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Modern Control Theoretic Approach for Gait and Behavior Recognition

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Session 1A
05-BRIMS-023



Outline

- Introduction - Behaviors as Connected Gestures
- Gesture Recognition
- Behavior Recognition
- Future Work



Supporting Contracts

- **MDA** - HQ000604C7004 - Physics Based Missile Trajectory Discrimination Algorithms
- **U.S. Army STRICOM** - N61339-00-C-0084 - An Automatic Learning Gesture Recognition Interface for Dismounted Soldier Training Systems
- **NASA JSC** - NAS9-99079 - Gesture Based Multimedia Information Kiosk to Enhance Science Understanding
- **Army ARI** - DASW01-99-C-004 - Recognition of Computer-Based Human Gestures for Device Control and Interacting with Virtual Worlds
- **AFRL Kirtland** - F29601-98-C-0096 - A Behavior Recognition System for Identifying and Monitoring Human Activities
- **DARPA** - DAAH01-97-C-R136 - Recognition of Human Gestures for Device Control, Interacting with Virtual Worlds, and Interpreting Human Activities



Body Motion Gestures

- Connected non-deformable links
- Human body: torso, head, arms, legs
 - Each has an individual gesture
- Similar for vehicles and robots



Surveillance Task

- Classifying
- Tracking
- Patrolling
- Warning



What is Gesture Recognition?

- The gesture is generated
- The gesture is perceived
- The gesture is interpreted and recognized
- The gesture elicits a response



Ways to Not use Gesture

- Text Input
- Data Entry
- Sign Language
- As a Mouse
- As a Joystick



Advantages of Gesture Recognition

- Intuitive Motion Commands
 - Rotate View
 - Zoom In/Out
 - Move Part
 - Stretch and Shrink
 - Check Collision
- Can Test Accessibility Motions
 - Vehicle Occupancy and Reach
 - Vehicle Repair
- Device Free System



More Gesture Control Advantages

- No moving parts
- No direct contact - alleviates hygiene problem
- No sound required
- Intuitive gesture control
- Easy to use
- Overcomes language barriers
- Easy to adapt



Gesture Control Issues

- How are the gestures generated?
- Which gestures are used?
- What is the information content of the gestures?
- How are the gestures recognized?
- How does a user initiate a gesture session?
- How are gestures represented?
- What is the allowable workspace?
- What is the environment?



Gesture Recognition Issues

- Consistency
- Common Domain Gestures
- Ease of Recall
- Identifiable Spatial Components
- Correspondence to:
 - Functional Command Components
 - Scope
 - Target
- Variability



Motion Gesture Recognition Methods

- Geometric
- Algebraic (splines)
- Hidden Markov Model (stochastic)
- Dynamic System Representation (deterministic)



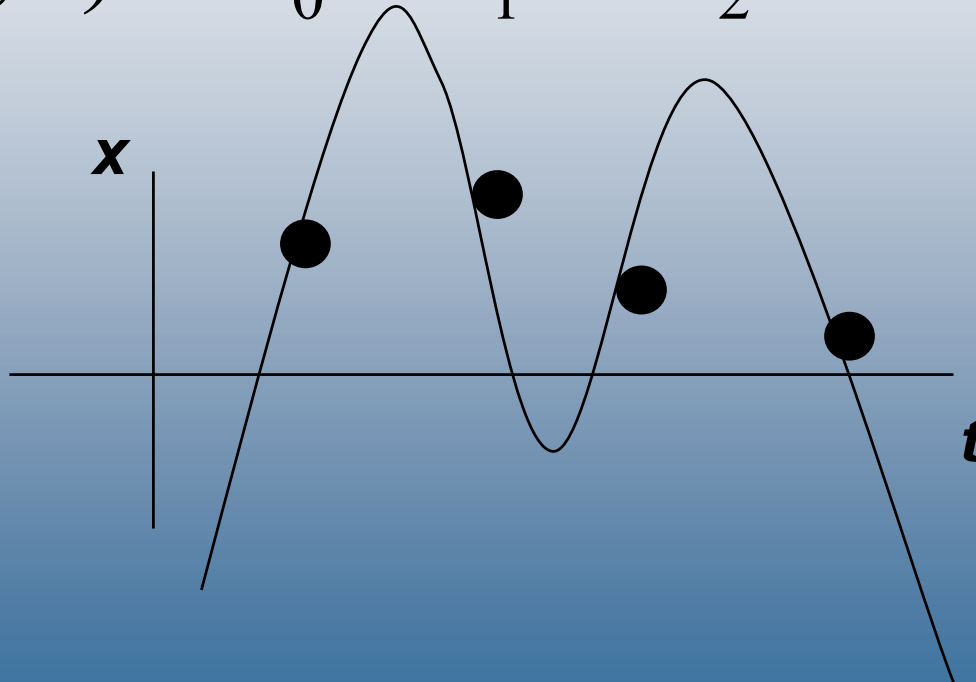
Geometric Methods

- Match to Various Templates:
 - Circle
 - Lines
 - Polygons

- Brittle to Noise

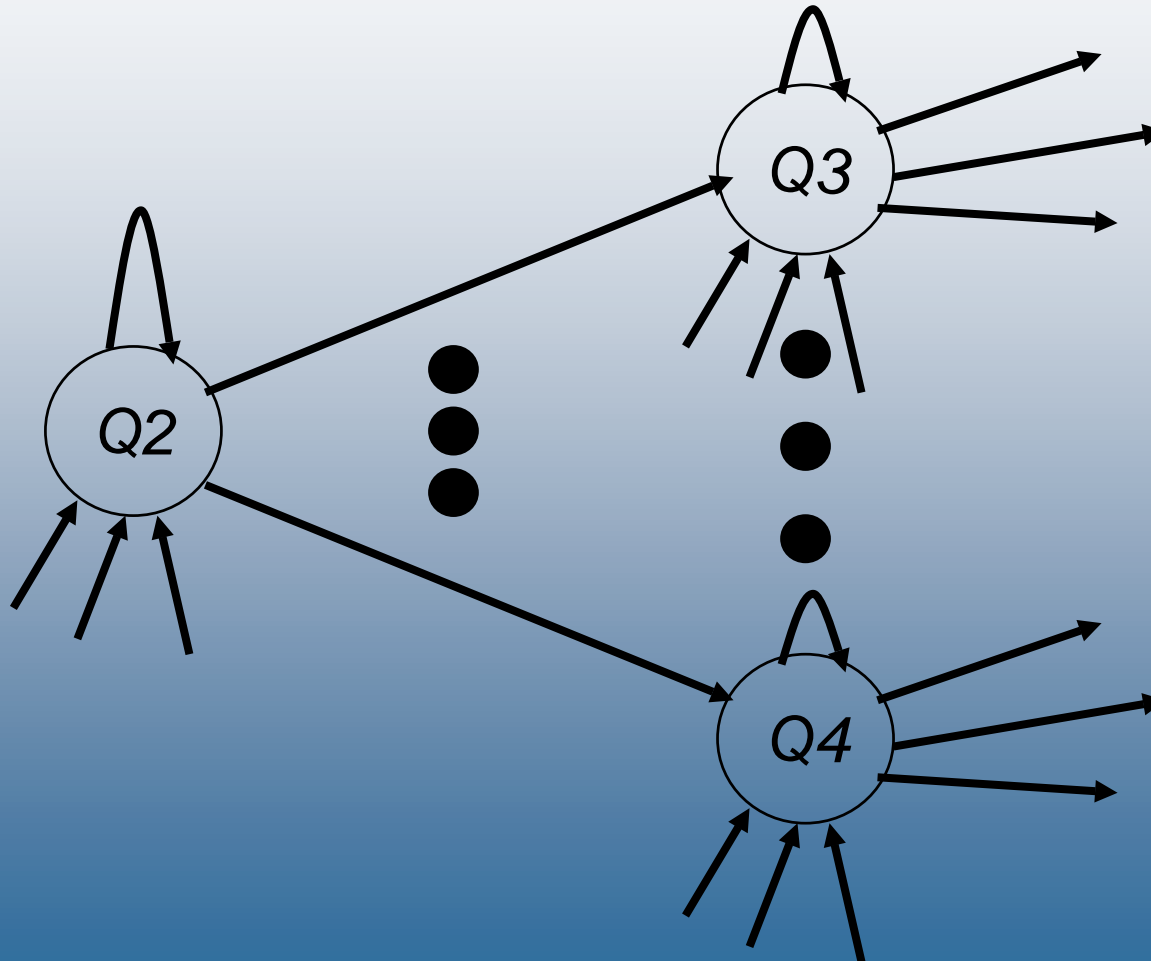
Algebraic Models - Splines

$$x(t, \theta) = \theta_0 + \theta_1 t + \theta_2 t^2 + \theta_3 t^3 + \theta_4 t^4 \dots$$





Hidden Markov Models





Dynamical Models

- Basic formulation

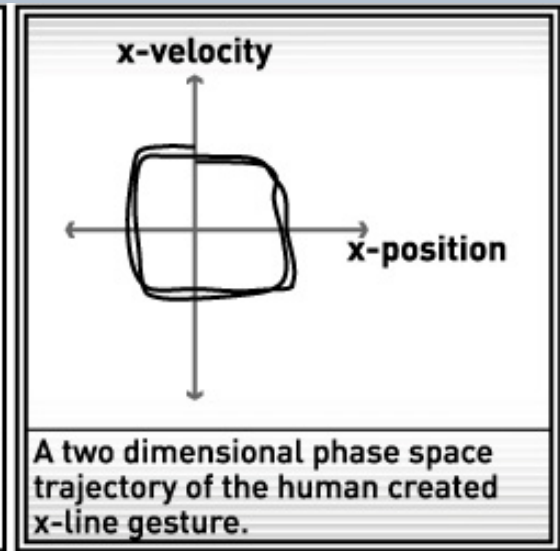
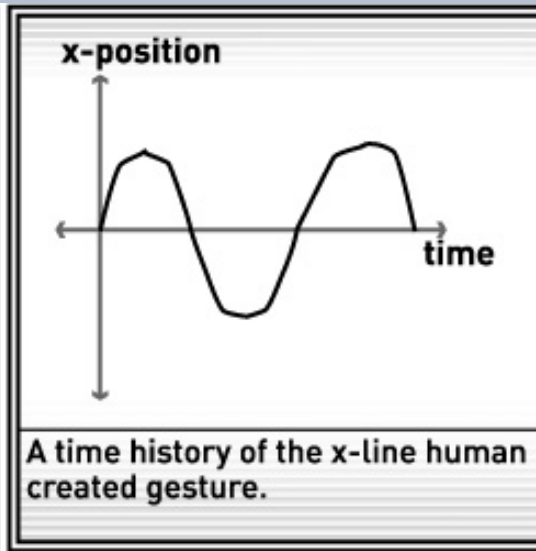
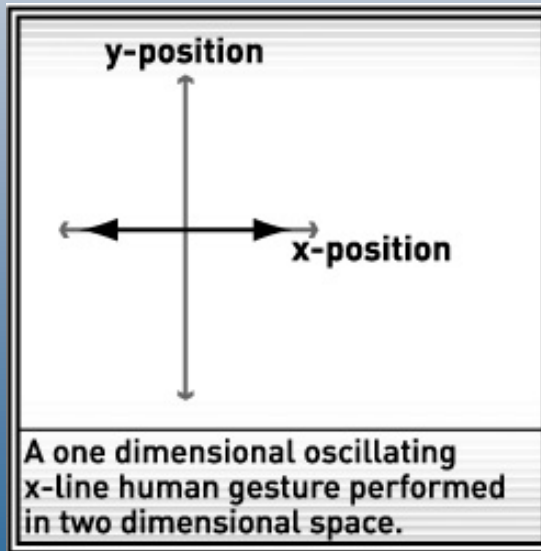
$$\dot{\mathbf{x}}(t) = \Theta(\mathbf{x}, t) f(\mathbf{x}, t)$$

- Types of dynamical models

		Parameters	
		Linear (LIP)	Non-Linear (NLIP)
States	Linear (LIS)	LIP/LIS	NLIP/LIS
	Non-Linear (NLIS)	LIP/NLIS	NLIP/NLIS

Advantages of Dynamical Model

- Accounts for inherent non-repeatability
- Compact representation
- Efficient identification computation





Model and Parameter Determination Issues

- Off-Line Batch vs On-Line Sequential
- State Availability
- Data Order Dependent vs Independent
- Linear vs Non-Linear



Gesture Models

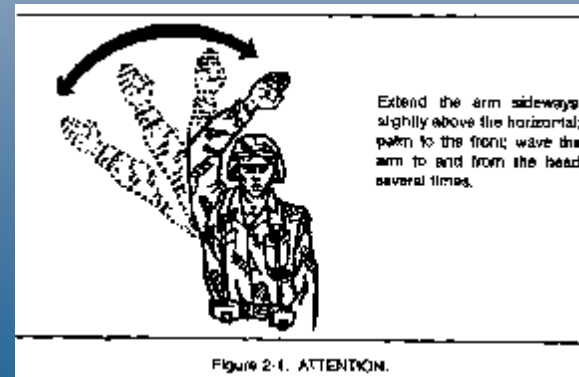
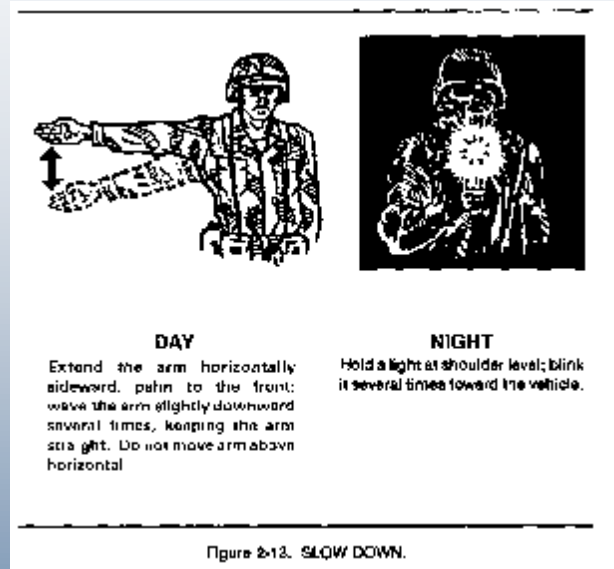
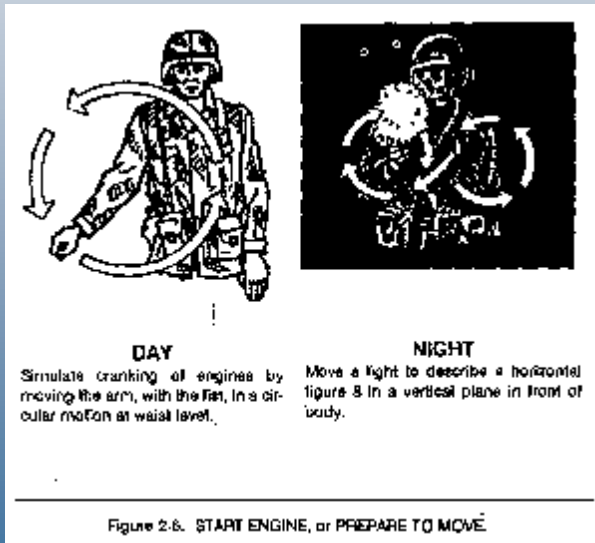
- Five models developed
 - Linear with offset (least complex)
 - Van der Pol
 - Van der Pol with offset
 - Higher order terms
 - Velocity damping (most complex)
- One set of parameters per gesture primitive
- Automatic tuning for parameter identification



Gesture Recognition

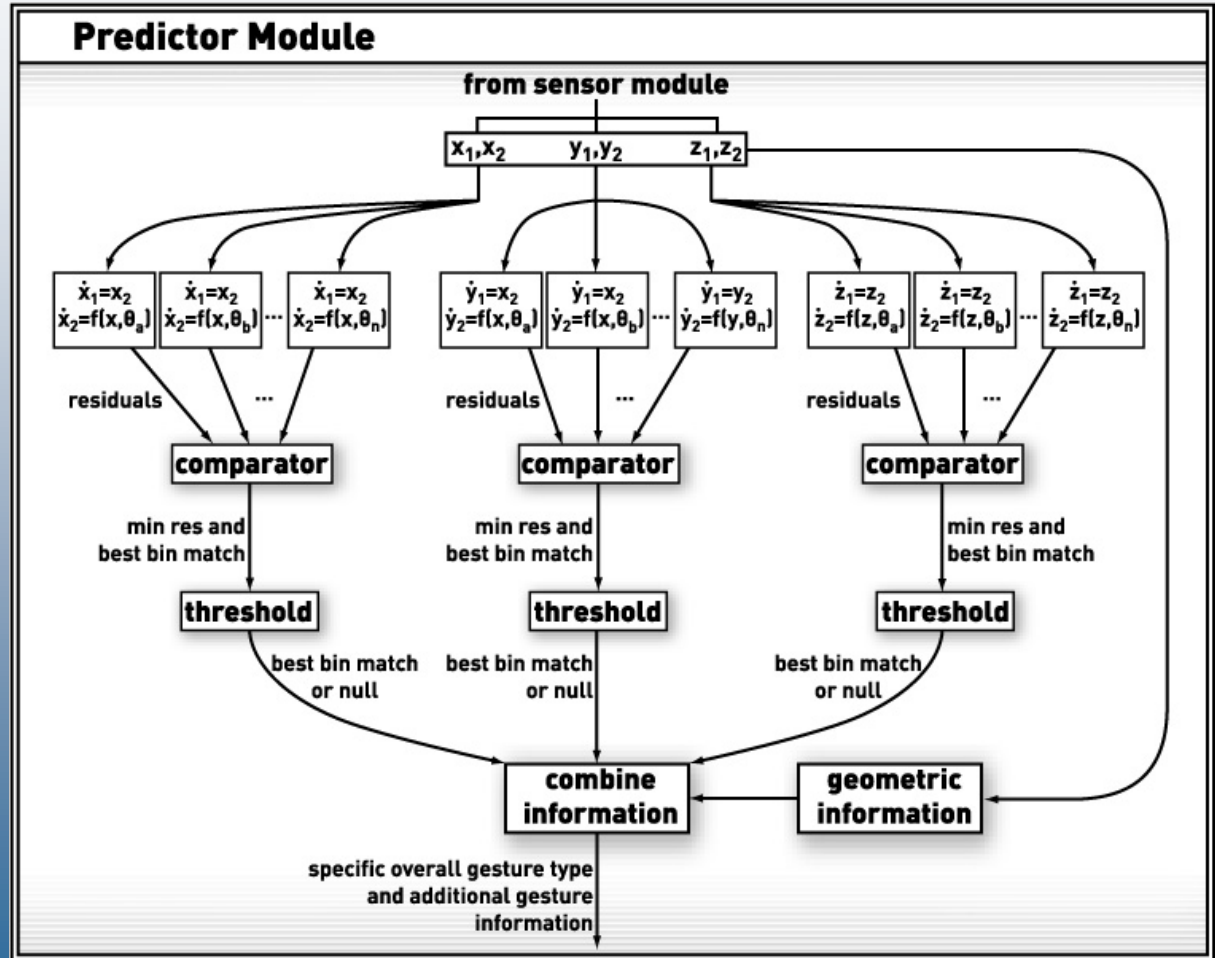
- Model selection
 - Predictor bins
 - Model with parameters for specific gesture primitive
 - parameters determined off-line
 - Predicts next gesture state
 - Residual error
 - Difference between model and actual gesture state
 - Smaller error indicates better model
- Linear with offset component chosen

Army Control Gestures: Dynamic

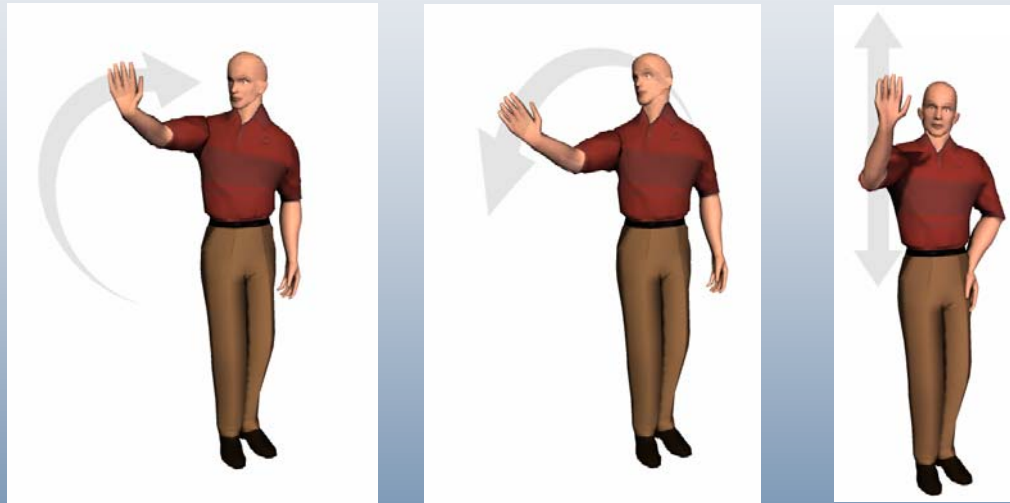


Gesture Recognition - Dynamic

- Differential equation representation
- Identification of non-perfect oscillations
- Bank of predictor bins tuned to specific gestures

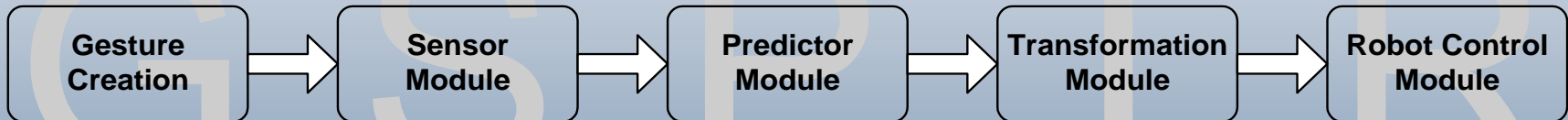


Dynamic Gestures



Clockwise, Counter-Clockwise, and Up-Down Dynamic Gestures

Gesture Recognition System





Non-Linear Gestures

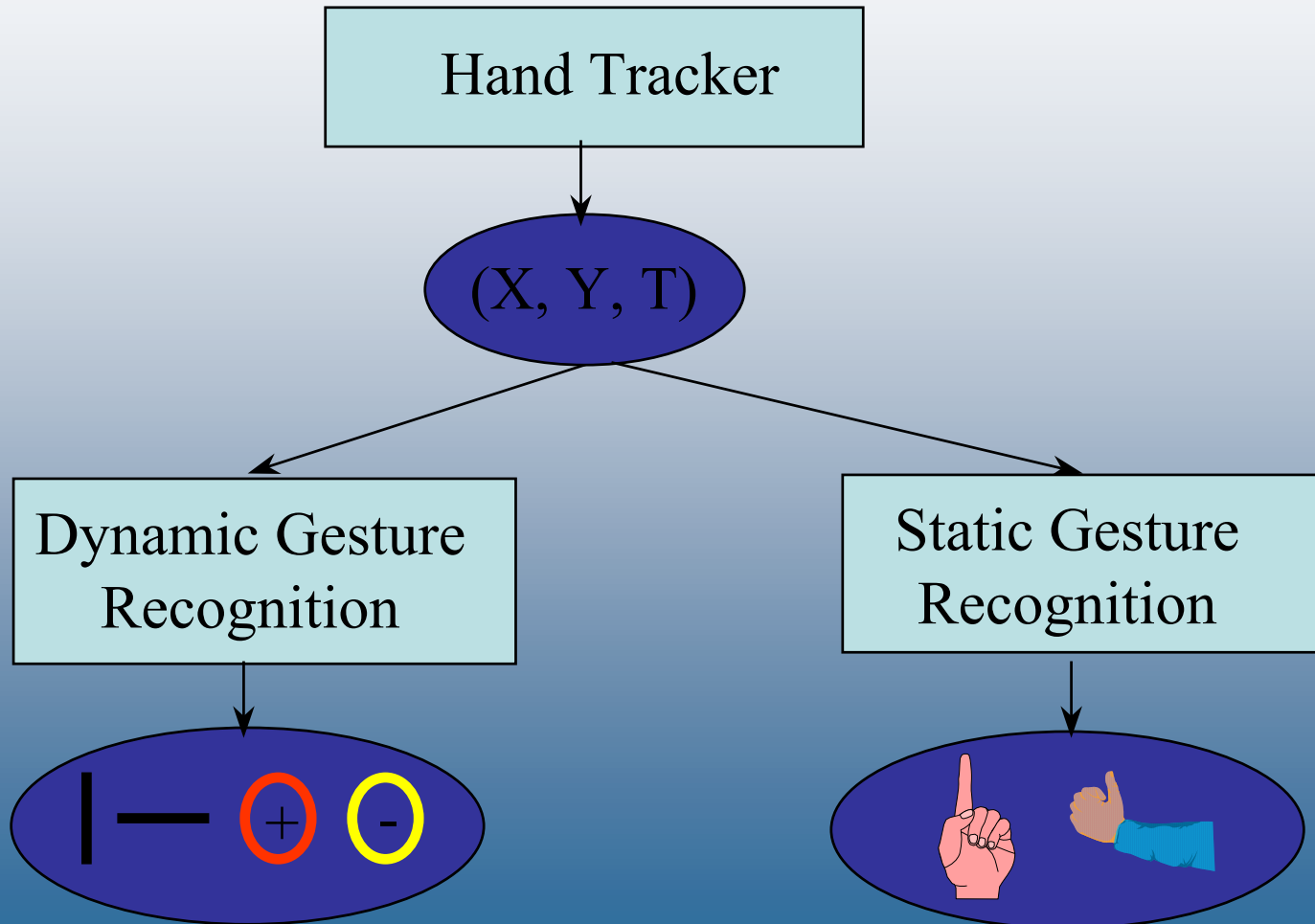
- Non-linear gestures
 - Dynamics of motion — time varying
 - Additional information content
 - More natural human motions
 - More complex model required



Non-Linear Gesture Models

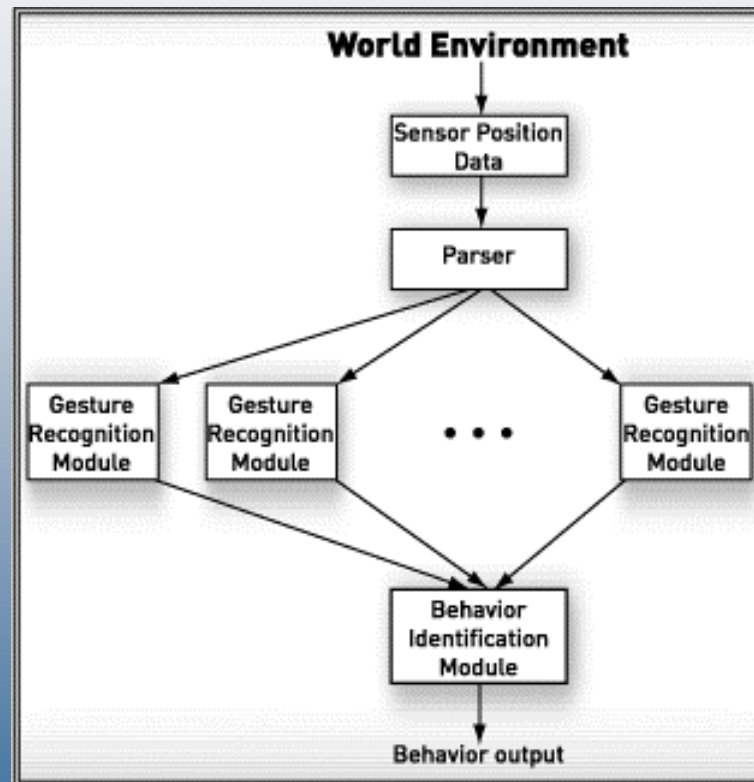
- Five previous models
- Three new models
 - Additional terms
 - Designed to handle speed-up/slow-down
- Experimental results
 - Original linear models insufficient
 - Velocity B model chosen
 - Recognition percentage unchanged

GRS Schematic



Behavior Recognition System

- Data input
- Parser
- GRM
- Behavior Identification
- Output





Sensor Data and Parser

- Multiple x,y,z coordinates from any source
- Coordinates from each body location
 - tagged or untagged

Issues:

- “Crossing the streams”
- Occlusions
- Multiple people



Gesture Recognition Module

- Pick fixed body point: Torso, head, or even hand
- All other gestures are in relation to “fixed” point
- Can also identify gestures between fixed body points for group dynamics



Behavior Identification

- Tested on: Jumping, walking, juggling, squats, running, and skipping
 - Different gaits
- 95%+ recognition rate (comparable to gesture recognition rate)



Future Directions

- Expand gesture lexicon
- Alternate behavior models
- Variations from typical behaviors
- Incorporate static activities
- Group behaviors



Patent Allowed!

- “Behavior Recognition System”
- To be issued: July 11th, 2005
- Other gesture patent: “Gesture Controlled Interface for Self-Service Machines and Other Applications,” Patent No. 6,681,031, issued January 20, 2004 .



Discussion

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Extra Slides Follow



Software Development Kit

- The GRS SDK consists of :
 - GRS API (Application Programming Interface)
 - Tools for Training, Evaluating
 - Reference Manuals, Tutorials, Code Examples



Software Development Kit

- The GRS SDK :
 - Allows any application to utilize gesture recognition
 - Straightforward training of new gestures
 - Diagnostics to check gesture compatibility and recognition rates (being implemented)



Software Development Kit

- The GRS API, in particular:
 - Allows easy integration into any C/C++ application on a Window/UNIX environment
 - Provides powerful and dynamic control over all aspects of the GRS
 - Encapsulates complexity of gesture recognition



Commercial Systems

- UseYourHead
- Northrop Grumman Map Control
- GestureStorm
- Navigaze
- PowerPoint Control