



# AWARE@ICU

**Colin Lea**

Automated Workflow and Activity Recognition  
CIS2 Proposal

# motivation

## Hundreds of micro-tasks

- Drug administration
- Emptying chest tubes
- Documentation

## Lack of written direction

- Which nurse is doing what?
- Hierarchy of staff

## Sensory overload

- Many alarms
- Sounds become meaningless





# motivation

Monitors

Infant

Staff

Movable  
Equipment



Typical Setup

# motivation



## Handoffs



# motivation



## Procedures

# objectives

## **Build algorithmic tools for analyzing workflow**

- **Gather data**
- **Develop/evaluate techniques for recognition**
- **Summarize staff activity**

## **Secondary:**

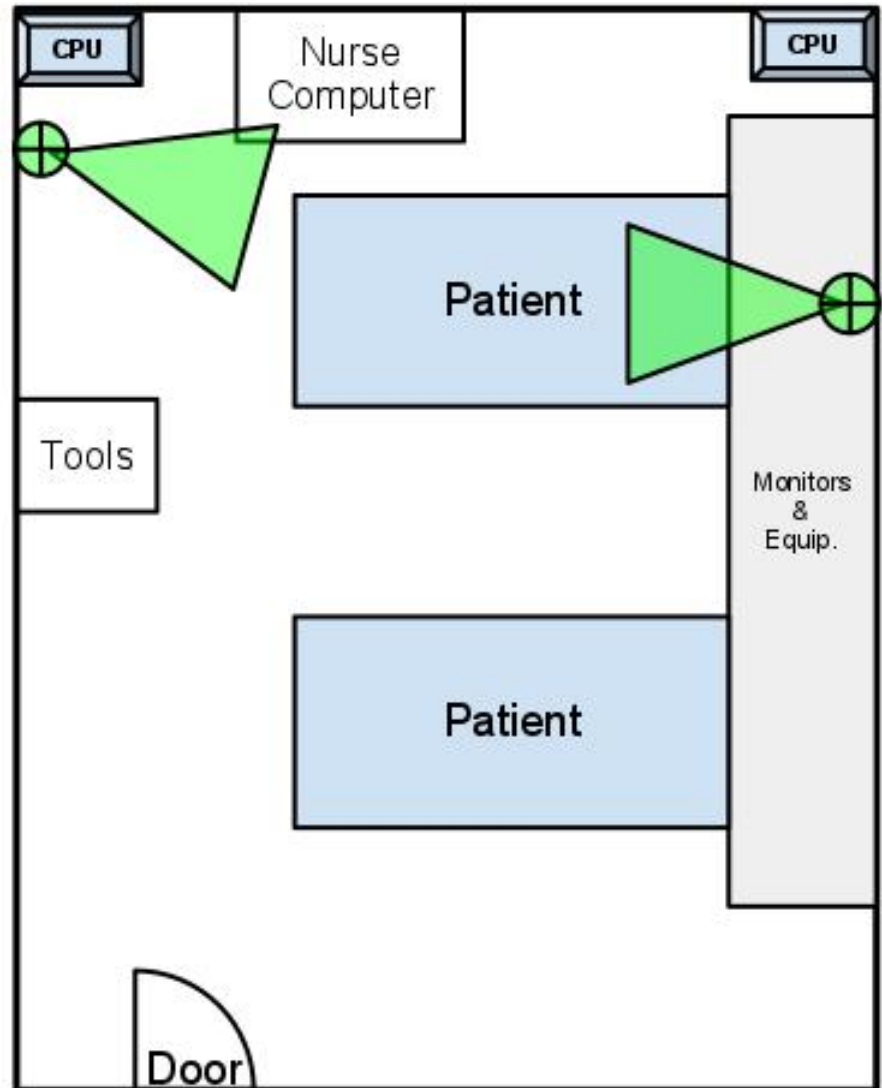
- **Understand patient movement**
- **Analyze microphone data**
- **Quantify nurse interaction times**
- **Examine medical device usage**

## **Retroactive + Preventative**

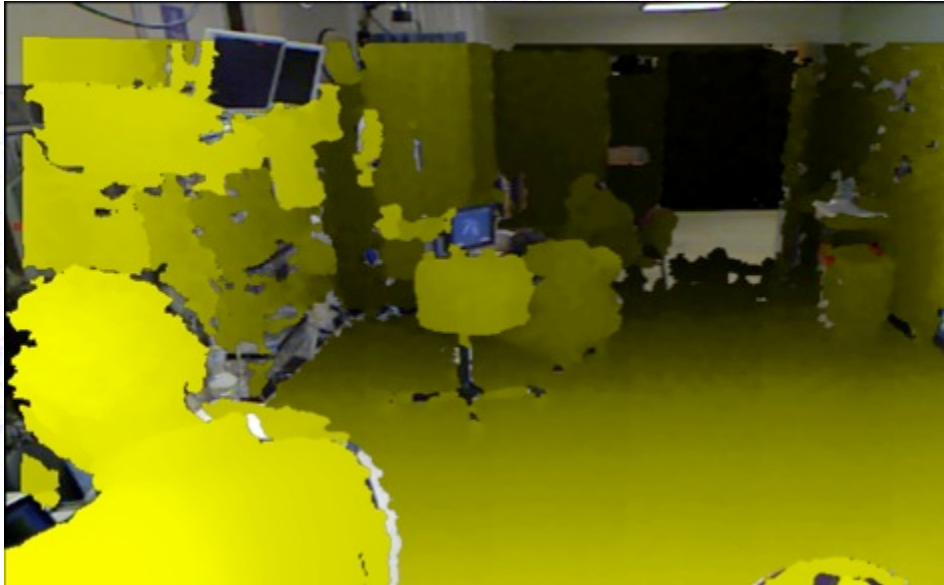


# hardware

**Xbox Kinect** 



# kinect



## Spatial cues

What/where are the people and instruments?

## Pose detection

What are people doing?



# preliminary direction

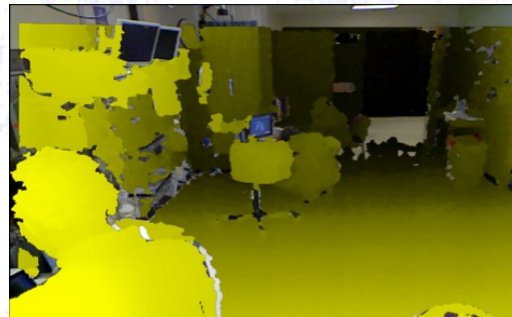
## Activity Summarization:

*What are the most frequent interactions?*

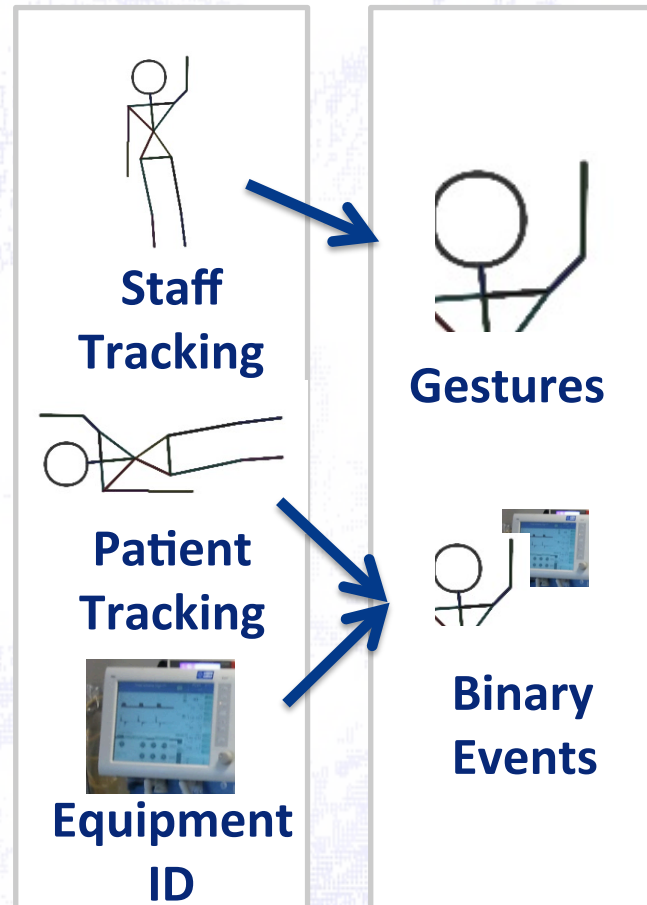
*What features are necessary to classify these actions?*

*With what accuracy can the top actions be recognized?*

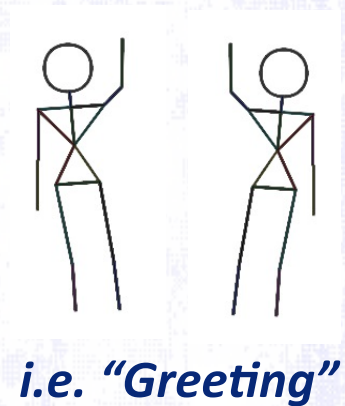
# activity pipeline



**Raw Signal**



**Derived Signals**



**Action**



# models

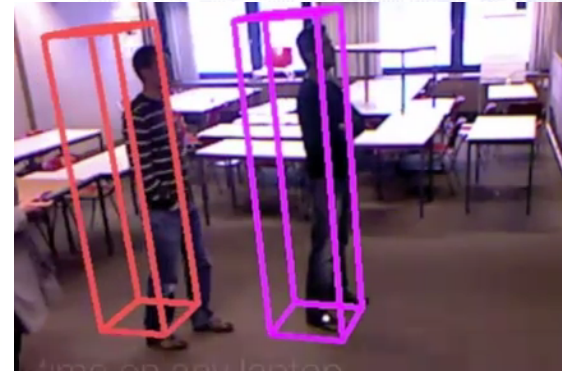
## Derived Signals

Staff location tracker:

- Bounding box of body from motion

Body pose estimation:

- Raw depth -> Joint positions
- Segmentation (PCA-kNN, Watershed)
- Parts model

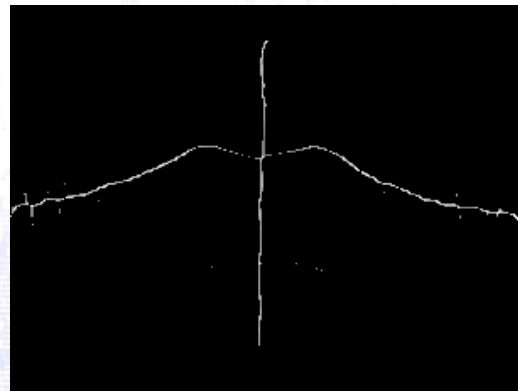


[EPFL-LTS2 2010]

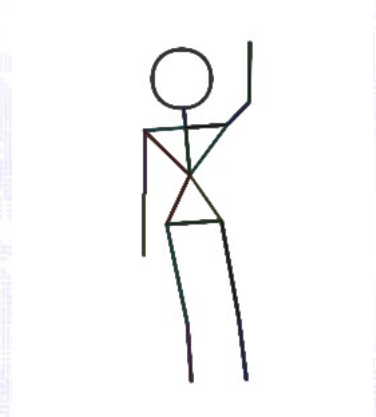


[CVPR'12]

Raw



In Progress



Goal

# models

## Derived Signals

Determine machine type/location

- Rough depth-based scene segmentation
- Feature-based detectors (i.e. SIFT)

Binary “touch” signals:

- Staff touching patient?
  - Location on patient? [Body tracker]
- Touching Equipment?
  - Type of equipment? [Scene analysis]



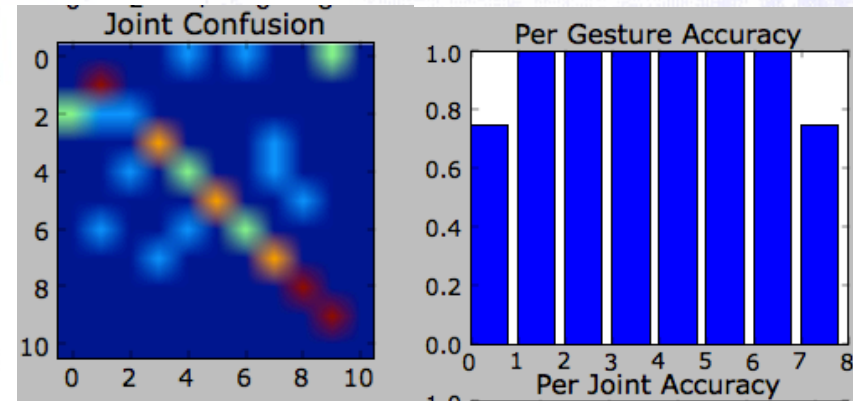


# models

## Action Recognition

### Staff gestures

- Determine sub-actions
  - i.e. Inserting tube
- Correlate input w/ each known gesture's PCA basis
- Temporal window?



Current results

### Activity Logger

- Fuse all derived signals and output “action”
- Time-series graphical model (i.e. CRF, S-LDS, HMM)

### Patient Body Tracker

- Establish metric for “unsafe” motion
- Track body over time
- Trigger alert (and log) when problematic

## Recorder

Task	Difficulty	Notes
General Purpose Recorder	Easy	In Progress
Face Tracking	Medium	In Progress
Blackout stretcher	Easy	
Video tracking failure	Medium	

## Experimentation

Task	Difficulty	Notes
Get IRB Approval	Easy	Pending
Record preliminary data	Easy	
Ensure de-identification	Easy	
Hand annotate activities	Medium	
Additional recording	Easy	

## Derived Data


Task	Difficulty	Notes
Location tracker	Easy	
Face direction tracker	Easy	CSIRO Software
Staff body pose estimation	Hard	
Patient tracker	Medium	
Equipment Identification	Hard	

## Activity recognition





Task	Difficulty	Notes
Gesture recognition	Medium	In Progress
Retrospective analysis	Hard	
Patient Tracking	Medium	
Multi-camera models	Medium	
Evaluation	Easy	14



## Recorder



Task	Difficulty	Notes
General Purpose Recorder	 Easy	In Progress
Face Tracking	Medium	In Progress
Blackout stretcher	Easy	
Video tracking failure	Medium	

## Experimentation




Task	Difficulty	Notes
Get IRB Approval	 Easy	Pending
Record preliminary data	 Easy	
Ensure de-identification	 Easy	
Hand annotate activities	 Medium	
Additional recording	Easy	

## Minimum

### Derived Data

Task	Difficulty	Notes
Location tracker	 Easy	
Face direction tracker	Easy	CSIRO Software
Staff body pose estimation	 Hard	
Patient tracker	Medium	
Equipment Identification	Hard	

### Activity recognition

Task	Difficulty	Notes
Gesture recognition	 Medium	In Progress
Retrospective analysis	 Hard	
Patient Tracking	Medium	
Multi-camera models	Medium	
Evaluation	 Easy	15

## Recorder

Task	Difficulty	Notes
General Purpose Recorder	★ Easy	In Progress
Face Tracking	★ Medium	In Progress
Blackout stretcher	★ Easy	
Video tracking failure	★ Medium	

## Experimentation

Task	Difficulty	Notes
Get IRB Approval	★ Easy	Pending
Record preliminary data	★ Easy	
Ensure de-identification	★ Easy	
Hand annotate activities	★ Medium	
Additional recording	★ Easy	

## Expected

### Derived Data

Task	Difficulty	Notes
Location tracker	★ Easy	
Face direction tracker	Easy	CSIRO Software
Staff body pose estimation	★ Hard	
Patient tracker	Medium	
Equipment Identification	★ Hard	

### Activity recognition

Task	Difficulty	Notes
Gesture recognition	★ Medium	In Progress
Retrospective analysis	★ Hard	
Patient Tracking	Medium	
Multi-camera models	Medium	
Evaluation	★ Easy	



## Recorder

Task	Difficulty	Notes
General Purpose Recorder	★ Easy	In Progress
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## Experimentation

Task	Difficulty	Notes
Get IRB Approval	★ Easy	Pending
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Ensure de-identification	★ Easy	
Hand annotate activities	★ Medium	
Additional recording	★ Easy	

## Maximum

### Derived Data

Task	Difficulty	Notes
Location tracker	★ Easy	
Face direction tracker	★ Easy	CSIRO Software
Staff body pose estimation	★ Hard	
Patient tracker	★ Medium	
Equipment Identification	★ Hard	

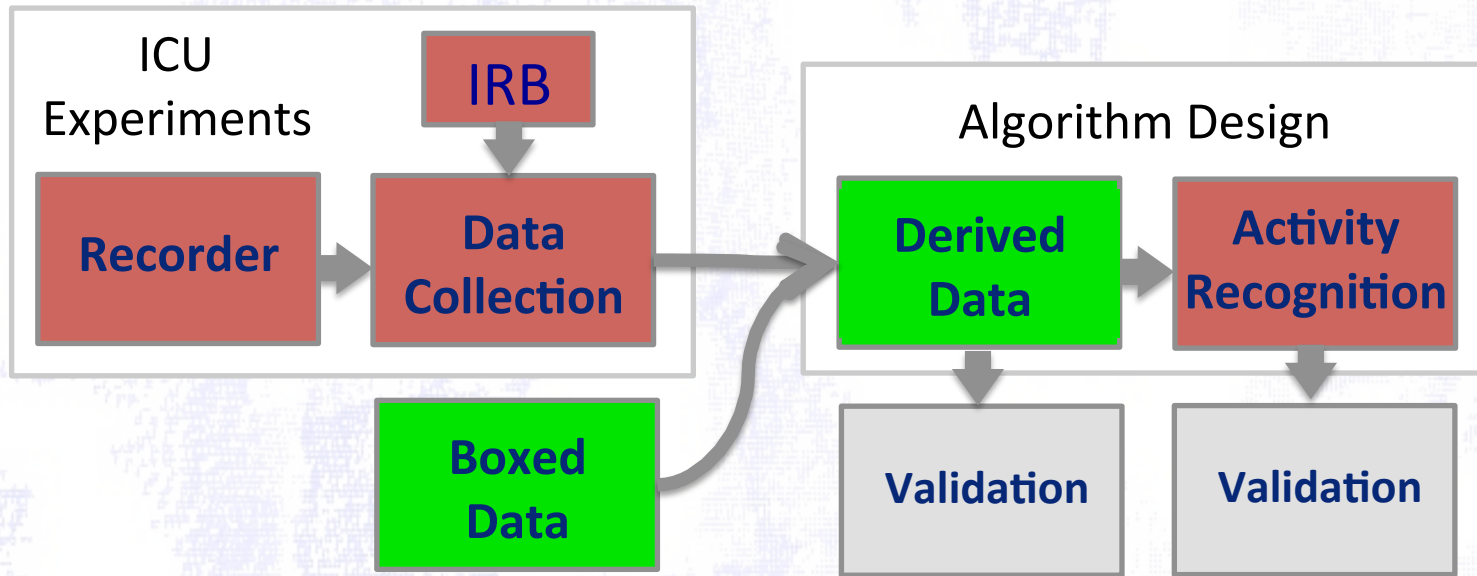
### Activity recognition

Task	Difficulty	Notes
Gesture recognition	★ Medium	In Progress
Retrospective analysis	★ Hard	
Patient Tracking	★ Medium	
Multi-camera models	★ Medium	
Evaluation	★ Easy	

<b>Task</b>	<b>Difficulty</b>
CVPR One Shot Gesture Competition	Medium
Multi-view reconstruction	Easy
Semi-supervised activity learning	Medium

supplemental tasks





dependencies

# milestones

## **Generic recorder**

- (depth + video + skeleton)

## **Experimental Data**

- Pending IRB Approval
- Preliminary + additional datasets

## **Activity Logger**

- Record actions

## **Derived Data Modules**

- Gesture based
- Scene analysis
- Touch sensors

## **Recognition Modules**

- Time-series recognition
- Patient body tracker



# literature

## Key Directions:

- Spatiotemporal techniques
- Sequential methods (ie. HMMs)
- Context free grammars
- Hierarchical Graphical Models



**Georgia Tech  
Aware Home**



**TUM  
Operating Room**



**CMU  
Kitchen**

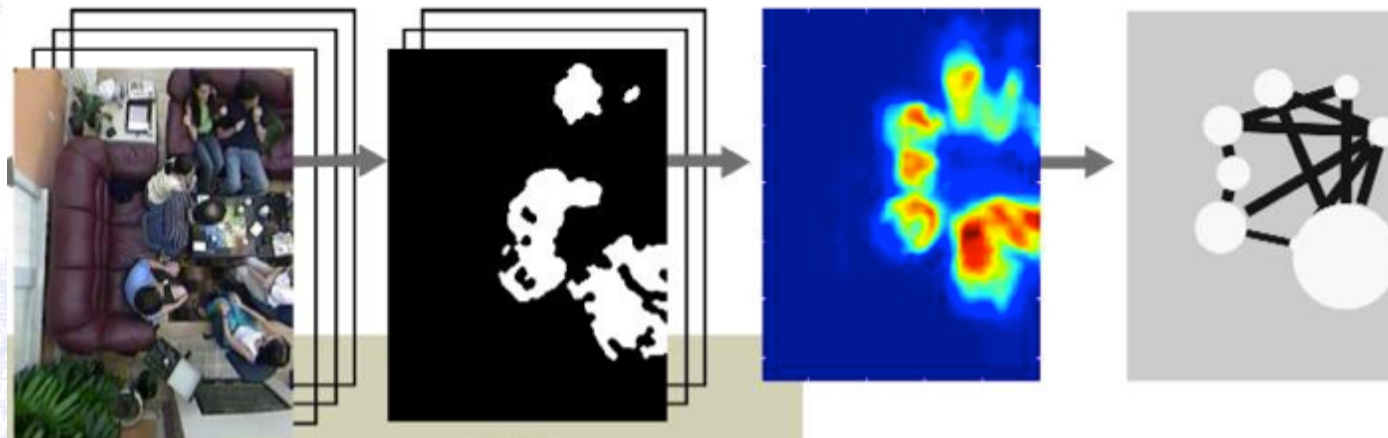
# Aware Home

**Goal: Capture & aggregate motion data. Visualize.**

- Unsupervised techniques
- Suffix trees (2008)
  - Discrete-data subsequences
  - Reduce redundant info
  - Finds & merges new activities

	Suffix Tree		VSM		3-grams		5-grams	
	<i>P</i>	<i>R</i>	<i>P</i>	<i>R</i>	<i>P</i>	<i>R</i>	<i>P</i>	<i>R</i>
Aloo Dam	55	60	55	50	50	60	55	60
Babka	50	40	-	-	56	50	38	30
Cereal	63	50	60	60	57	40	33	30
Fruit Salad	50	60	-	-	-	-	33	40
Omelet	63	70	-	-	-	-	-	-
Raita	47	70	-	-	18	70	33	70
Chicken	70	70	16	100	44	40	42	50
Setup Table	88	70	60	60	50	50	45	50
Green Salad	64	70	-	-	40	20	38	30
Wash Dishes	60	30	50	50	44	40	28	20
<b>Average</b>	<b>61</b>	<b>59</b>	<b>24</b>	<b>32</b>	<b>36</b>	<b>37</b>	<b>35</b>	<b>38</b>
<b>% Discovery</b>	<b>100</b>		<b>50</b>		<b>80</b>		<b>90</b>	

## Activity Discovery

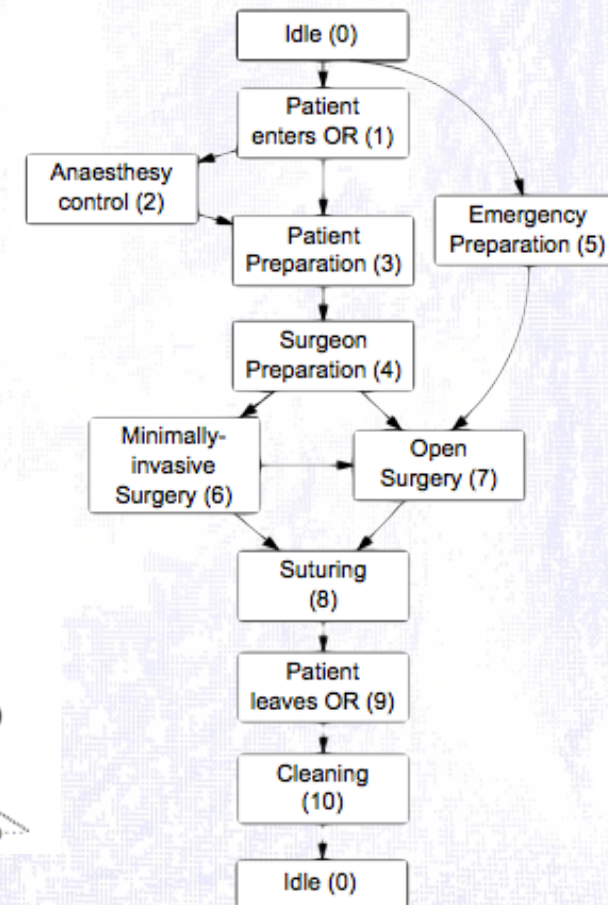
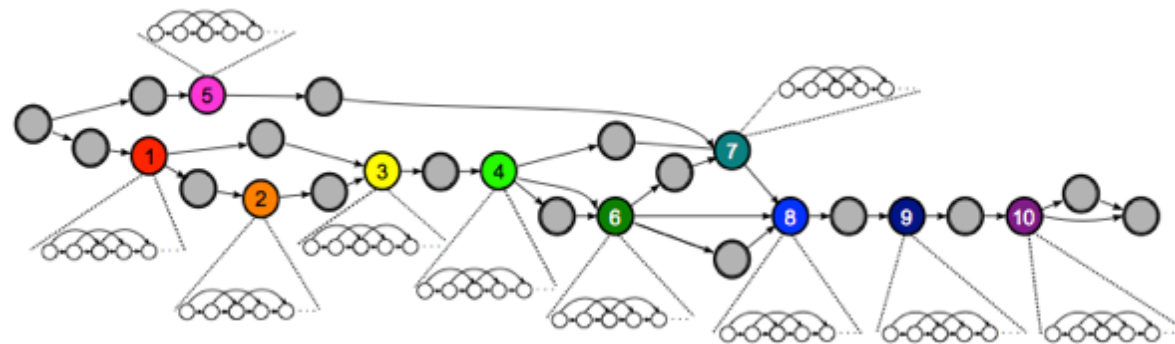




# Operating Room

## Goal: Analyze surgical workflow

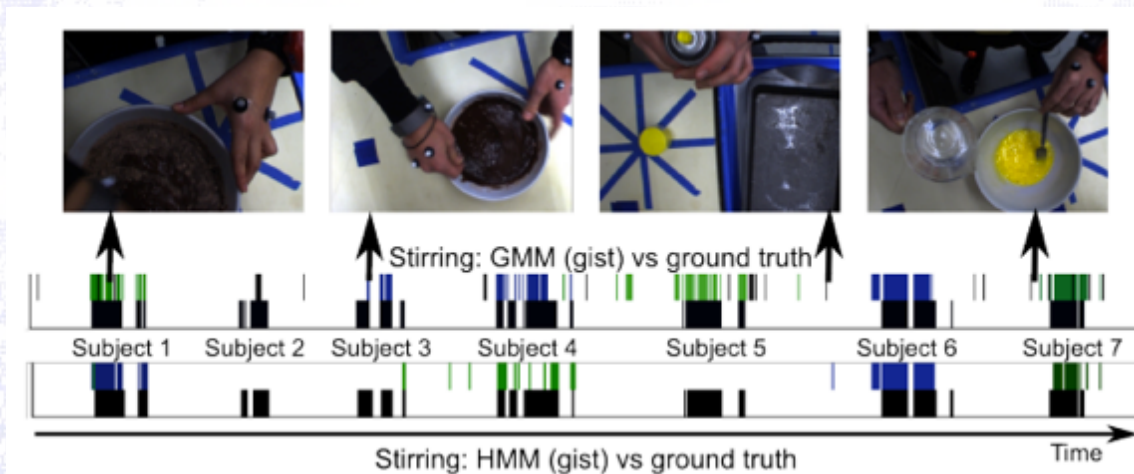
- Supervised techniques
- Workflow HMMs
  - Prob. of going in and out of state
  - Sub-HMM per phase
- Dynamic Time Warping



# QoLT Kitchen

## Goal: Recognize actions in food preparation

- Video + IMU + Motion + RFID
- Unsupervised temporal segmentation
  - PCA + GMM
- Supervised activity classification
  - Scene Gist (ie. counter vs fridge)
  - k-NN beat HMM with multimodal data
  - Less data can beat more





## **LCSR:**

- **Dr. Russ Taylor**
- **Dr. Greg Hager**
- **Dr. Suchi Saria**

## **JHMI:**

- **Dr. Jim Fackler**

**collaborators**

questions?