INTEGRATING PERCEPTION, COGNITION, AND ACTION FOR DIGITAL HUMAN MODELING

HCII 2007
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Project Rationale

- DHM goal: Simulate the totality of factors in human performance for research, design, and evaluation
- DHM should:
  - Perform a broad range of tasks
  - Match human physical performance
  - Match human mental performance

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Broad Capability

- "All-singing, all-dancing digital human model" – Porter
- The ideal DHM can be applied to any task
  - Learn only one tool
  - Write only one model
  - Work in only one environment
- Requires very strong predictive capabilities for both cognition and biomechanics
  - Got a long way to go…

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Physical: Biomechanics

- Commercial DHM require significant designer effort
- Current DHM efforts improving prediction of novel postures and motions
- Improved posture and motion prediction still leaves a significant burden on the ergonomist

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Mental: Cognition

- Cognitive science and AI models
  - 30 years of development
  - Multiple approaches
- Goal: modeling the whole cognitive system
- Currently focused on HCI and/or purely mental tasks

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Integrated Efforts

- MIDAS – NASA cognitive model + JACK
- HUMOSIM + QN-MHP
- ACT-R/DHM

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ACT-R/DHM

- Physical: 2 models
  - Eva, Simple IK model available as part of virtual environment software
  - Santos, University of Iowa's optimization-based digital human model (Yang, Abdel-Malik, Kim, et al, 2007)
- Cognitive: 1 model
  - ACT-R, hybrid model of perception, cognition and action (see "How Can the Human Mind Occur in the Physical Universe?" - Anderson, 2007)

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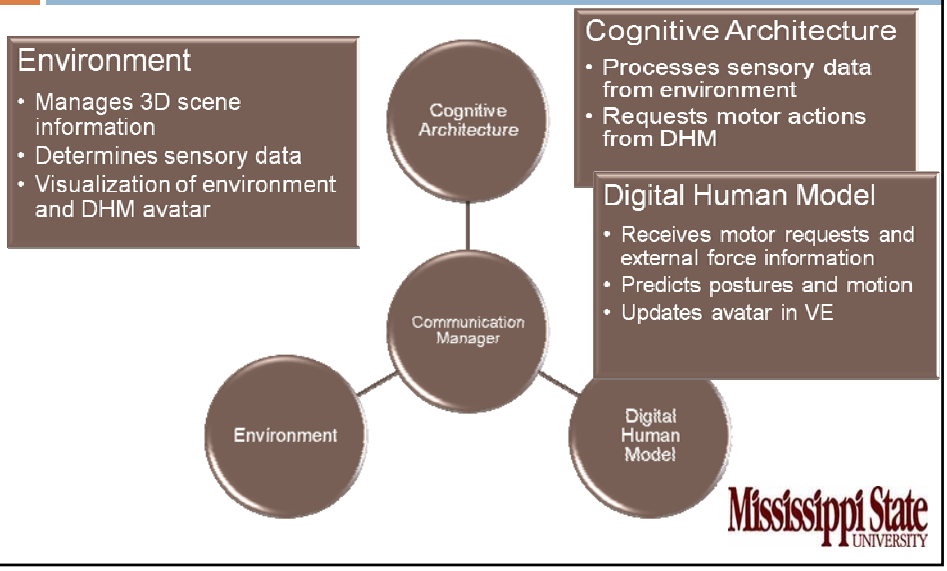
Integration Architecture



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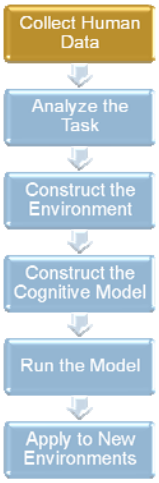
Using the Model



- Use Drink Machine
  - 12 Male Participants
  - Eye tracking and motion capture
  - Given 10 coins, told to purchase a drink of their choice

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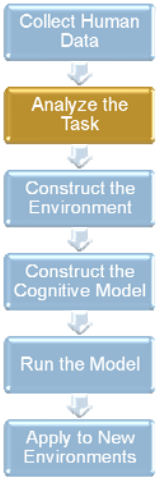
Using the Model



- Task Analysis
  - Analyze 9 Participants
    - 3 dropped due to data loss
  - Identified 5 sub-tasks
    - Learn the machine layout (Pelz, 2004)
    - Deposit Coins
    - Select Preference
    - Push Button
    - Retrieve Drink

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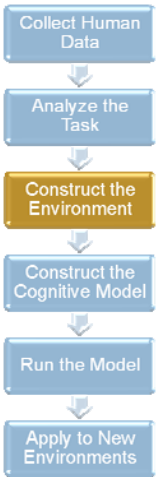
Using the Model



- Environment
  - Consists only of the vending machine and the DHM avatar

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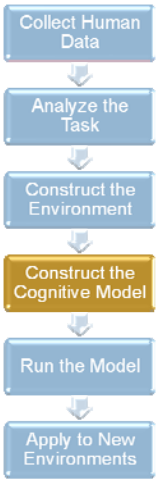
Using the Model



- Cognitive Model
  - Build rule-based models for each sub-task
  - Utilizes vision, spatial, memory, and action modules
  - Integrate sub-task models for appropriate multi-tasking

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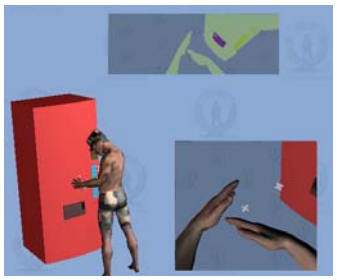
Using the Model

- Collect Human Data
- Analyze the Task
- Construct the Environment
- Construct the Cognitive Model
- **Run the Model**
- Apply to New Environments

- Run the Model
  - Compare model to real world data
    - *Not there yet*



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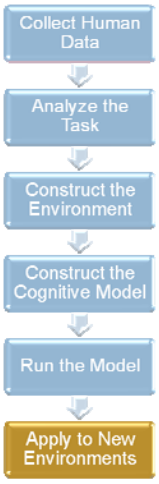
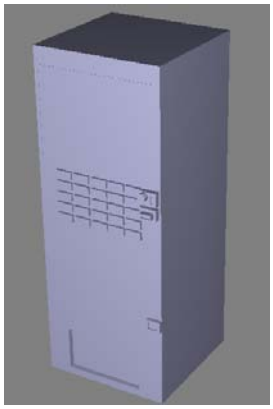
Using the Model



- Apply to New Environments
  - Create novel designs



Labels are the buttons
Model must be slightly modified

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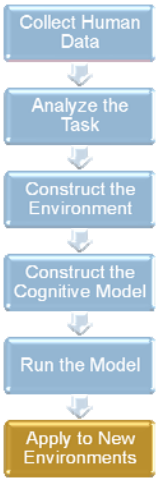
Using the Model



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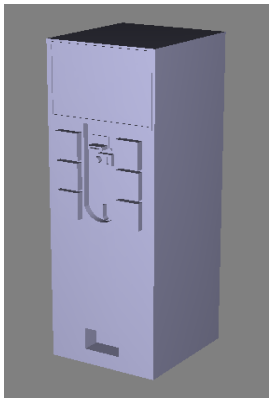

Labels are buttons
Model needs no modification

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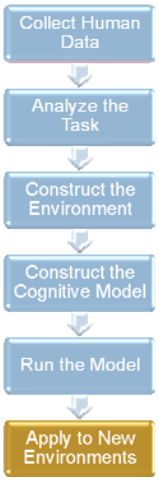
Using the Model



- Apply to New Environments
  - Create novel designs

Items are labeled with codes that must be entered into the keypad.
Model must be modified to store the desired object's code and to press the appropriate keypad buttons.

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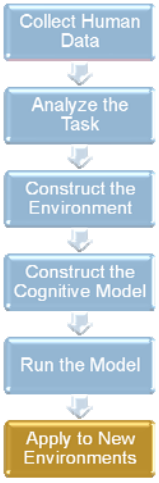
Using the Model



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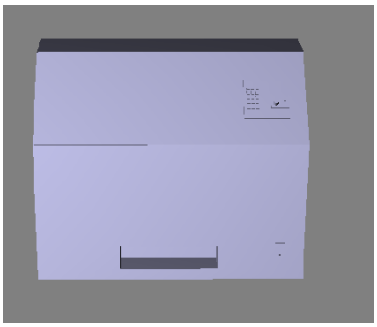

Items are labeled with codes that must be entered into the keypad.
Vending machine is low and horizontal but no changes need to be made to the model.

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Summary

- True DHM requires integration of cognitive and biomechanics
- Our integration architecture supports multiple DHM and (theoretically) multiple cognitive architectures
- ACT-R/DHM currently being applied to "simple" tasks to test integration

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Future Work

- Need time required for motions to predict total task times
- Need rigorous validation against human data
- Generate more complex task performance
- Which requires additional motor capabilities
- Apply cognitive modeling to existing COTS environments
- And more…

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Q&A

- Thank you for your attention!

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ACT-R Capabilities

- Core Production System
  - If-then rules define procedural memory
  - Manages transfer of information amongst module buffers
  - Serial bottleneck – 1 rule every 50 ms
- Perceptual System
  - Vision
  - Audition
- Action System
  - Speech
  - Keyboard and Mouse Use
- Declarative Memory
  - Associative Model of Memory
- Generates comparable data
  - Predicts reaction times
  - Predicts BOLD response for fMRI (New)
  - Predicts learning rates and human error

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ACT-R Pros/Cons

- Popular modeling architecture with large community of developers
- Open-source, free, and real-time software
- Annual workshops and meeting
- Programming Language – difficult to learn
- Difficult to model without human factors/psychology training
- Vulnerable to claims of parameter fitting
- Not all architectural decisions are theory-based

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RoadMap

Year	Vision	Audition	Spatial	KP	Tactile	Motor	Integration	Validation
1	Extract and process visual features	Extract and process auditory features				Request simple stored animation	Network communication between ACT-R and virtual environment	
2	Extend ACT-R and improve match to human performance		Implement system to encode, store, and manipulate spatial information	Implement knowledge of body position and motion		Shift end-effectors to drive Santos posture prediction	Plug-and-play integration layer – support multiple DHM, cognitive, and environment frameworks	Simple Tasks Vending machines, navigation, model building, etc.
3	VOR, OKR	Localization, tracking, environment simulation		Update spatial	Extract and process contact between avatar and environment	Efferent cross-talk to KP	User interface work; document and test intergration layer	Real-world tasks Driving, room clearing, manufacturing

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