Model & Simulation Environment for

UCADS

(User-Centric Automation Devices/Systems)

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http://sisarl.org

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About Us and Our Work

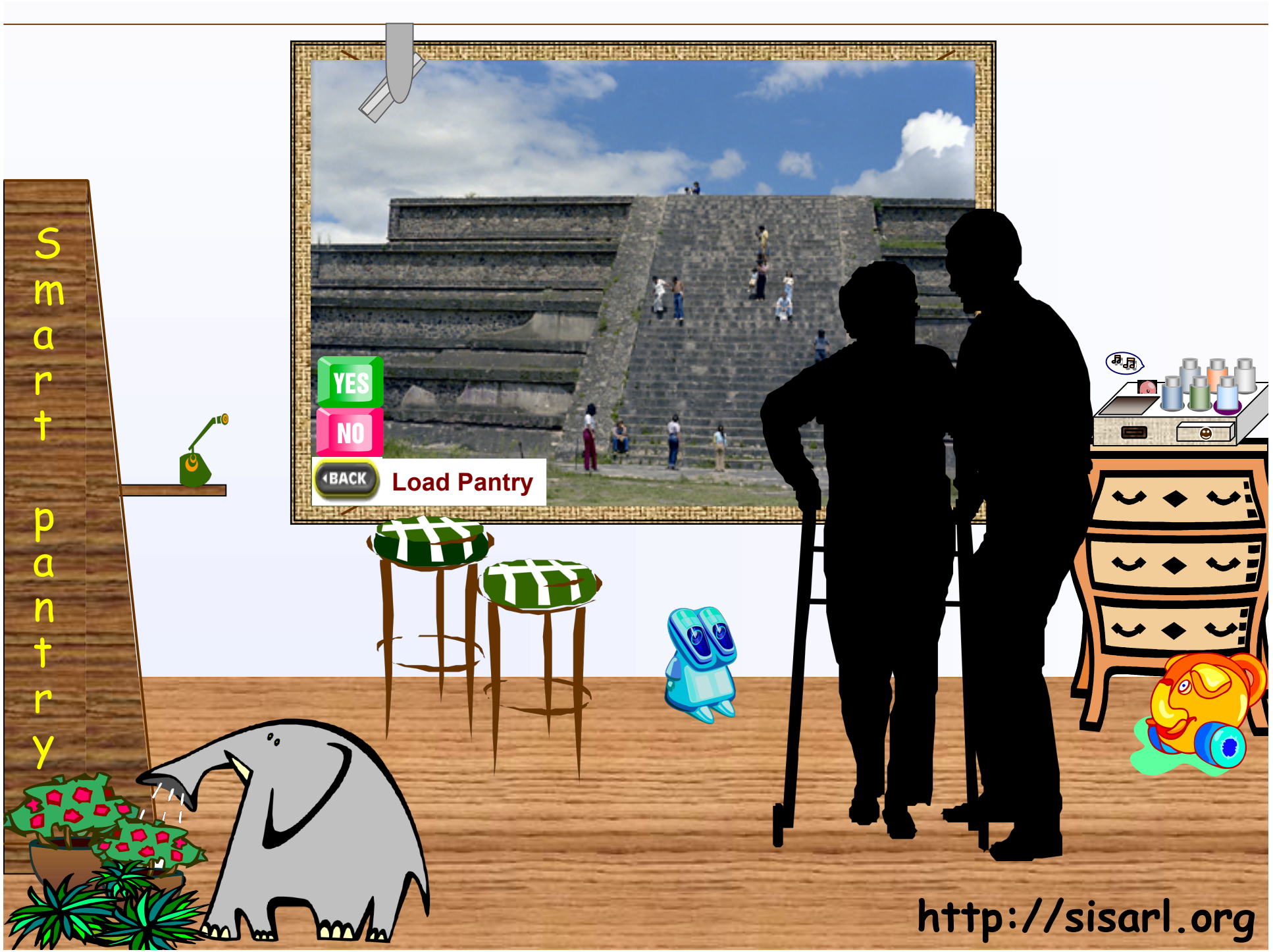
- People
  - Faculty members and students from NTU, NTHU, NCTU and Academia Sinica, including ***C. S. Shih and T. K. Kuo***
  - Nurses, pharmacists and IT staff from NTUH and mechanical engineers from ITRI
- Projects
  - SISARL (2007-2009) Academic Sinica thematic project
  - iNuC: Intelligent nursing cart project supported by NTUH
  - MeMDAS: Medication management, dispensing and administration systems project supported by MOEA, NTUH and Academia Sinica
- Research emphases: user-centric approach
  - Component-based design, production, & quality assurance
  - Methods and tools for trading off usability, configurability and other figures of merits

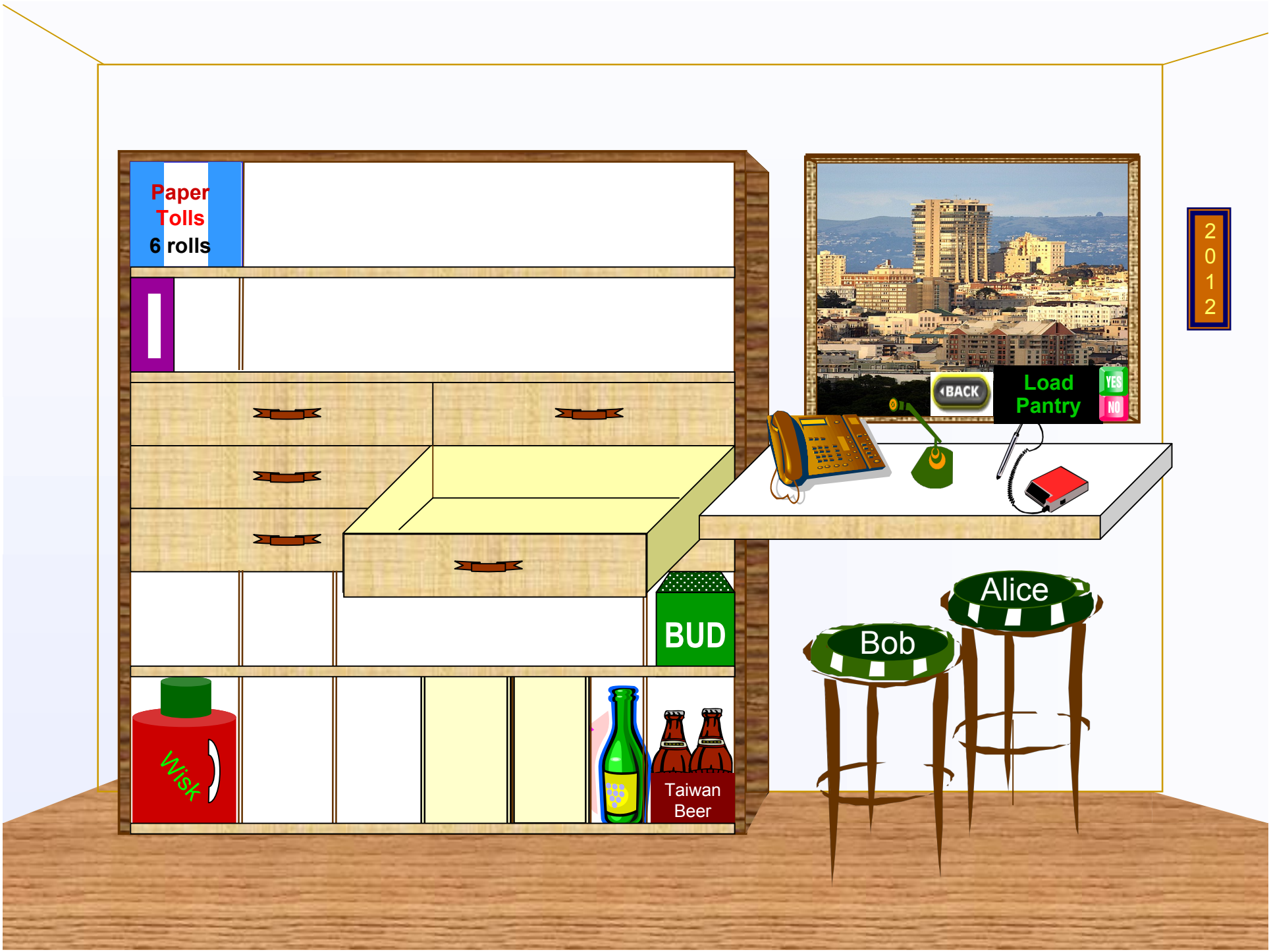
OUTLINE

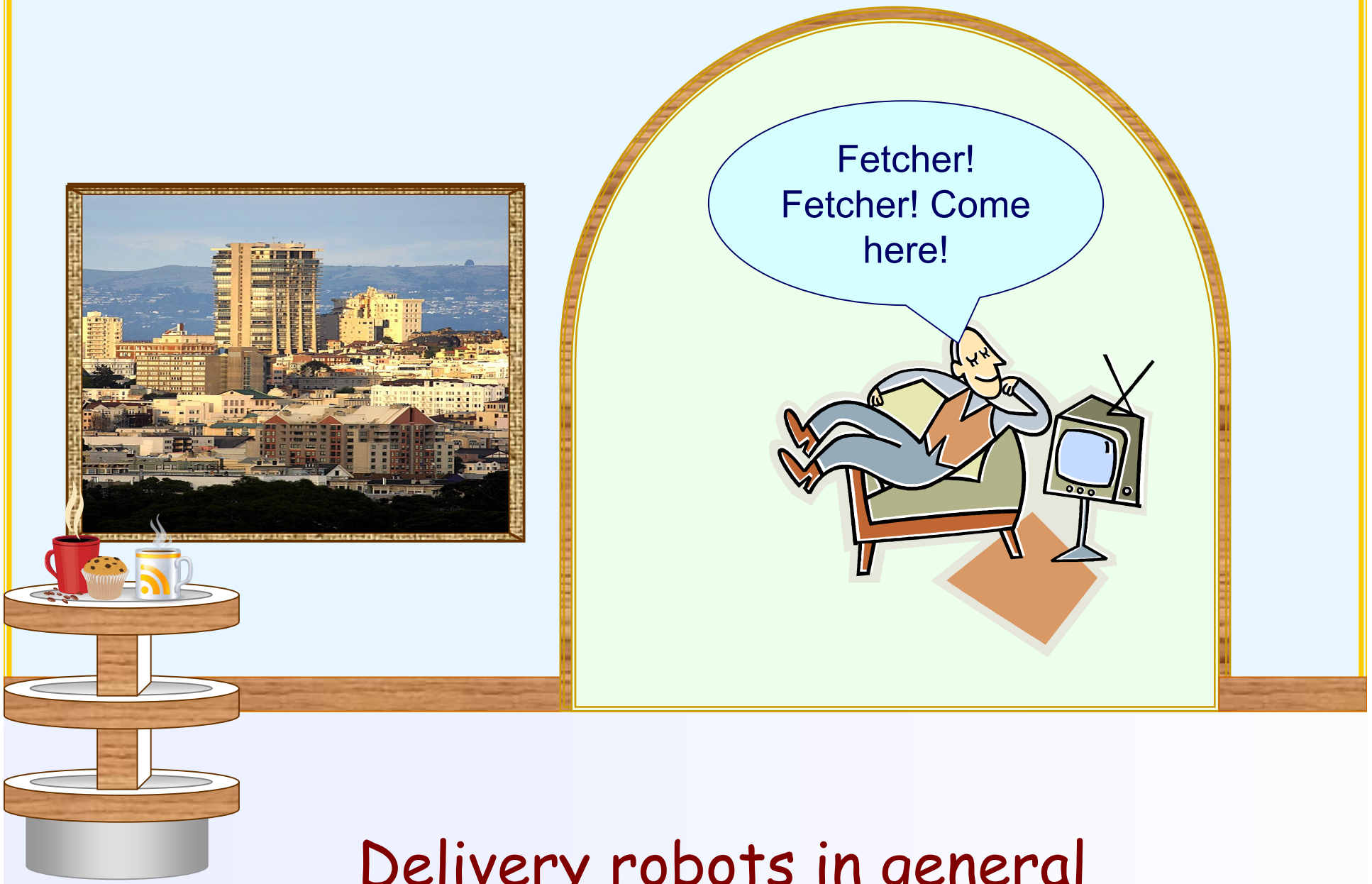
- Motivation and rationales
  - Examples of UCADS
  - Requirements and characteristics
- UCADS model: Workflow and GOMS
- USE: UCADS simulation environment
- Case studies
- Missing pieces/wish list

Examples of UCADS

- ***Home and personal automation devices***: Smart storage panty, medication dispensers, fetcher, object locator, & housekeeping aids
- ***Automation equipment for care-providing institutions***: Medication dispensing and administration tools, delivery roots, tools for moving and bathing patients, etc.
- ***Service and social robots***: Medication delivery robots, exercise companions, etc.
- ***iGaD:*** Intelligent guards against disaster


Smart pantry
YES
NO
BACK
Load Pantry
http://sisarl.org


Paper
Tolls
6 rolls
BACK
Load
Pantry
YES
NO
2012
BUD
Wisk
Taiwan
Beer
Alice
Bob



Delivery robots in general

MeMDAS Components

Basic Mobile Units (BaMU)
(on a basic nursing cart)

Intelligent
Nursing Cart
(iNuC)

Drawers &
interlocks

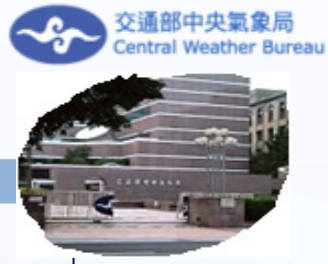
iNuC in use

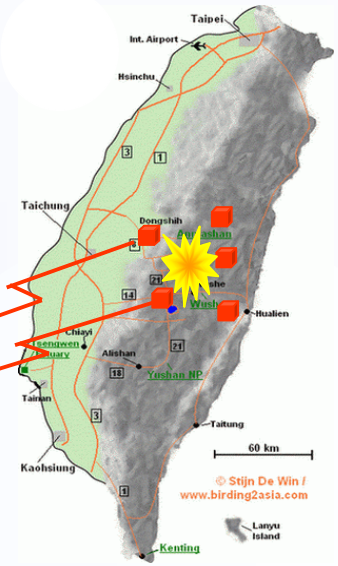
Smart
medication
cabinets

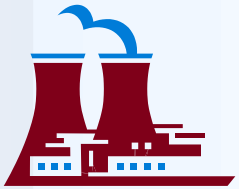
MUMS: Multi-user smart medication cabinets and server

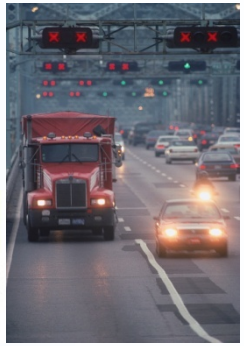
A Future Scenerio

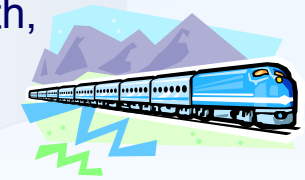
Alert xmlns: …
Sender: Central Weather Bureau
Status: Actual
MsgType: Alert
Scope: Public
Info
  Category: Geo
  Event: Earthquake
  Urgency: Immediate
  Severity: Strong
  Certainty: Observed
Description: A strong earthquake measuring 6.9 occurred in …
Parameters: Magnitude, depth,
Areas: Polygons specifying affected areas
Resources: … …

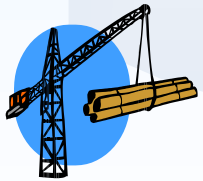


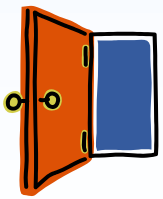












Common Requirements

- ***Easy and safe to use:***
  - Serve users with little or no training
  - Can tolerate, and recover from, misuses and abuses by users
  - Can prevent harmful conditions & user actions
- ***Flexible*:**
  - Are *configurable* to support different processes and rely on different infrastructures
  - Are easily *customizable* to suit different users
  - Can *adapt* to changes in user's needs

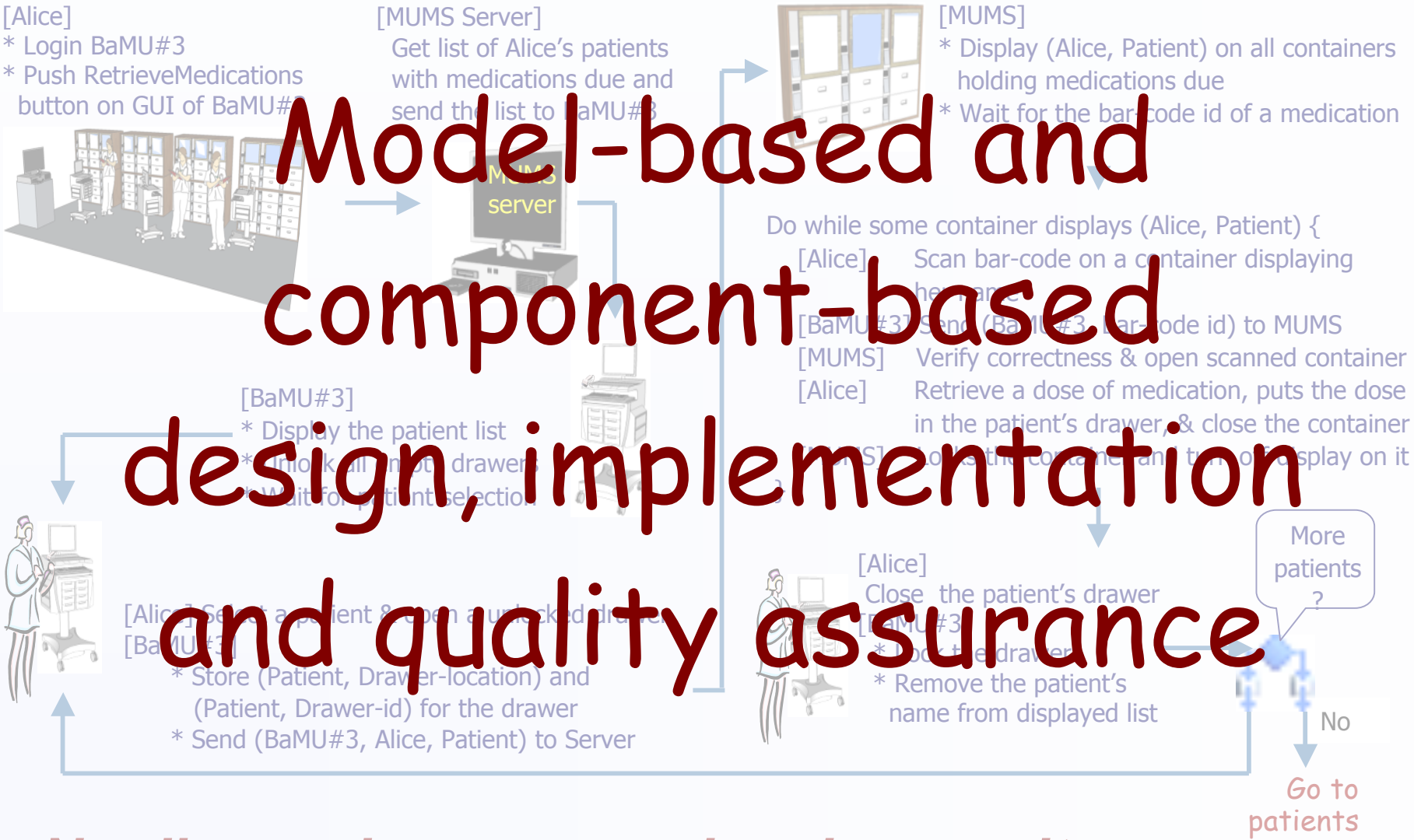
Typical Characteristics

- Do not (should not) have technologically challenging functional features
- Are not small like handheld devices
- Should have good interactive response (e.g., 50 – 100 milliseconds)
- Have no hard real-time requirements
- ***May rely on users to do critical work***

No erroneous
(compartment, bar-code) – mappings !

Multi-User Medication Station (MUMS)

User-System Interactions During Bar-code Controlled Medication Dispensing



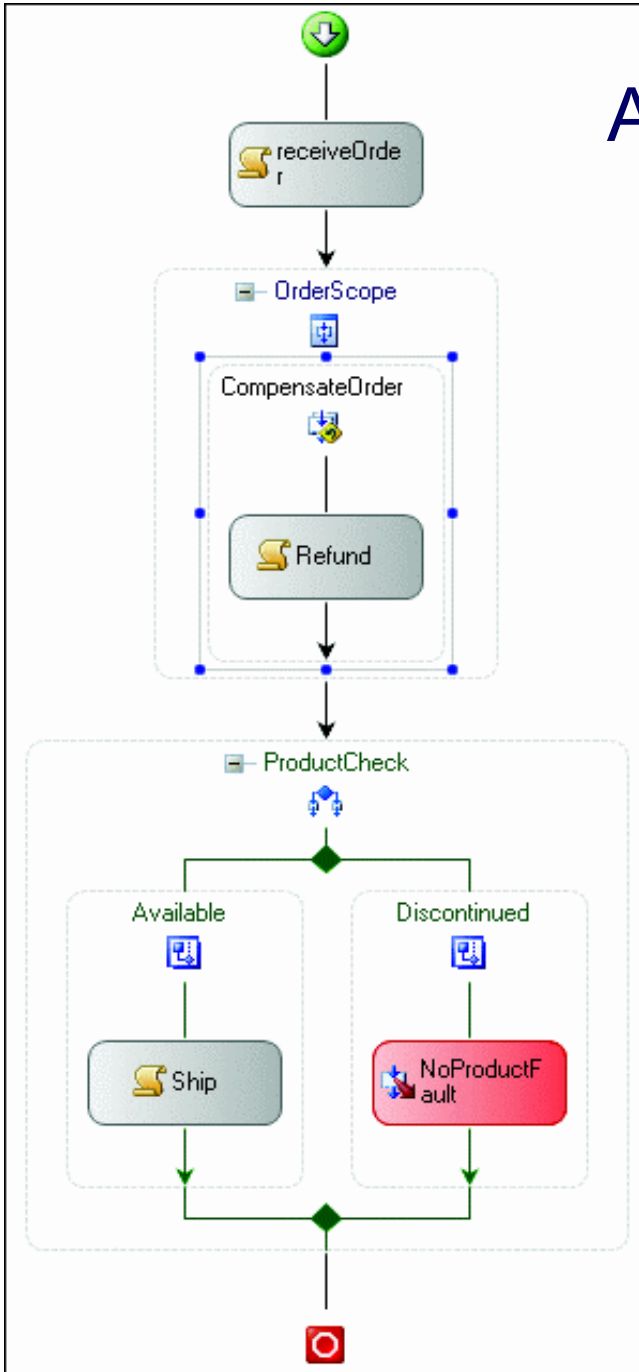
Model-based and component-based design, implementation and quality assurance

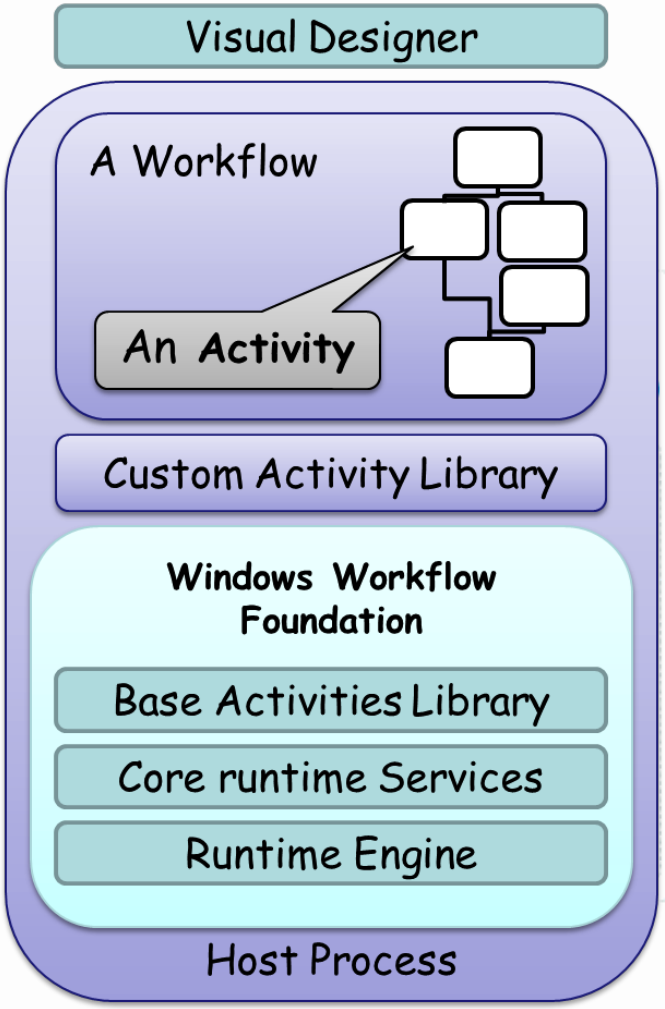
No dispensing error and no long waits

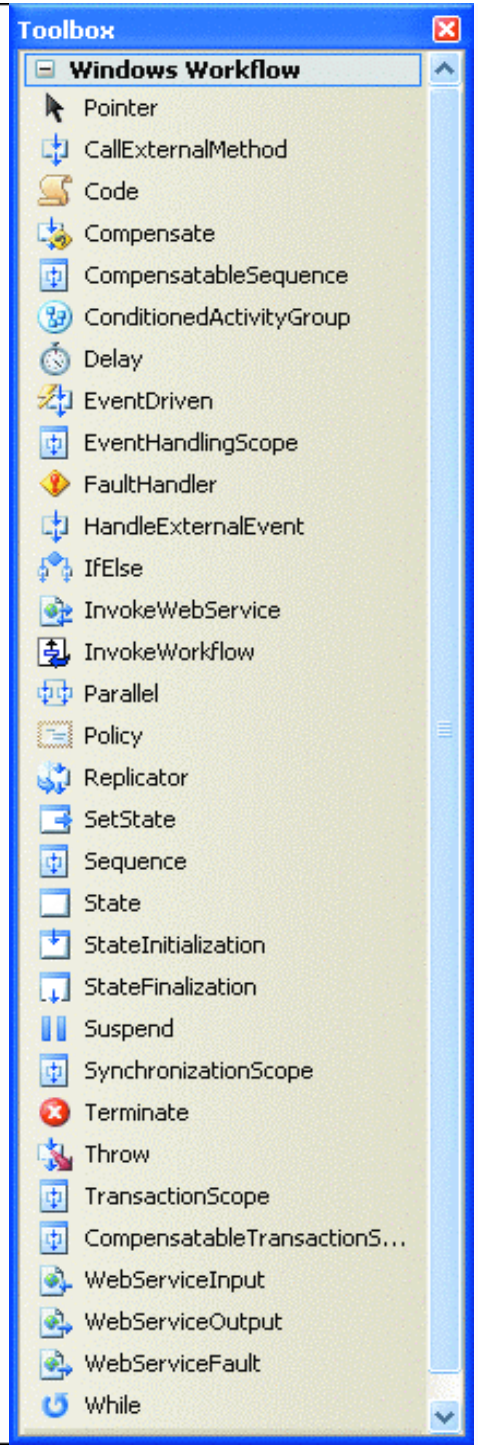
About UCADS Model

- Leverages two widely used technologies:
  - Workflows: for specification of device behavior, use actions, and user-device interactions,
  - CPM-GOMS (Goals, Operators, Methods, and Selection rules): for modeling human user behavior and abilities
- Is easy to understand and executable
- Becomes implementation for devices built from workflow components

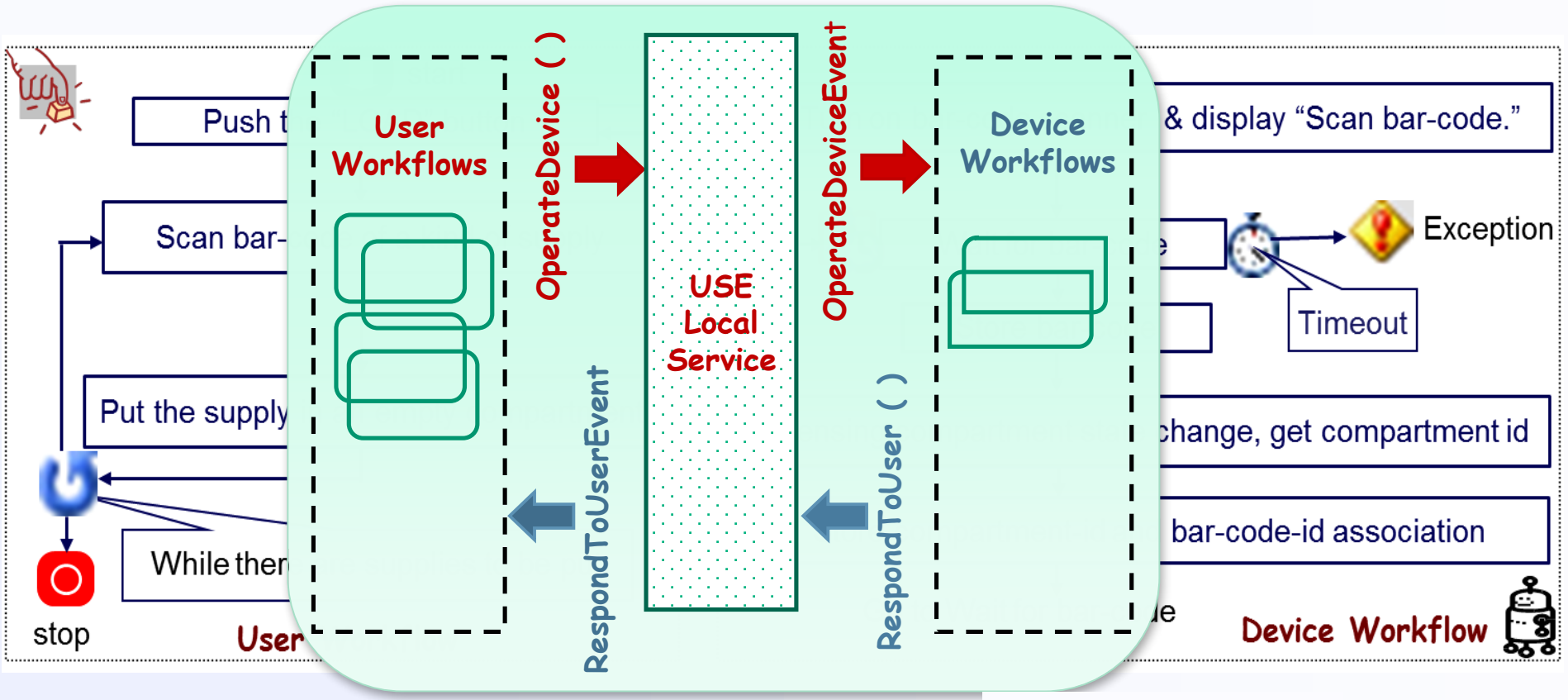
Activities and Workflows and Microsoft .NET Workflow Foundation







Workflow Definition of Load Pantry Process



On GOMS Model

- Proposed by Card, Moran and Newell in 1983 for description of human-computer interactions
- Comes in several variants, including
  - Card, Moran and Newell model (CMN)
  - Keystroke-Level model (KLM): simplified CMN
  - Natural GOMS Language (NGOMSL)
  - Cognitive Perceptual Motor model (CPM), used with critical path method
  - Queuing network model (QN-MHP/GOM)
- Uses MHP (Model Human Processor)

A CPM-GOMS Model

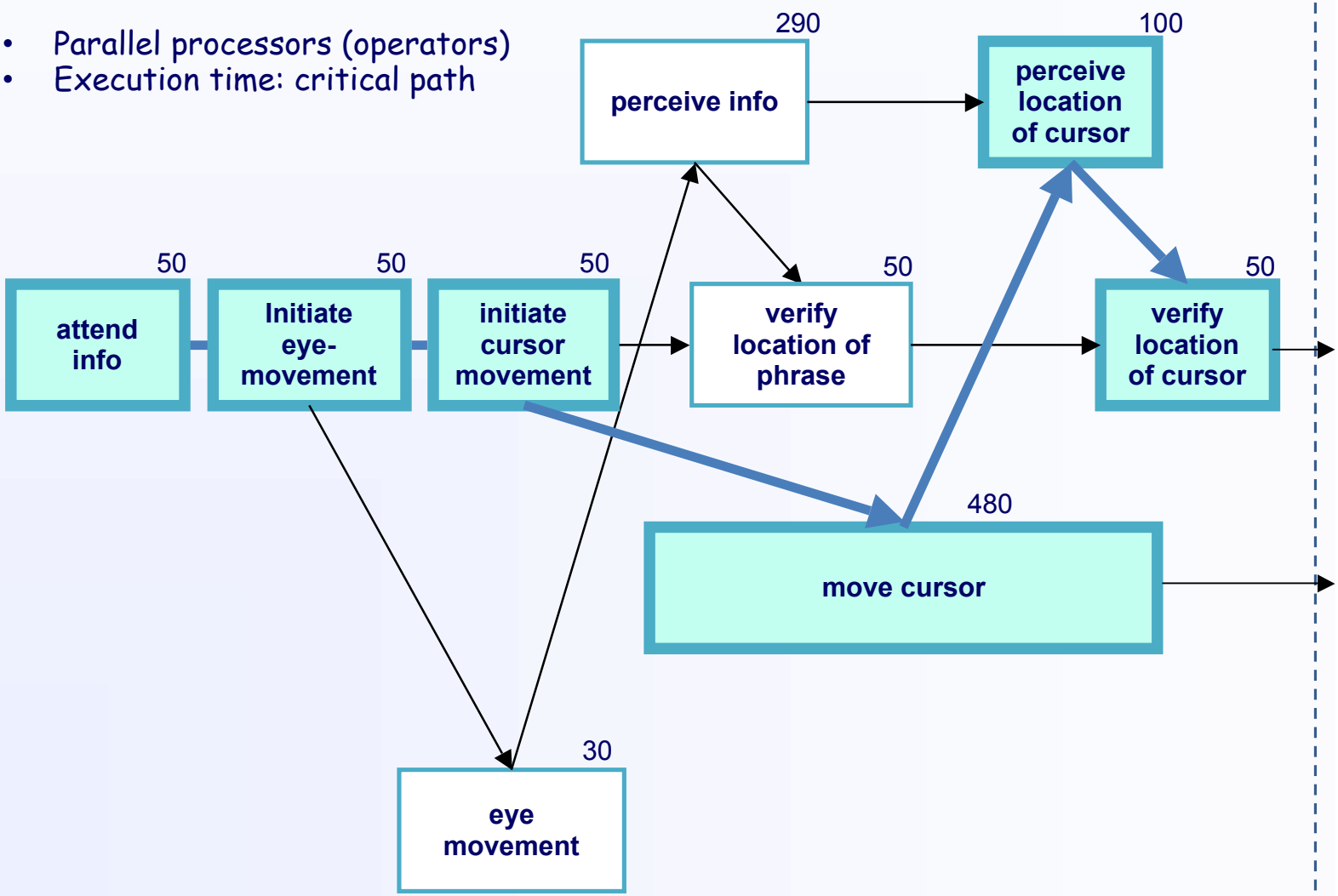
Visual Perception

Cognition

Right Hand Motor

Eye Motor

- Parallel processors (operators)
- Execution time: critical path

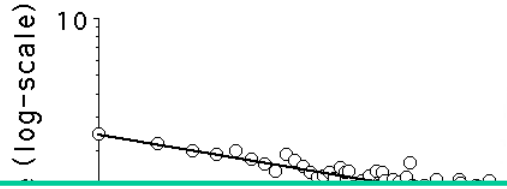


Examples of Behavior Laws

- Response time of perception depends on intensity of stimulus
- Stored information decays from working memory
- Power Law of Practice: Cognition response time decreases exponentially with practice
- Fitts Law: Time taken by hand to move to target is proportional to $log_2(2 * distance/size)$
- Hick-Hyman Law: Choice reaction time is given by $a + b\ log_2\ (number\ of\ choices)$

Estimate Execution Time in CPM-GOMS

Parameter	Mean	Range
Eye movement time	230 ms	70-700 ms
Decay half-life of visual image storage	200 ms	90-1000 ms
Visual Capacity	17 letters	7-17 letters
Decay half-life of auditory s		
Auditory Capacity		
Perceptual processor cycle		
Cognitive processor cycle ti		
Motor processor cycle time		
Effective working memory c		
Pure working memory capa		
Decay half-life of working m		
Decay half-life of 1 chunk w		
Decay half-life of 3 chunks		

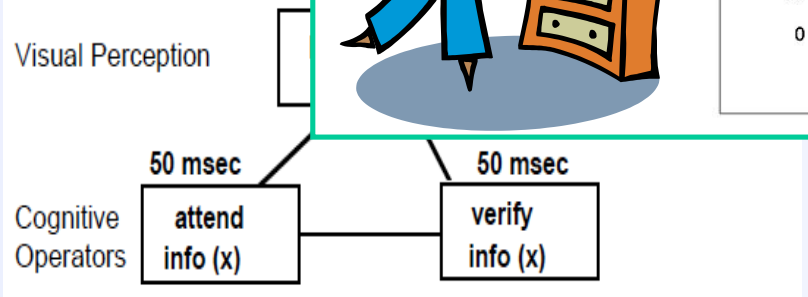


Power Law of Practice.

$$T_n = T_1 n^{-\alpha},$$

re α = .4 [.2~.6] .

- Extend operations by following GOMS-MHP principles and rules
- Use existing statistical data
- Measure by volunteer users



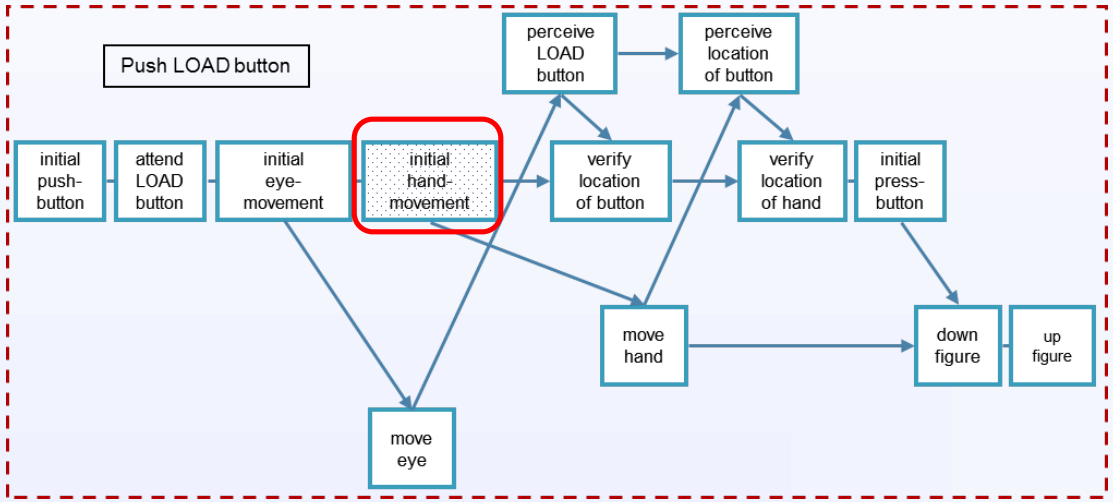
The time Tpos to move the hand to a target size S which lies a distance D away is given by:

Tpos = I_M log2 (D/ S + .5), where I_M = 100[70~ 120] ms1

Transform CPM-GOMS PERT Chart to Workflow

Together XPDL and BPMN Workflow Editor (TWE)

PERT chart view (BPMN notation)



Attribute	Description	Examples
Type	Common types in CPM-GOMS are VP (Visual Perception), C (Cognitive), RH (Right Hand), E (Eye Movement)…etc.	{T: RH;}, {T: VP;}
Duration	Estimated execution time of the operator.	{D: 200ms;} {D: Fitt("LOAD");}
Action	Parameters of OperateDevice( ) method of the USE local service.	{A: (Pantry, Push, LOAD);}
Response	Id and type of device waited by the user.	{S: (Pantry, LCD);}

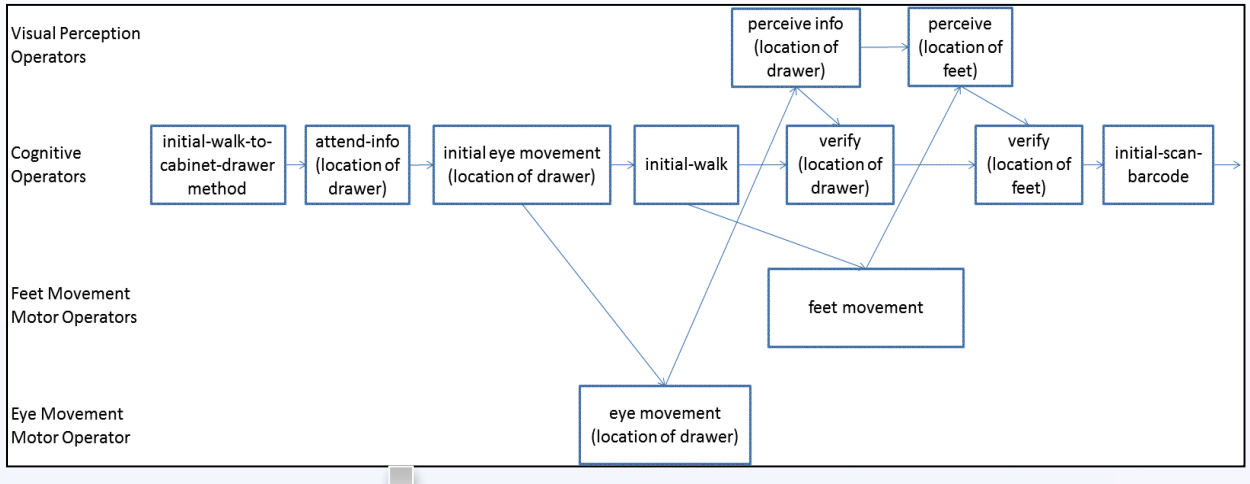
XPDL code view

```
<xpdl:Activity Id="initial-hand-movement">
  <xpdl:Description >
    <!-- Attributes of the operator. -->
  </xpdl:Description >
  <xpdl:Implementation ></xpdl:Implementation >
  <xpdl:Performers ></xpdl:Performers >
  <xpdl:TransitionRestrictions >
    <xpdl:TransitionRestriction >
      <xpdl:Split Type="Parallel">
        <xpdl:TransitionRefs >
          <xpdl:TransitionRef Id="transition6" />
          <xpdl:TransitionRef Id="transition7" />
        </xpdl:TransitionRefs >
      </xpdl:Split >
    </xpdl:TransitionRestriction >
  </xpdl:TransitionRestrictions >
  <xpdl:NodeGraphicsInfos ></xpdl:NodeGraphicsInfos >
</xpdl:Activity >
```

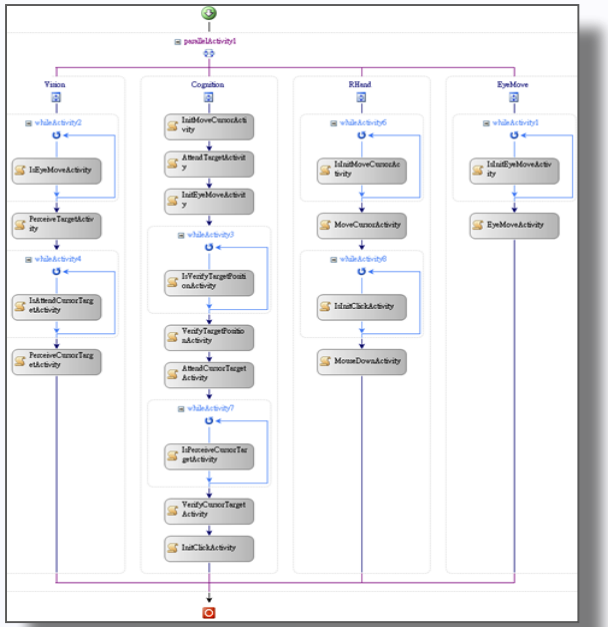
```
<xpdl:Transition From="initial-hand-movement"
Id="transition6" To="verify-location-of-button">
  <xpdl:ConnectorGraphicsInfos >
  </xpdl:ConnectorGraphicsInfos >
</xpdl:Transition >
```

WF ← Transformation Tool (XPDL Parser + Translator) → EMWF, WfMOpen

Walking to Cabinet in CPM-GOMS PERT chart



Workflow in WF



Pseudo code of Transformation Tool (Parser + Translator)

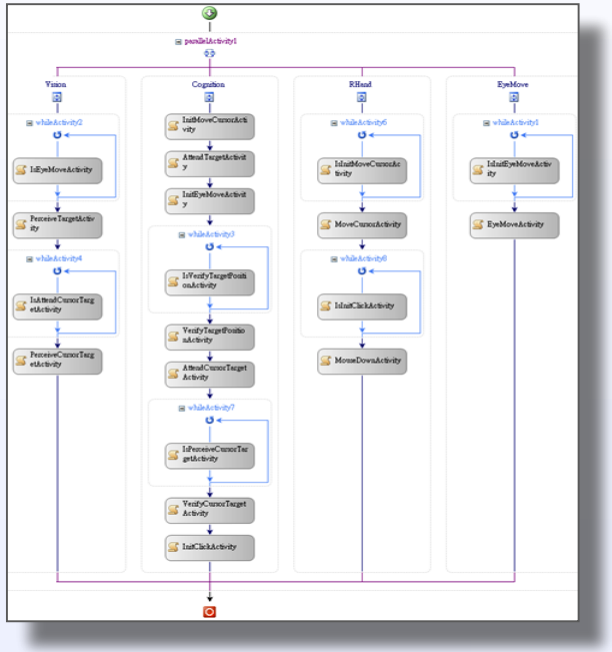
Input: XPDL file of CPM-GOMS PERT chart *G*
Output: A parallel workflow *W*

parse G and save operators and transitions in it.
create a parallel workflow *W;*
for each human processor *P* in *G*
    // add a sequential sub-workflow *S* as a branch of *W*
    for each operator *o* carried out by *P,* starting from the first operator of *P*
        if *o* has a predecessor that is carried out by another human processor *P* ';
            // add a wait-for-all-predecessors activity in *S*
            ADD-Wait-For-ALL-PREDECESSORS (predecessors of *o*, *S*);
        // add the activity for the operator *o*
        ADD-OPERATOR (*o, S*) in the sub-workflow *S*;
        APPLY-OPERATOR-ATTRIBUTES (*o*);

One-to-one mapping:
Isomorphic
- Check in/out degrees
- Check critical path of both graphs

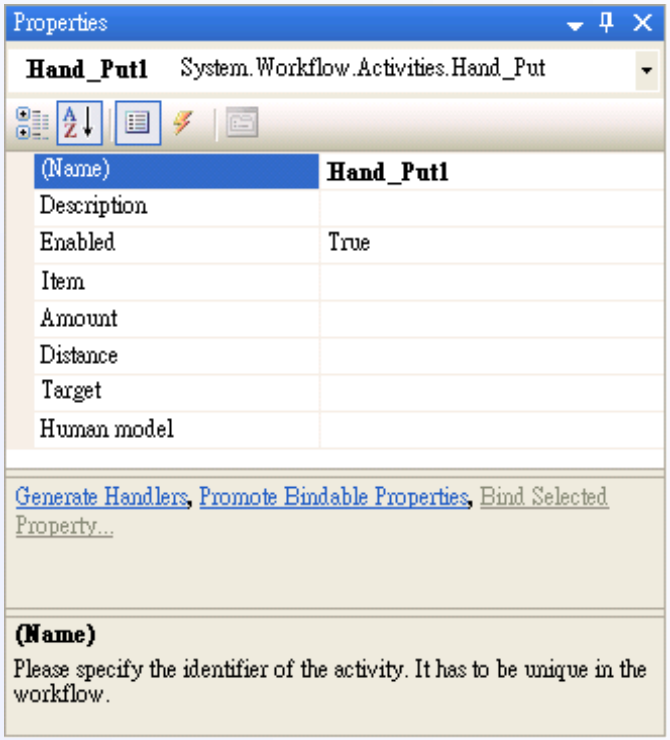
User Action Library

Hand_Put Workflow

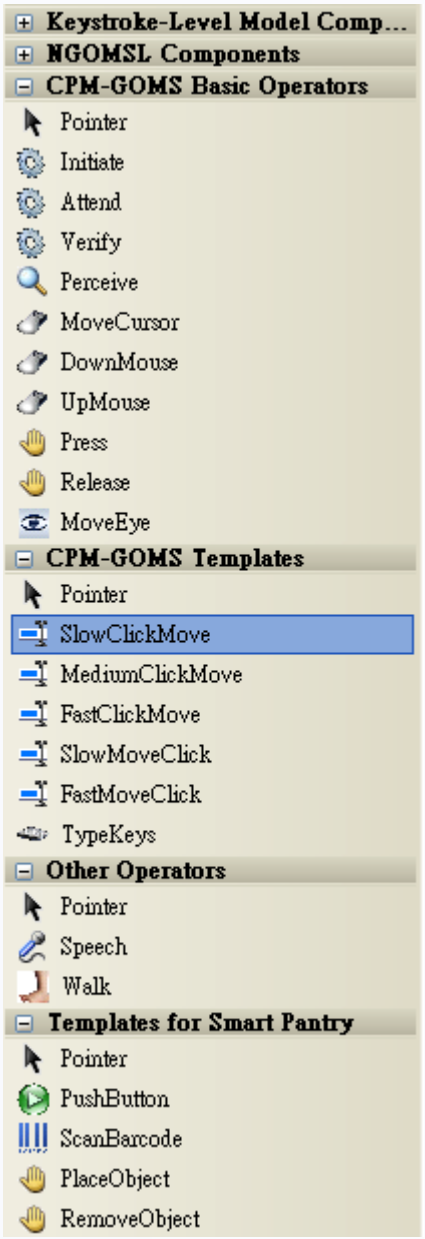


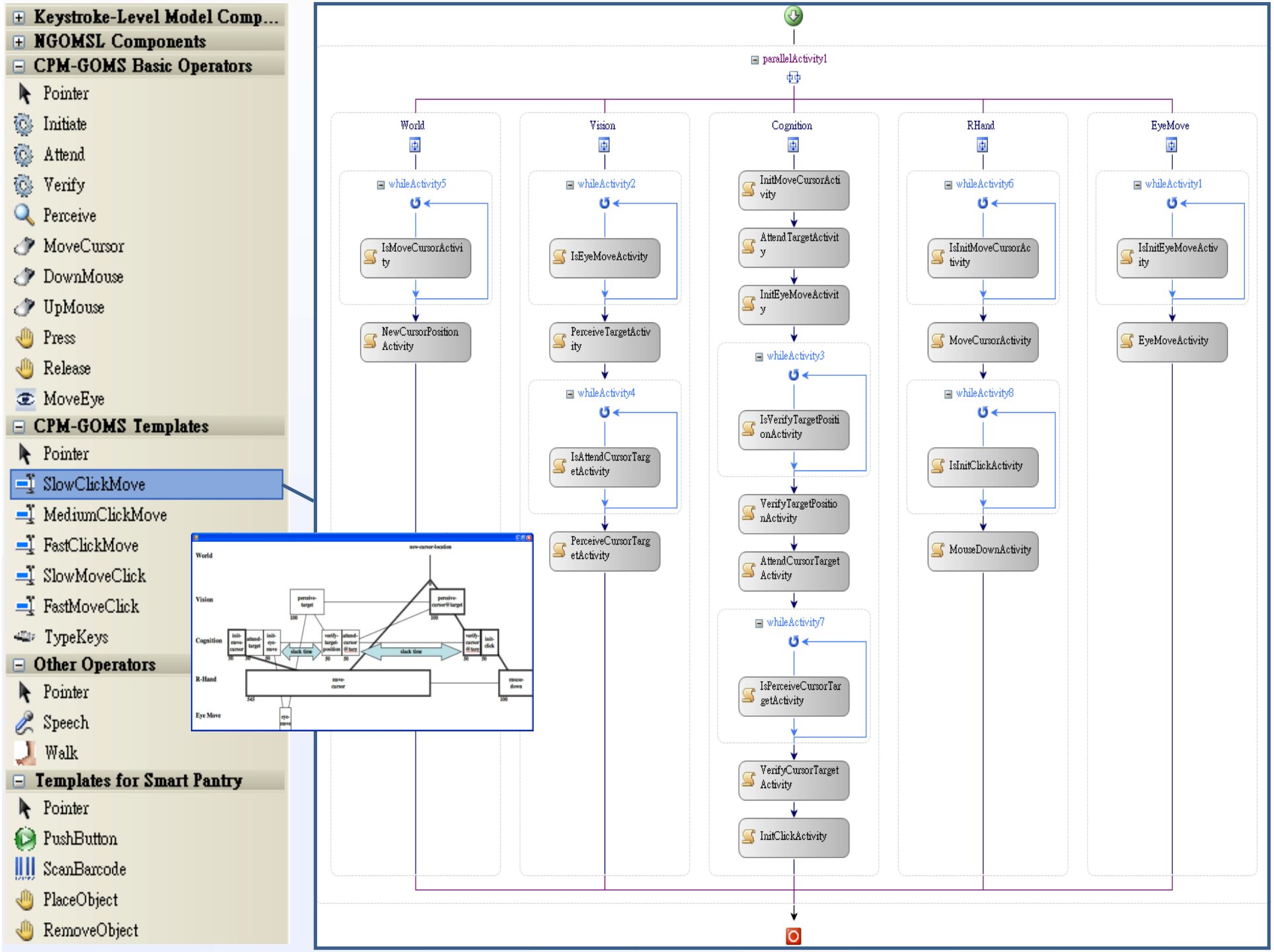
Hand_Put in Custom Activity

Properities of Hand_Put



Hand_Put in ToolBox




Keystroke-Level Model Comp...
NGOMSL Components
CPM-GOMS Basic Operators
Pointer
Initiate
Attend
Verify
Perceive
MoveCursor
DownMouse
UpMouse
Press
Release
MoveEye
CPM-GOMS Templates
Pointer
SlowClickMove
MediumClickMove
FastClickMove
SlowMoveClick
FastMoveClick
TypeKeys
Other Operators
Pointer
Speech
Walk
Templates for Smart Pantry
Pointer
PushButton
ScanBarcode
PlaceObject
RemoveObject
parallelActivity1
World
whileActivity5
IsMoveCursorActivity
NewCursorPositionActivity
Vision
whileActivity2
IsEyeMoveActivity
PerceiveTargetActivity
whileActivity4
IsAttendCursorTargetActivity
PerceiveCursorTargetActivity
Cognition
InitMoveCursorActivity
AttendTargetActivity
InitEyeMoveActivity
whileActivity3
IsVerifyTargetPositionActivity
VerifyTargetPositionActivity
AttendCursorTargetActivity
whileActivity7
IsPerceiveCursorTargetActivity
VerifyCursorTargetActivity
InitClickActivity
RHand
whileActivity6
IsInitMoveCursorActivity
MoveCursorActivity
whileActivity8
IsInitClickActivity
MouseDownActivity
EyeMove
whileActivity1
IsInitEyeMoveActivity
EyeMoveActivity
World
Vision
Cognition
R-Hand
Eye Move
new-cursor-location
perceive-target
perceive-cursor@target
init-move-cursor
attend-target
init-eye-move
verify-target-position
attend-cursor@target
verify-cursor@target
init-click
slack time
slack time
move-cursor
mouse-down
eye-move

USE: UCADS Simulation Environment

Simulation Set up Tools

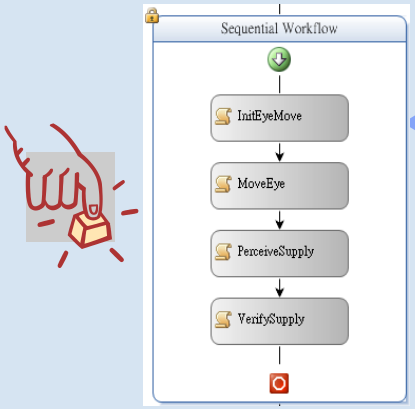
- GUI
- Environment Settings
- Run-Time Setting

Report Analysis Tools

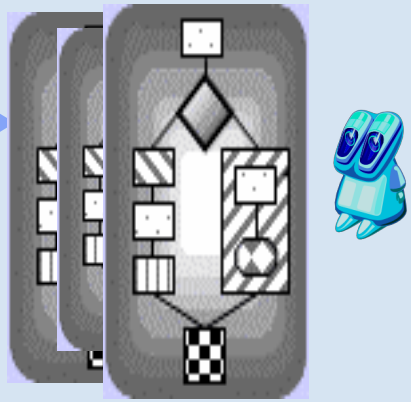
- Report Generators
- Data Handling

Run-time Environment

User Workflows



Device Workflows



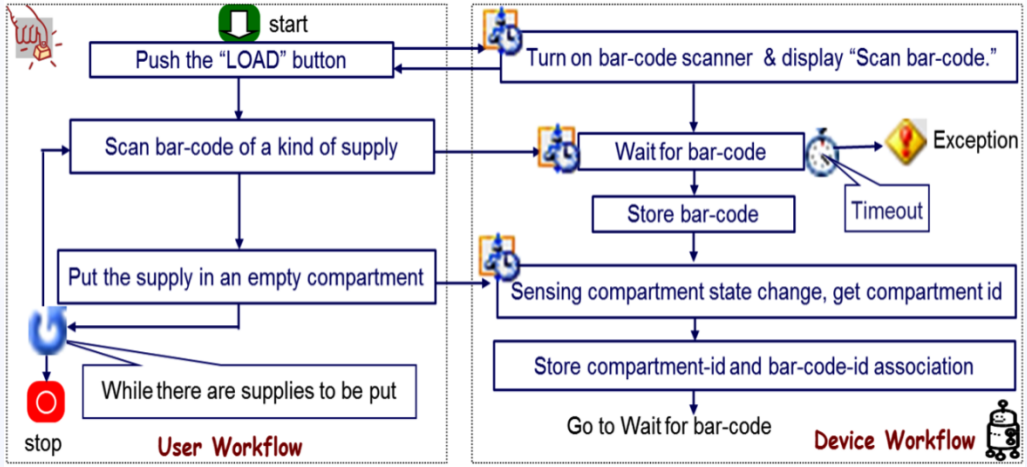
Scheduling Service	Comm Services
Recording Service	Model Generator
Workflow Engine	

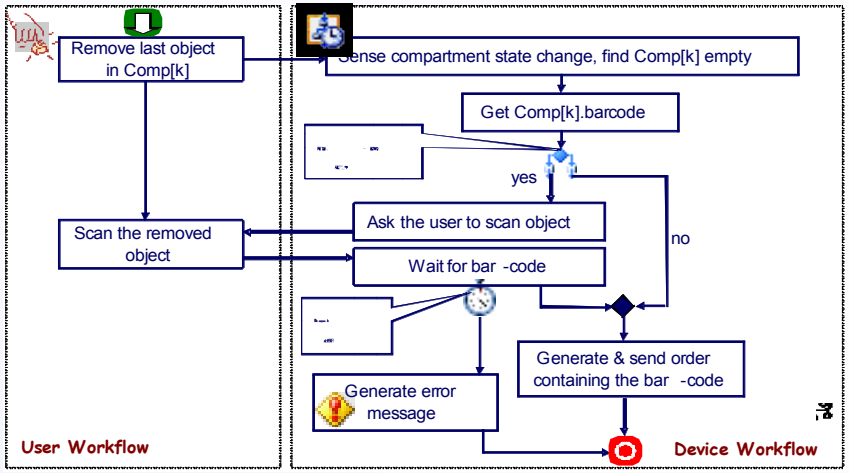
Report

Development Environment

- Device Workflow Library
- Resource Library
- User Action Library
- Human Model Library

Case Study 1: Debugging Smart Storage Pantry





Load_Pantry (Low Priority)

```
15:46:25.267 LoadPantryWorkflow Created
15:46:25.267 RemovePantryWorkflow Created
15:46:25.267 LoadPantryWorkflow Started
15:46:25.267 RemovePantryWorkflow Started
15:46:25.267 Executing LoadPantryWorkflow, Type=Load_Pantry
15:46:25.267 Executing RegisterUser, Type=CallExternalMethodActivity
15:46:25.267 Closed RegisterUser, Type=CallExternalMethodActivity
15:46:25.267 Executing User_LoadPantryWorkflow, Type=User_LoadPantry
15:46:43.267 SendUserEvent, Type=CallExternalMethodActivity
15:46:43.280 UserData from User_LoadPantry model :children
15:46:43.280 UserData from User_LoadPantry Item:Beer
15:46:43.280 UserData from User_LoadPantry Amount :6
15:46:43.280 UserData from User_LoadPantry Compartment:4
15:46:43.280 Executing User_RemovePantry, Type=User_RemovePantry
15:46:44.280 SendUserEvent, Type=CallExternalMethodActivity
15:46:44.280 UserData from User_RemovePantry model :older
15:46:44.280 UserData from User_RemovePantry Item:shampoo
15:46:44.280 UserData from User_RemovePantry Amount :1
15:46:44.280 UserData from User_RemovePantry Compartment:2
. . .
```

Remove_Pantry (High Priority)

User 1: Push "LOAD " Button .

Pantry: Turn on bar-code scanner and waits for the user to scan bar-code id of an object.

User 1: Scan bar-code of a six pack of mineral water.

Pantry: Say "You just scanned an object."

User 2: Remove the last bottle of shampoo in Compartment 4.

Pantry: Say "You just remove the last unit of an unknown object. Please scan its bar-code id so I can reorder it for you."

User 2: Scan bar-code id of shampoo.

Pantry: Say "Do you want me to re-order the object?"

User 2: Push "Yes" Button.

User 2: Walk away.

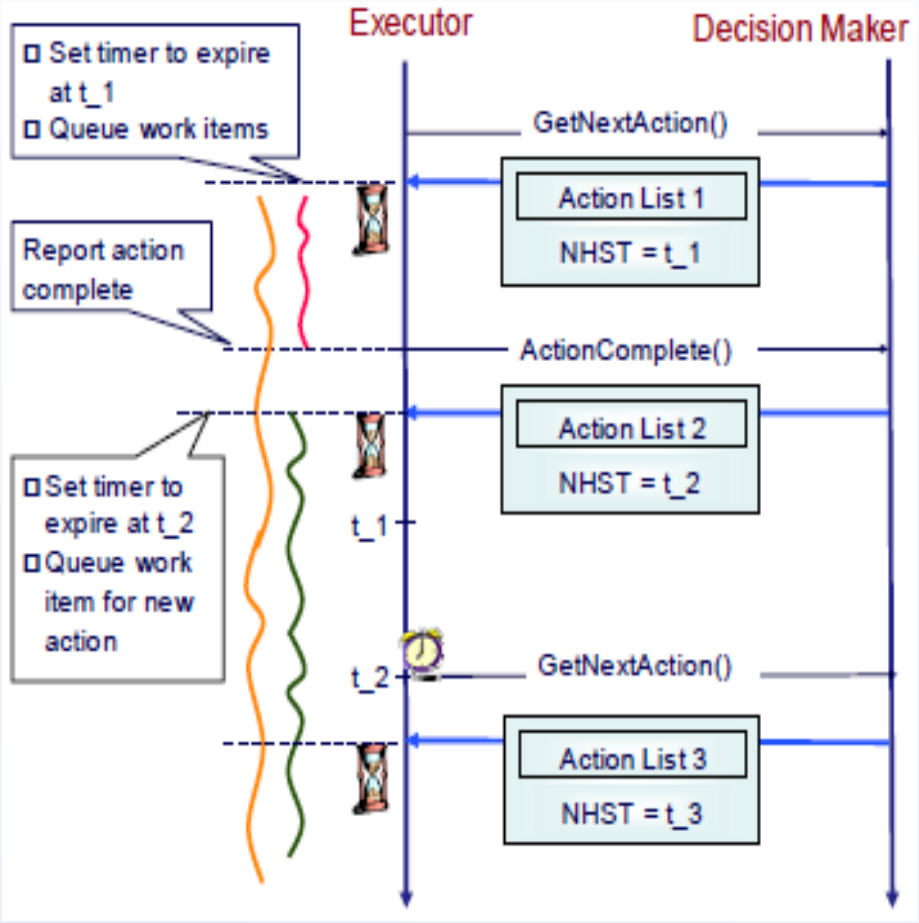
User 1: Put a six pack of mineral water into Compartment 3.

Pantry: Say "You have just put an object in Compartment 3." and associate bar-code id of shampoo with Compartment 3.

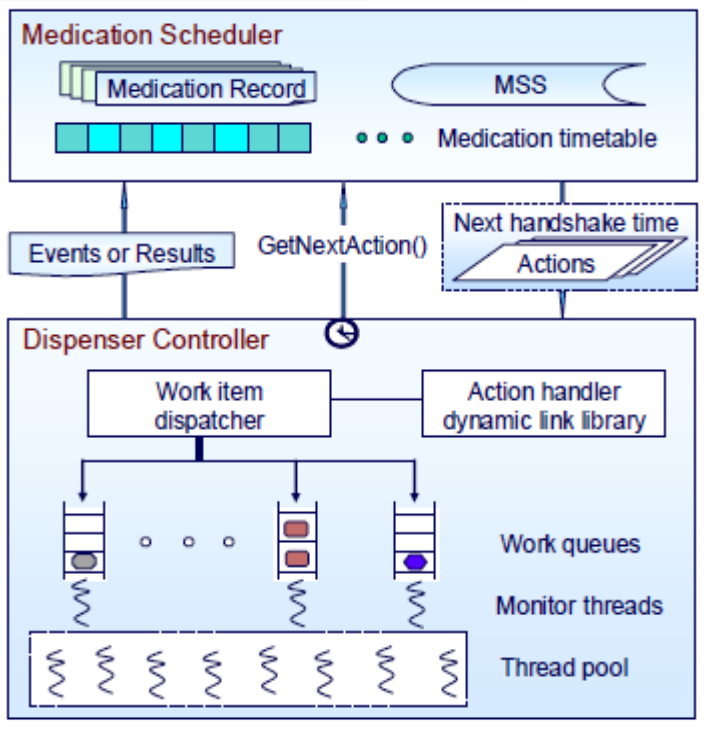
User 1: Walk away.


Container socket
Indicator light
LED display
PTD button
Memory card reader
Verification boxes
Base
Dispensing cup
Take medicine
X2
Mode
Time 12:45
Medicine input
SINICA
SINICA
Medication dispenser

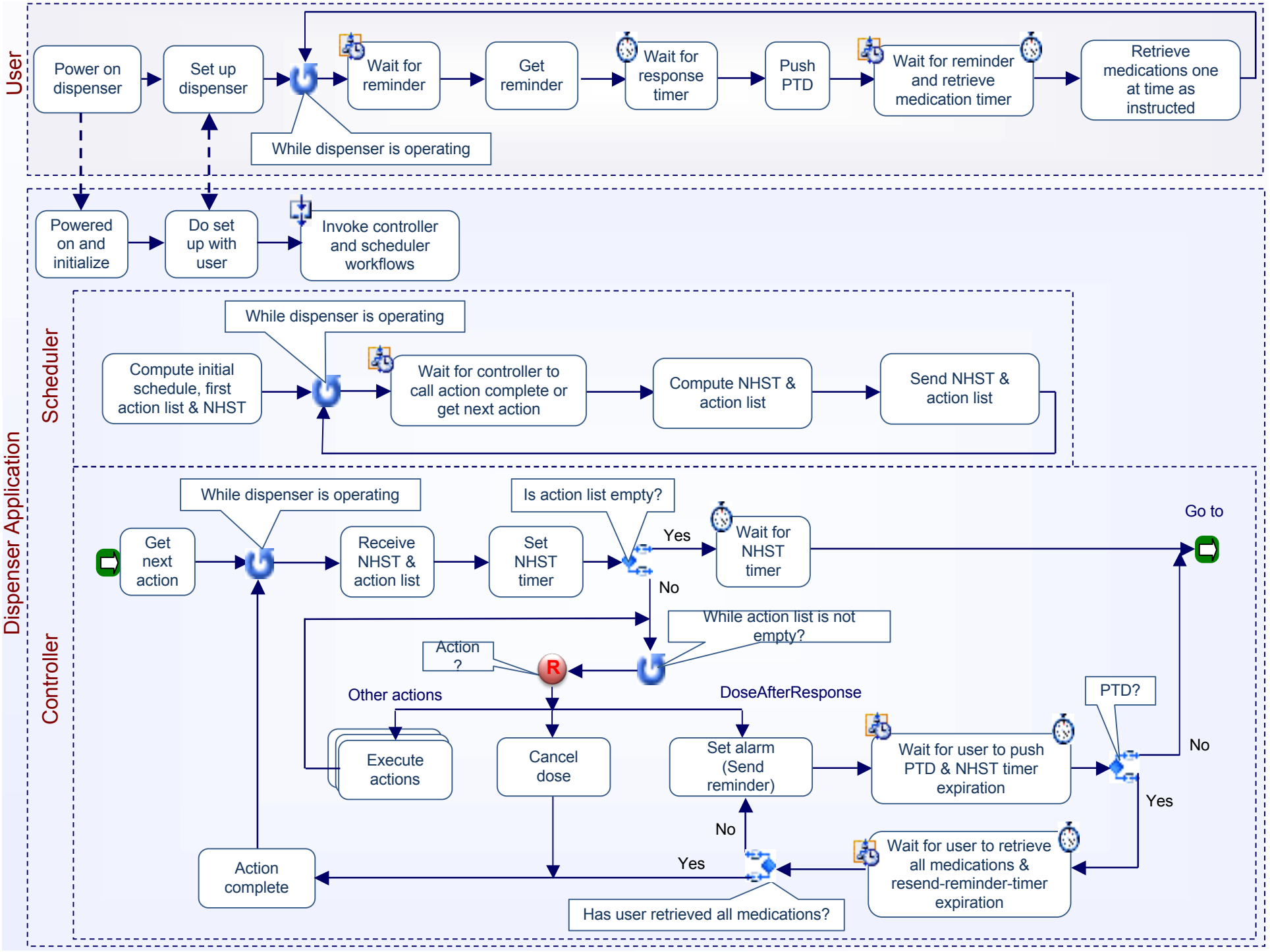
Case Study 2: Testing Smart Medication Dispenser



Action-oriented model
Executor-decision-maker communication



Dispenser controller structure


Dispenser Application
User
Power on dispenser
Set up dispenser
While dispenser is operating
Wait for reminder
Get reminder
Wait for response timer
Push PTD
Wait for reminder and retrieve medication timer
Retrieve medications one at time as instructed
Powered on and initialize
Do set up with user
Invoke controller and scheduler workflows
Scheduler
While dispenser is operating
Compute initial schedule, first action list & NHST
Wait for controller to call action complete or get next action
Compute NHST & action list
Send NHST & action list
Controller
While dispenser is operating
Get next action
Receive NHST & action list
Set NHST timer
Is action list empty?
Yes
Wait for NHST timer
Go to
No
While action list is not empty?
Action ?
R
Other actions
DoseAfterResponse
Execute actions
Cancel dose
Set alarm (Send reminder)
Wait for user to push PTD & NHST timer expiration
PTD?
No
Yes
Wait for user to retrieve all medications & resend-reminder-timer expiration
No
Yes
Action complete
Has user retrieved all medications?

A user is tardy by an amount of time. (0% ~ 100% noncompliance)

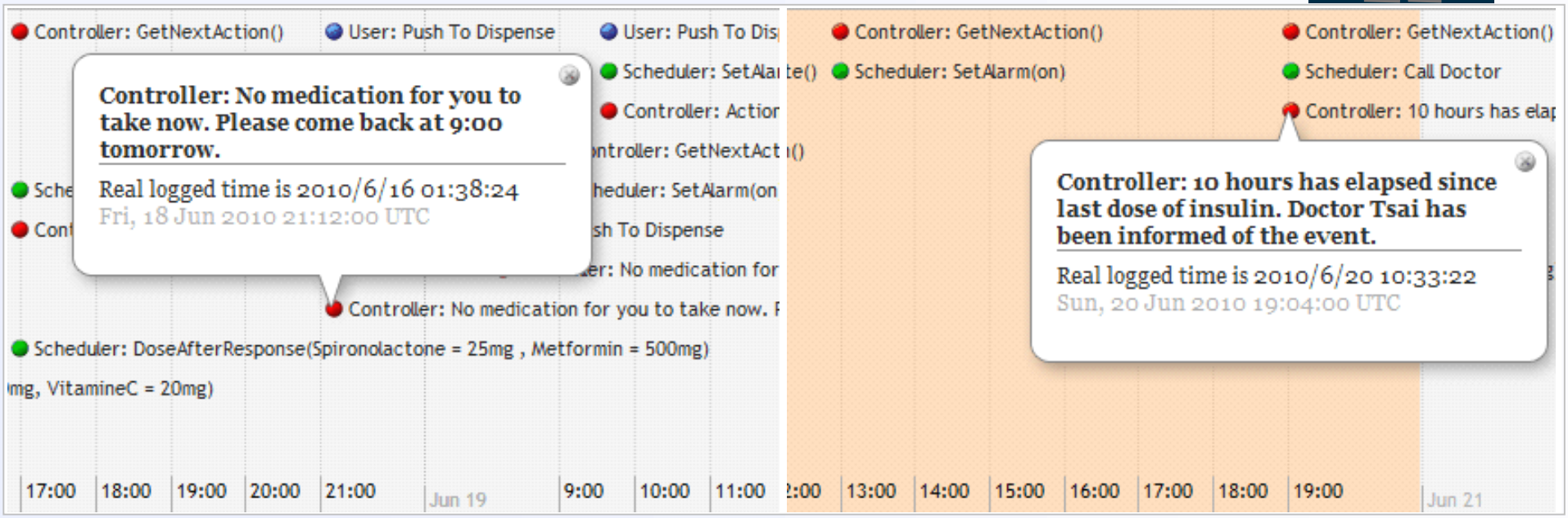
Select	User / Device	Workflow class	Workflow instance ID	Identifier
☑	Device	DispenserSchedulerWorkflow	b77f9bb8-f244-4adc-8129-0d1fdbd41b7b	DispenserScheduler
☑	Device	DispenserControllerWorkflow	b77f9bb8-f244-4adc-8129-0d1fdbd41b7c	DispenserController
☑	User	ComplianceUserWorkflow	0492fd3f-322e-4d8e-8269-fcff27bf3659	ComplianceUser
☑	User	SporadicNonComplianceUserWorkflow	22eeedb2-725d-4671-8ed4-48324c4bcb29	SporadicNonComplianceUser
☑	User	SporadicComplianceUserWorkflow	22eeedb2-725d-4671-8ed4-48324c4bcb30	SporadicComplianceUser
☑	User	NonComplianceUserWorkflow	0492fd3f-322e-4d8e-8269-fcff27bf3660	NonComplianceUser

Simulation Run1:

Should the user take some drugs now?

Simulation Run2:

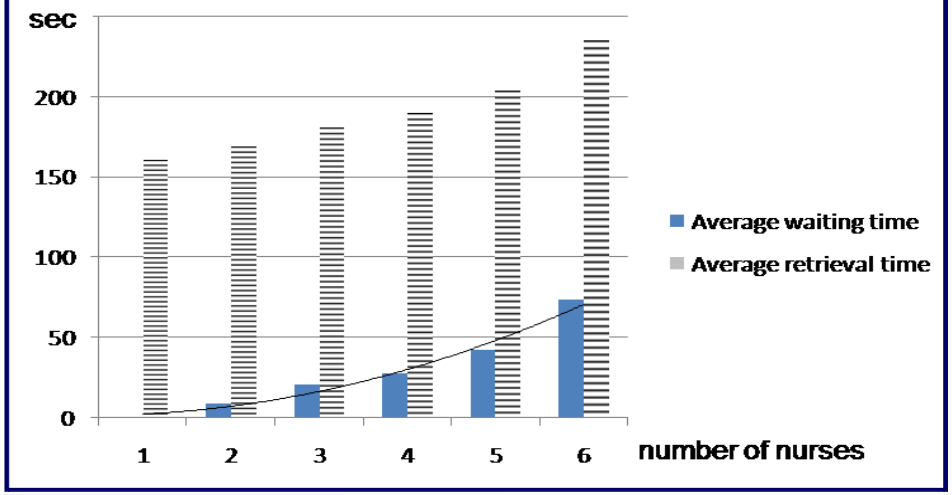
How the device behave when user is tardy?

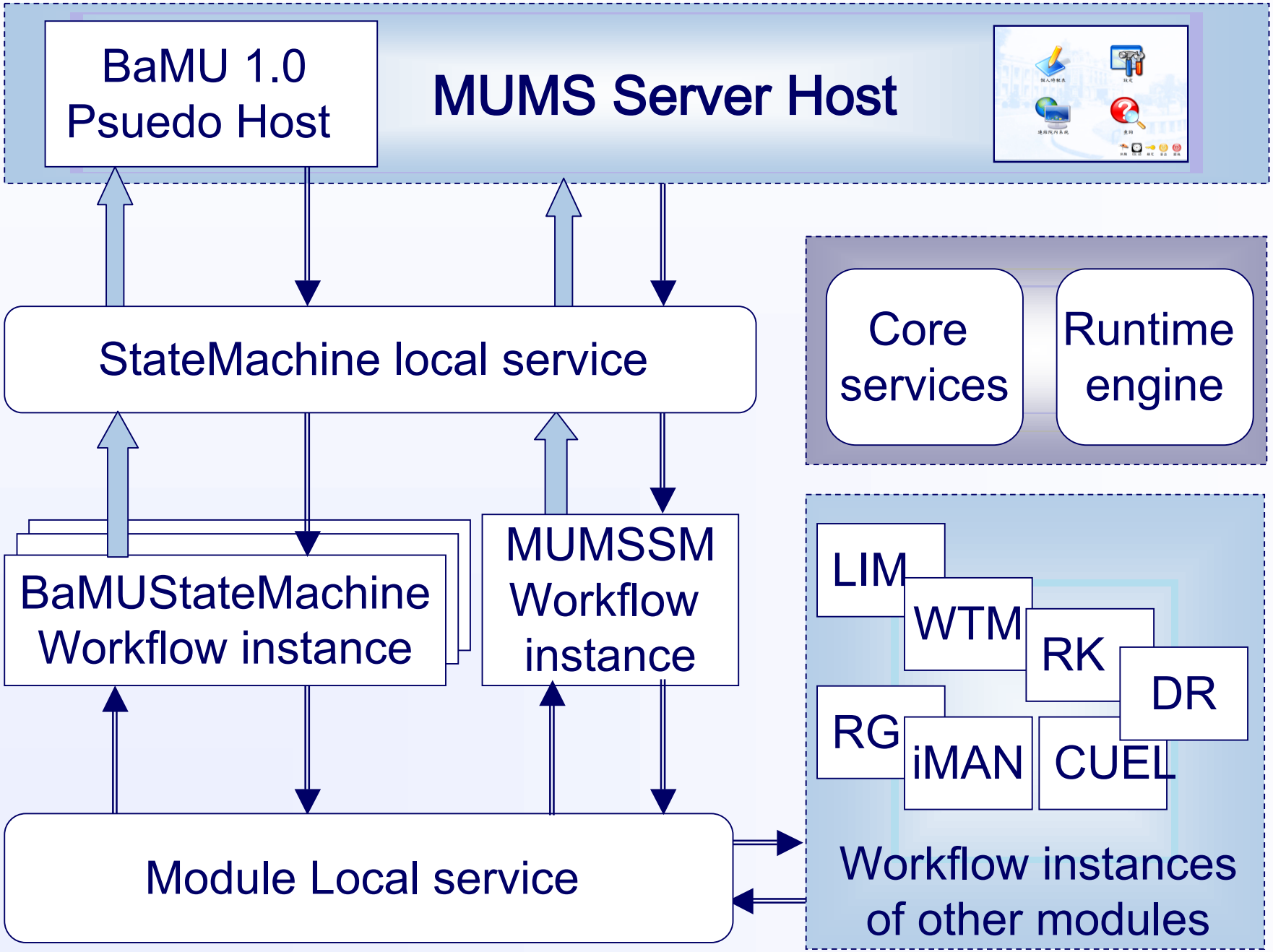


Case Study 3: Debugging and Performance Evaluation of Multi-User Medication Station

Simulation Parameters

- No. of patients per nurse: 6
- No. of medications for each patient: 6 -12
- No of medication containers: 138
- Medication use pattern: Zipf's law
- Operation of BaMU: CPM – GOMS
- Times of user operations (e.g., walking, scan bar-code id, etc.): measured
- Machine response time: 0.1 ~ 10 seconds




BaMU 1.0
Psuedo Host
MUMS Server Host
StateMachine local service
Core
services
Runtime
engine
BaMUStateMachine
Workflow instance
MUMSSM
Workflow
instance
LIM
WTM
RK
DR
RG
iMAN
CUEL
Module Local service
Workflow instances
of other modules

OUTLINE

- Motivation and rationales
  - Examples of UCADS
    - Intelligent monitoring
  - Characteristics and requirements
    - Models of user-assistive-device and human-robot interaction
- UCADS model: Workflow and GOMS
- USE: UCADS simulation environment
- Case studies
- Missing pieces/wish list

A User Actions Monitor

Plug memory card into MSS port

Plug a container into a socket

More container to plug?

Yes

No

User Workflow

Interface Service

Device Workflow

Initial State

Initialize dispenser

Waiting for Plug-in State

MSS Not Ready

Plug in MSS

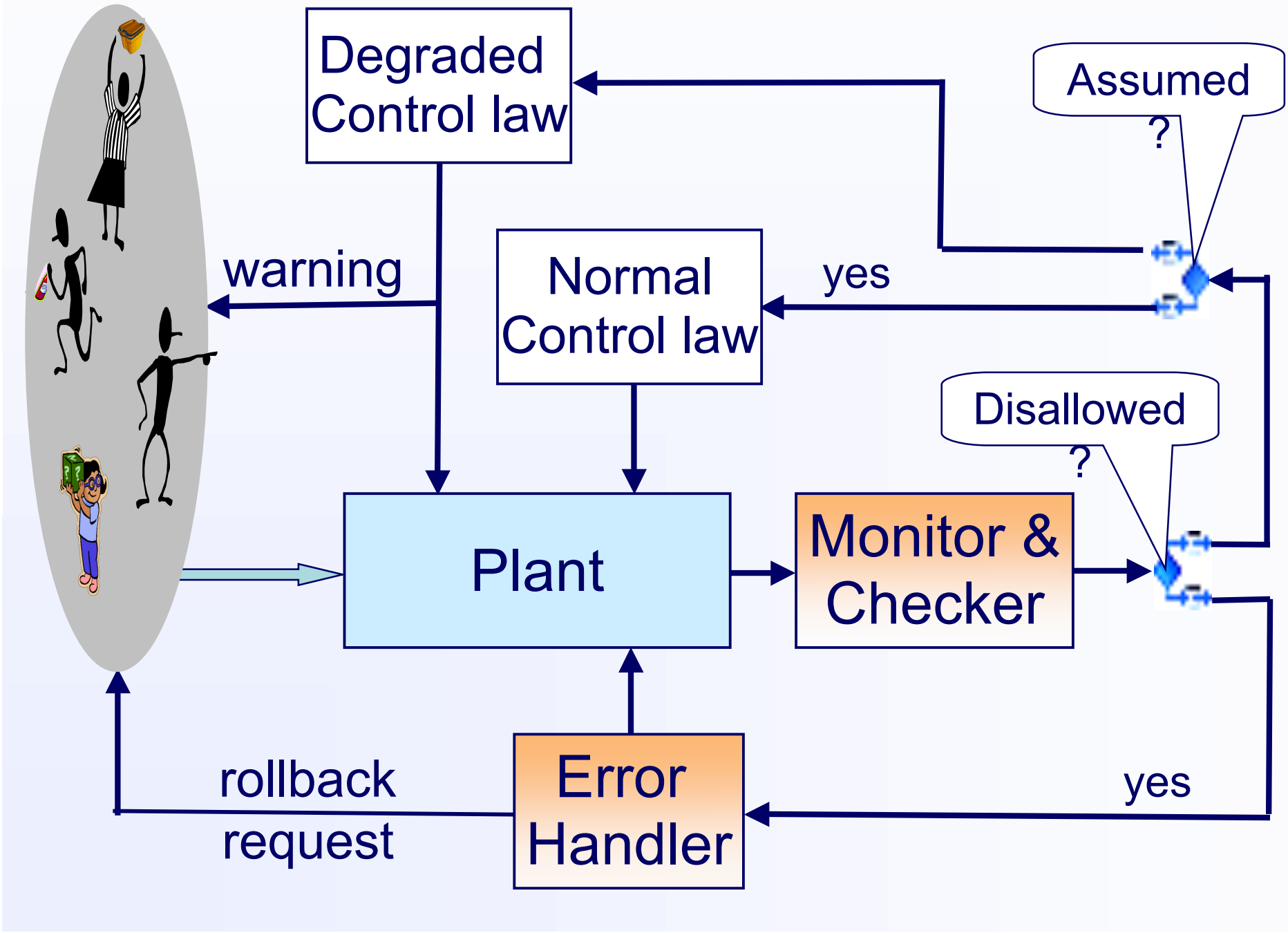
Plug in Container

MSS Ready

Plug in Container

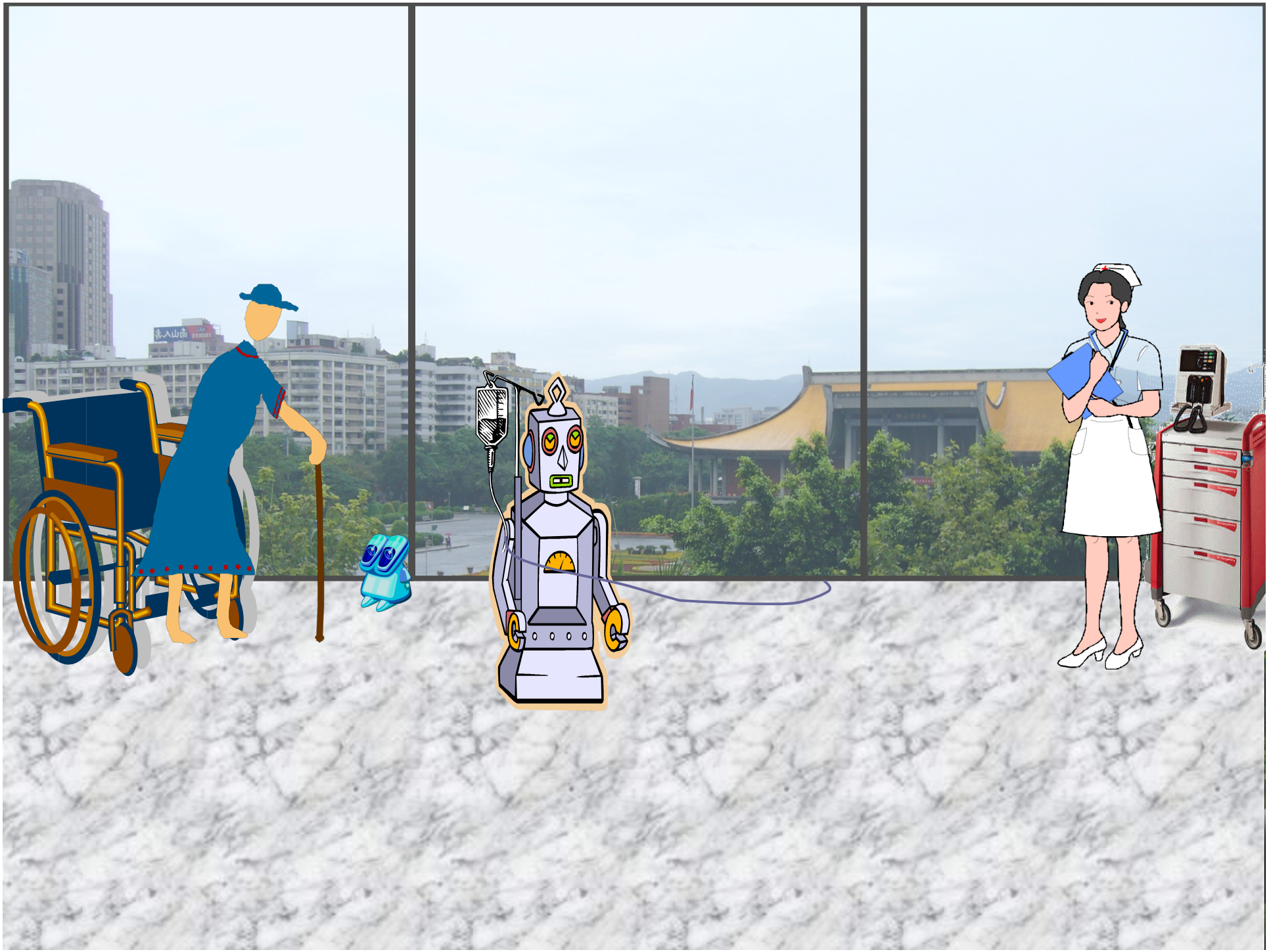
Error State

Ready for Scheduling State


Degraded
Control law
Assumed
?
warning
Normal
Control law
yes
Disallowed
?
Plant
Monitor &
Checker
rollback
request
Error
Handler
yes

We lack

- Conditions for action sequences to be
  - Observable and
  - Recoverable (undoable)
- Methods and tools



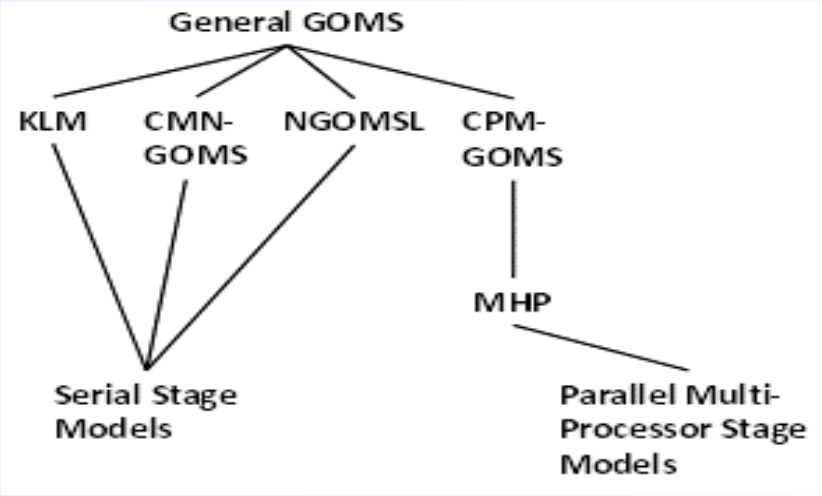
Thank You

Workflow Definition Languages and Workflow Management Systems

- Workflow Definition Languages
  - XPDL: XML Process Definition Language
  - C# + XAML
  - BPEL: Business Process Execution Language
  - YAWL: Yet Another Workflow Language
  - BPMN: Business Process Model Language
- Workflow Management Systems
  - Enhydra Shark
  - Workflow Foundation
  - jBPM
  - Bonita
  - YAWL System
  - WfMOpen
  - ActiveBPEL
  - ProcessMaker

GOMS (Goals, Operators, Methods, and Selection rules)

- Why GOMS?
  - John, B. E. (1995) Why GOMS? Interactions, vol. 2, no. 4. pp. 80-89.
  - John, B. E. and Kieras, D. E., "Using GOMS for User Interface Design and Evaluation: Which Technique?" in ACM Transactions on Computer-Human Interaction, Volume 3, Issue 4, December 1996.
  - Lu Luo, and Bonnie E. John, "Predicting task execution time on handheld devices using the keystroke-level model," in Conference on Human Factors in Computing Systems, 2005.
  - John, B. E. and Suzuki, S., "Toward Cognitive Modeling for Predicting Usability," in Proceedings of HCI, 2009 (19-24 July 09, San Diego, CA).
  - J. L. Drury, J. Scholtz, and D. Kieras, "Adapting GOMS to model human-robot interaction," in Proceedings of the ACM/IEEE international conference on Human-robot interaction, Arlington, Virginia, March USA , 2007.
- GOMS family
  - KLM
  - CMN-GOMS
  - NGOMSL
  - CPM-GOMS



Prototyping tools

- CogTool, http://cogtool.hcii.cs.cmu.edu/
- Hartmann, B., Klemmer, S.R., Bernstein, M., Abdulla, L., Burr, B., Robinson-Mosher, A., Gee, J., “Reflective physical prototyping through integrated design, test, and analysis,” in Proceedings of UIST 2006.
- Björn Hartmann , Loren Yu , Abel Allison , Yeonsoo Yang , Scott R. Klemmer, “Design As Exploration: Creating Interface Alternatives through Parallel Authoring and Runtime Tuning,” in Proceedings of UIST 2008.
- Barboni, E., Ladry, J., Navarre, D., Palanque, P., and Winckler, M., “Beyond modeling: an integrated environment supporting co-execution of tasks and systems models,” in Proceedings of the 2nd ACM SIGCHI Symposium on Engineering interactive Computing Systems (Berlin, Germany, June 19 - 23, 2010).
- Rémi Bastide, David Navarre, and Philippe Palanque, “A Model-Based Tool for Interactive Prototyping of Highly Interactive Applications,” in Proceeding CHI EA '02 CHI '02 extended abstracts on Human factors in computing systems, Minneapolis, Minnesota, USA, 2002.