sensing modalities
  - Reconfigurable computing capability

- **Action Agent**
  - Adaptive control, calibration
  - Adaptive communication

- **Decision Agent**
  - Feature Modeling, Behavior Analysis
  - Tracking, Recognition

- **Database Agent**
  - Behavior template
  - Context/situation models (context awareness)
  - Information of registered agents (group awareness)
Interaction of Agents

Interaction Drivers

(1) Data-to-feature driver
(2) Compression driver
(3) Aggregation and filtering driver
(4) Calibration driver
(5) Diffusion Driver
Behavioral biometrics

- Identify subjects based on their behavioral traits
- Gesture, gait, walking trajectory, body pressure dynamics, speech habit, handwriting habit, keystroke/mouse dynamics
- Collection of geometric information of subjects over time
- Finding repeatable signal patterns in the temporal-spatial domain
Pros and Cons

• Pros
  – Long distance measurement
  – No need for cooperation of subjects
  – Low sensing resolution
  – Easy information fusion of multiple sensing modalities
  – Useful for psychological information measurement
  – Robust against disguise and cosmetic conditions

• Cons
  – Higher error rates
  – Longer collection time
Applications

• Surveillance and security
• Tele-health care and hospital/prison monitoring
• Intelligent human machine interface
• Energy-aware buildings
• Robotics
Compressive Behavioral Biometrics

Subject Binary Measurements Statistical Model Visualization

Compressive/Agile Sensing Statistical Manifold Learning 3D Model Reconstruction
Multi-agent Cognitive Sensing for Behavior Biometrics

Behavioral Biometrics Applications

Decision Agent

Database Agent

Inter-agent Interaction

Adaptive Control and Communication

Reconfigurable Digital Signal Processing

Action Agent (Servo Control)

Sensing Agent (Infrared)

Sensing Agent (Fiber-optic Pressure)

Sensing Agent (Acoustic)

Sensing Agent (Laser/photonic)

Physical Layer

Object Space

Behavioral Biometrics Database

Multi-agent Architecture

System Adaptation

Reconfigurable Computing

Wireless Link and Networking