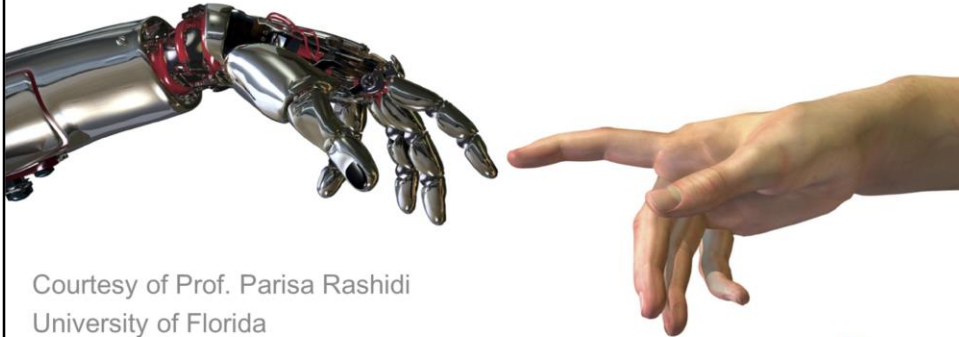


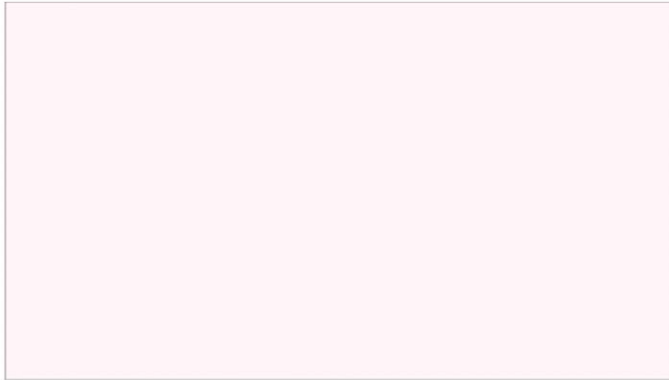
# Assistive Technologies for Older Adults



Courtesy of Prof. Parisa Rashidi  
University of Florida



# Assistive Technologies (AT)



## Example: Network-Enabled Powered Wheelchair Adaptor Kit (Ryerson, 2004)

*Any medical treatment, health regimen  
or product information contained in  
this program should not be used for  
self-diagnosis or treatment and does  
not represent the opinions or policies  
of the producers or this network.  
Viewers should seek medical or  
health-related advice from their  
own medical practitioners.*



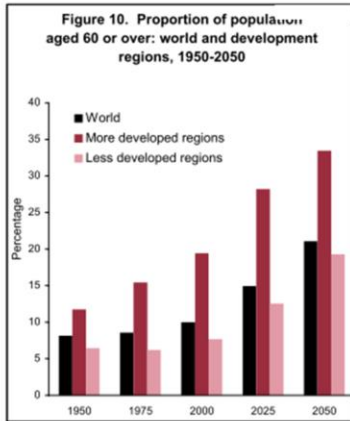
## Why Assistive Technology is Important

- **Scope**
  - **8.5 million** American seniors require some form of assistive care
    - **80%** of those over 65 are living with at least one chronic disease
    - Every **69** seconds someone in America develops Alzheimer's disease
      - **Costs (annual)**
        - » Out of Pocket expenses: **\$18,500-\$36,000**
        - » Nursing home care costs: **\$70,000-\$80,000**
        - » Loss to employers: **\$33 billion (nationaly)**
- **The Missing Caregiver dilemma**
  - **120,000** nurses **159,300** doctors by 2025
  - Understaffed nursing homes: **91%**
  - Family caregivers in US: **31%** of households
    - **70%** of caregivers care for someone over age 50





\* By 2050, 1 in 5 people in the world will be age 60 or older



UN Report, Department of Economic and Social Affairs, Population Division, 2001  
<http://www.un.org/esa/population/publications/worldageing19502050/>



## Consequences

By 2040: Alzheimer (alone) costs

\$2 trillion /yr

- An increase in age-related diseases
- Rising healthcare costs
- Shortage of health-care professionals
- Increase in number of individuals unable to live independently
  - Facilities cannot handle coming “age wave”



Which would you rather have?



VS



## Older Adults Challenges

- Normal age related challenges
  - Physical limitations
    - Balance, reaching, etc.
  - Perceptual
    - Vision, hearing
  - Cognitive
    - Memory, parallel tasks
- Chronic age related diseases
  - Alzheimer's Disease (AD)





## Older Adults Need

- Help with daily activities
  - Activities of Daily Living (ADL)
    - e.g. Personal grooming
  - Instrumented Activities of Daily Living (IADL)
    - e.g. Transportation, cooking
  - Enhanced Activities of Daily Living (EADL)
    - e.g. Reading, social engagement
- Memory Functions
- Health monitoring
- Goal: Remove burden from caregiver



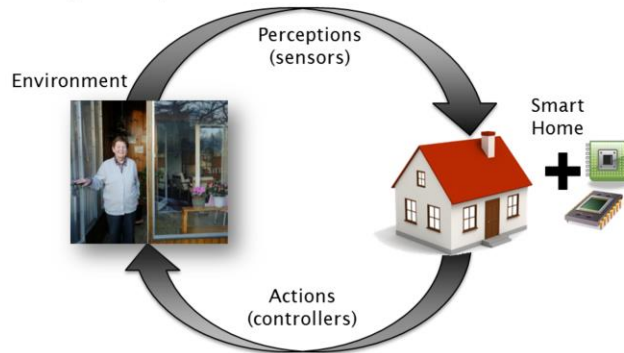
## Tools & Infrastructure

- What makes Ambient Assisted Living (AAL) possible?
  - Smart homes
  - Mobile devices
  - Wearable sensors
  - Smart fabrics
  - Assistive robotics



## Smart Homes

- Sensors & actuators integrated into everyday objects
- Knowledge acquisition about inhabitant

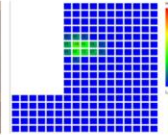


## Smart Home Sensors

- PIR (Passive Infrared Sensor)
- RFID
- Ultrasonic
- Pressure sensors (in beds, floor)
- Contact switch sensors
- ...



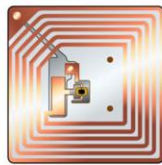
A) A photo of the floor



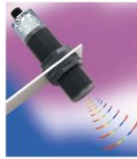
B) Floor Sensor Data



PIR



RFID



Ultrasonic

School of Computer Science

# Example

## TigerPlace (U of Missouri)



School of Computer Science

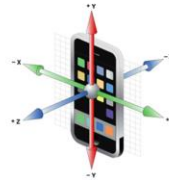
# Example

## Silverline (Singapore)



## Wearable & Mobile Sensors

- Applications
  - Health monitoring
  - Navigation and stray prevention
  - Mobile persuasive technologies



LifeShirt By Vivometrics®



AMON Cardiac Monitor,  
ETH Zurich





# Measurements & Sensors

## Movement

- Accelerometer
- Gyroscope



## Biochemical

- Stress markers (lactate in sweat)
- Wound healing (pH and infection markers)



## Vital Signs

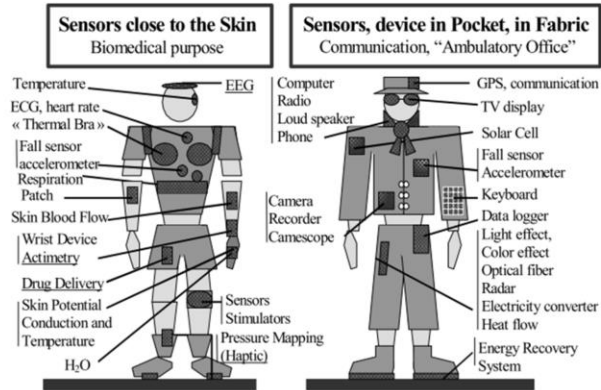
- Respiration sensors
- Thermal sensors
- Galvanic skin response (GSR) sensors
- Cardiac Activity
  - Pulse oximeter
  - ECG devices
  - Doppler radars





## Wearable Device Types

- Harness type
- Patches
- Body-worn
- Smart garments
  - Garment level
  - Fabric level
  - Fiber level



\*A. Dittmar; R. Meffre; F. De Oliveira; C. Gehin; G. Delhomme; , "Wearable Medical Devices Using Textile and Flexible Technologies for Ambulatory Monitoring," *Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the* , vol., no., pp.7161-7164, 2005



## Data Transfer Architecture

- Most common setup
  - Sensors on body + a handheld or wearable data hub to communicate data wirelessly + a central node to process data
- Short range standards
  - Bluetooth (IEEE 802.15.1)
  - ZigBee (IEEE 802.15.4)
- Short range technologies
  - RFID
  - Inductive links, Intrabody Communication



## Why Wearable and Mobile?

- Pros.
  - Anywhere, anytime
  - Portable
  - Continuous recordings rather than “snapshot “
  - Avoid “white coat” syndrome
- Cons.
  - Anywhere, anytime
  - Should be worn/carried all the time
  - Wearing a tag can be regarded as stigma
  - Privacy concern, 24/7 monitoring



## Assistive Robotics

- Helpful in physical tasks
- Communication
  - People consider them as social entities.



Care-O-bot® by Fraunhofer IPA: grasping items and bringing them to resident



RIBA, Japan: Transferring patients, 2009



PARO by U Penn, 2011



## Hospital work is dangerous work

- In 2011, U.S. hospitals recorded 58,860 work-related injuries and illnesses
- It is more hazardous to work in a hospital than in construction or manufacturing.



## Example: Patient Transfer

**Transfer from  
Bed to Wheelchair**

**Skill# 19**

[www.4YourCNA.com](http://www.4YourCNA.com)





# ALGORITHMS & METHODS



## Algorithms

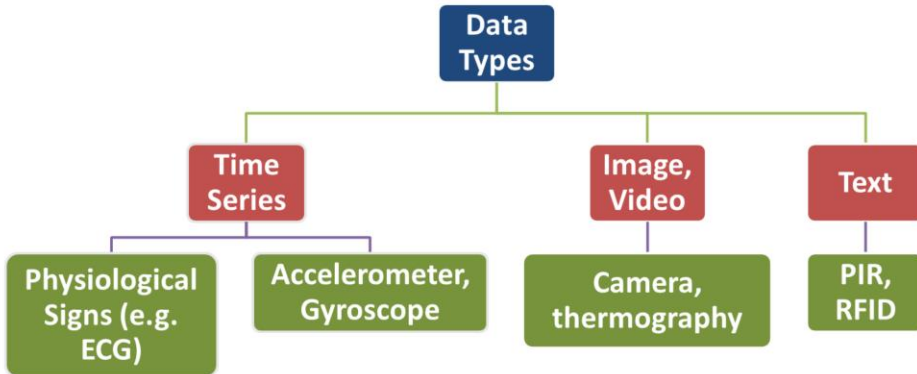
- The ones we will discuss
  - **Activity recognition from**
    - **Wearable & mobile sensors**
    - **Ambient sensors**
    - **Camera (Vision)**
  - Context Modeling
  - Other algorithms
    - Indoor Location detection
    - Reminding





## Data Sources

- Different mediums generate different types of data





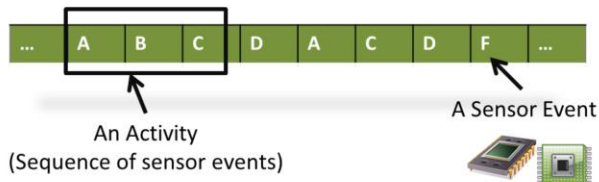
# “ACTIVITY RECOGNITION”

## Algorithms & Methods:



## What is Activity Recognition?

- The basic building block in many applications
  - Recognizing user activities from a stream of sensor events

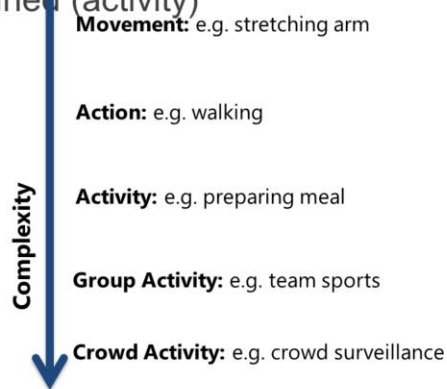


KES

Source: ADI  
MASTER OF DIGITAL MEDIA

## Activity Resolution

- Fine grained (individual movements, especially in vision)
- Coarse grained (activity)



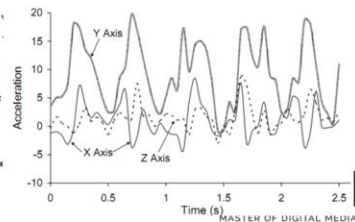
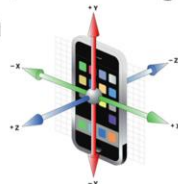
# ACTIVITY RECOGNITION: “WEARABLE & MOBILE”

## Algorithms & Methods:



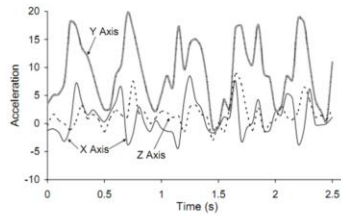
## Activity Data from Wearable Sensors

- Mostly in form of time series
  - Accelerometer [& gyroscope]
- Most actions in form of distinct, periodic motion patterns
  - Walking, running, sitting,..
- Usual features
  - Average, standard deviation
  - Time between peaks, FFT energy
  - Correlation between
  - ...

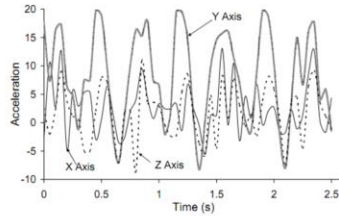


## Example Activities

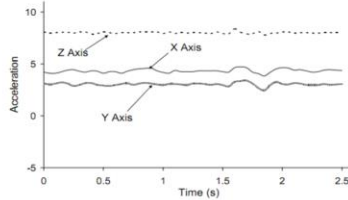
- Example activities from mobile phone accelerometer



(a) Walking



(b) Jogging



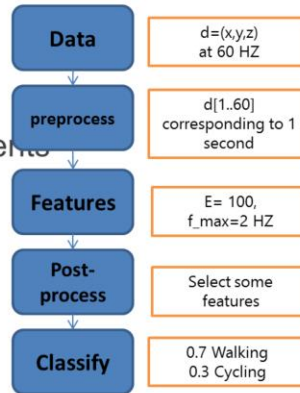
(e) Sitting

Kwapisz et al, SIGKDD  
 exploration, 2010



## Processing Steps

- Stages
  - Data collection
  - Preprocessing
  - Feature extraction
    - Mean, SD, FFT coefficients
  - Dimensionality Reduction
  - Classification

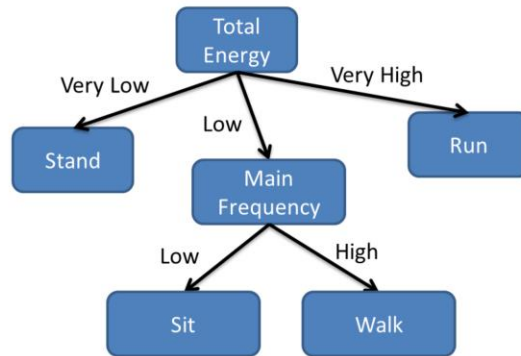






## Classification

- Supervised
  - SVM, DT, ...
- Semi-supervised
- Unsupervised
  - Clustering
  - Motif discovery



A simple decision tree



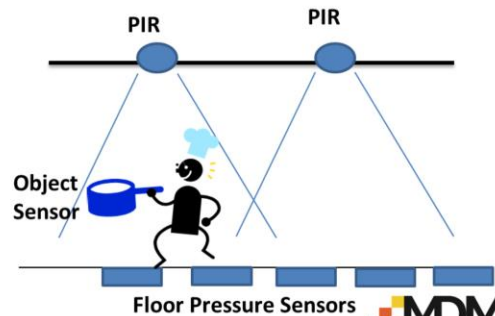
# ACTIVITY RECOGNITION: “AMBIENT SENSORS”

## Algorithms & Methods:



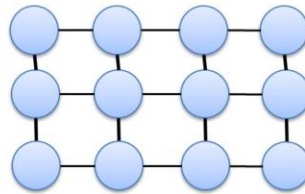
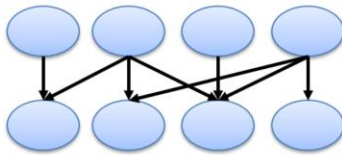
## Activity Recognition

- More complex activities need more sophisticated sensors
  - Sensor networks of PIR sensors, contact switch sensors, pressure sensors, object sensors, etc.
- Approaches
  - Supervised
    - Probabilistic
  - Semi/Unsupervised



## Probabilistic Approaches

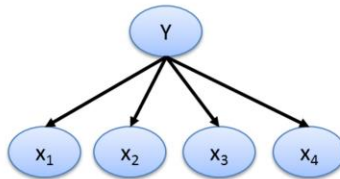
- Graphical models
  - Naïve Bayes (NB)
  - Hidden Markov Model (HMM)
  - Dynamic Bayesian Network (DBN)
  - Conditional Random Field (CRF)



## Naïve Bayes

- A very simple model, yet effective in practice [Tapia 2004]
- Assumes observations are independent of each other

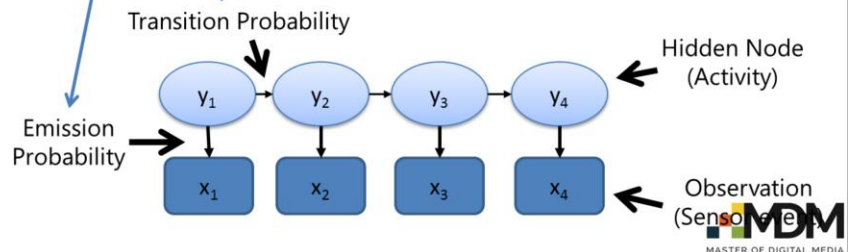
- $Y$  = activity (e.g. ON)
  - $X$  = observations
- $$P(y|x) = P(y) \prod_{m=1}^M P(x_m|y)$$



## Hidden Markov Model (HMM)

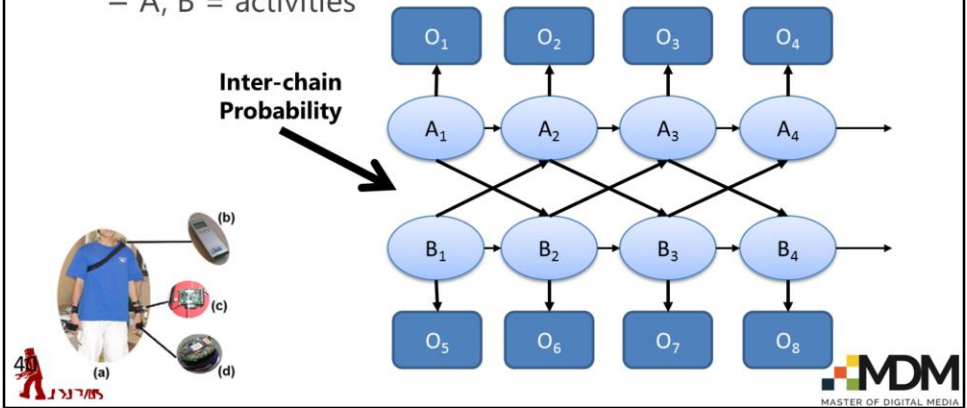
- A model for inferring hidden states from observations
- Well known, efficient algorithms

$$P(y, x) = \prod_{t=1}^T P(x_t | y_t) \cdot P(y_t | y_{t-1})$$



## Multiple Residents?

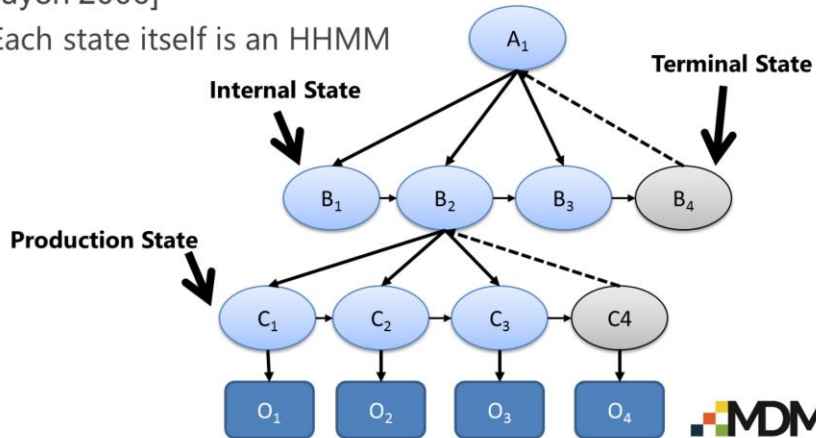
- Coupled Hidden Markov Model (CHMM) [Wang 2010]
- O = observations
- A, B = activities



## Hierarchical Definition of Activities?

– Hierarchical Hidden Markov Model (HHMM) [Choo 2008, Nguyen 2006]

- Each state itself is an HHMM

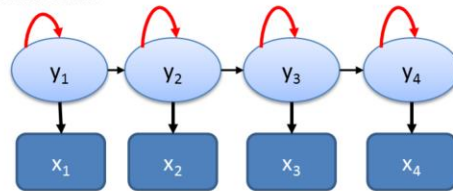




## Hidden Semi-Markov Model

- Hidden Semi-Markov Model (HSMM) [Duong 2006]
- Activity duration modeling
  - Arbitrary probability distribution of staying in a state

Arbitrary Duration  
Distribution



## Markov Logic Network

- Markov logic networks [Helaoui 2011]
  - Easily including background knowledge of activities + non-deterministic approach
  - First order logic + Markov network





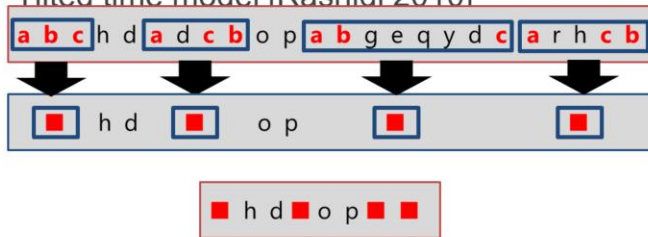
## Other Graphical Models

- Dynamic Bayesian Network (DBN)
- Conditional Random Fields (CRF)
- ...



## Unsupervised Methods

- Data annotation problem!
- Emerging patterns
  - Mining frequent patterns [Gu 2009, Heierman 2003]
  - Mining periodic sequential patterns [Rashidi 2008]
- Stream mining
  - Tilted time model [Rashidi 2010]



## Other Techniques

- Transfer learning [TLM van Kastere 2010, VW Zheng 2009]
  - Bootstrap for a new resident
  - Bootstrap in a new building
  - ...
- Semi-supervised learning [D Guan 2007,]
  - Co-training
- Active learning [M Mandaviani 2007, Rashidi 2011]



# ACTIVITY RECOGNITION: “VISION”

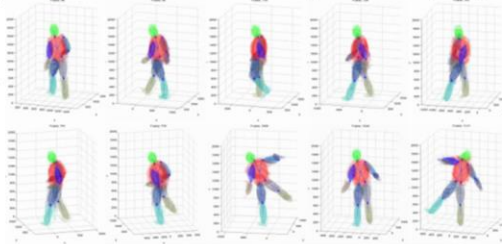
## Algorithms & Methods:



## Vision Based Systems

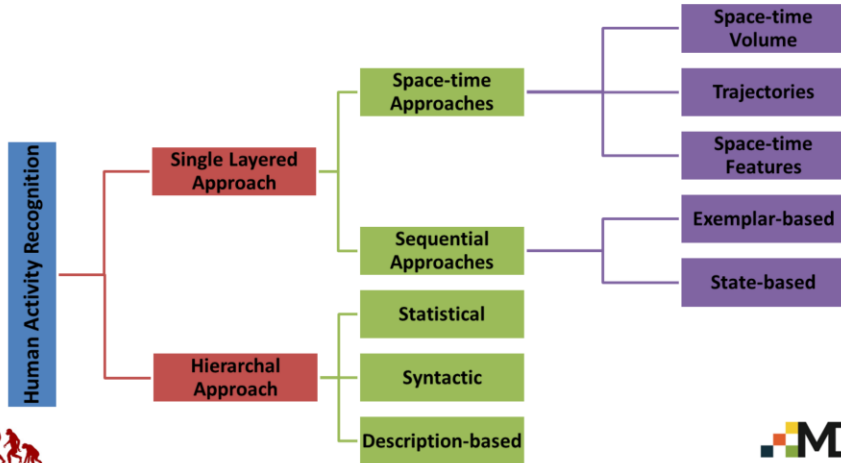
- Used in many related application domains
  - Video surveillance, sports analysis, ...
- Advantages
  - Rich information
- Disadvantages
  - Highly varied activities
    - Privacy concerns
    - Algorithm complexity

[Cheng and Trivedi, 2007]



# Algorithms

- Taxonomy of methods [Aggarwal & Ryoo 2011]





## Single Layered

- Suitable for recognition of gestures & actions
- Two different representations
  - Space-time distribution
    - Data oriented, spatio-temporal features
  - Sequence
    - Semantic oriented, tracking

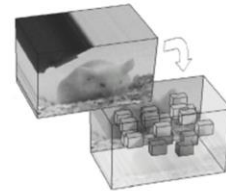
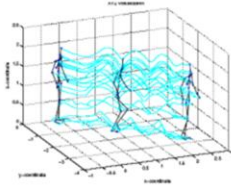


## Space-time Approaches

- Space-time approach representation
  - Volume
  - Trajectories
  - Local features

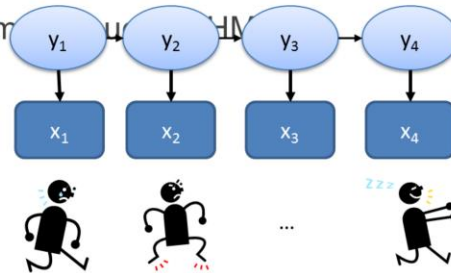


2D nonparametric template matching, Bobick & Davis, IEEE Trans. Pattern Anal. Mach. Intel, 2001

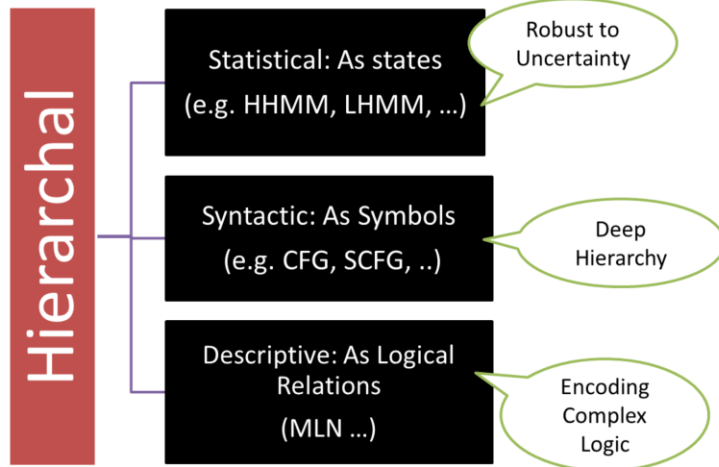


## Sequential Approaches

- Sequential approach
  - Exemplar:
    - Directly build template sequence from training examples
  - State-based
    - Build a m



# Hierarchical Approach





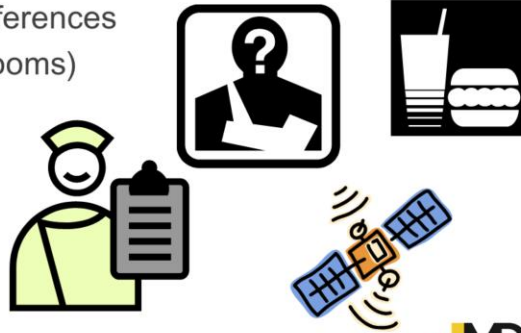
“ ”  
... ”

# Algorithms & Methods:



## Context Information

- Different types of context data
  - Information from sensors
  - Activities and their structure
  - User profile & preferences
  - Static data (e.g. rooms)



## Context Modeling Approaches

1. Key-value models  
e.g. Context Modeling language (CML)
2. Simple markup schema  
e.g. HomeML
3. Ontology  
e.g. SOUPA
4. Uncertain context  
e.g. Meta-data (e.g. freshness, confidence, resolution)
5. Situation modeling & reasoning  
e.g. Situation calculus



## Indoor Location Identification

Method	Disadvantage
Smart floor	Physical reconstruction
Infrared motion sensors	Inaccurate, sensing motion (not presence)
Vision	Privacy
Infrared (active badge)	Direct sight
Ultrasonic	Expensive
RFID	Range
WiFi	Interference, inaccurate







## Person Identification

- Multiple residents
  - Active Identification
    - RFID Badges
  - Anonymous
    - Motion models (Wilson 2005, Crandall 2009)



## Reminders

- Problems [Pollack 2003 , Horvitz 2002, 2011]
  - When to remind?
  - What to remind?
  - Avoiding activity conflicts
- Solutions
  - Planning & scheduling
  - Reinforcement learning





# SOME CASE STUDIES



## Applications



### Cognitive Orthotics

- Reminders
- Planners
- Navigation and stray prevention



### Health Monitoring

- Continuous Monitoring of Vital Signs
- ADL
- Sleep Monitoring



### Therapy & Rehabilitation

- Tele-Health



### Emergency Detection

- Fall Detection
- Medical emergency



### Emotional Wellbeing

- Social Connectedness
- Facilitating Communication

## Reminders

- Simple reminders
  - NeuroPager (1994), MAPS (2005), MemoJog (2005)
- AI-based
  - PEAT (1997), Autominder (2003)



## Autominder

- Developed by Martha E. Pollack et al. (U. Of Michigan)
- Reminders about daily activities
  - Plan manager to store daily plans
  - Resolving potential conflicts
  - Updating the plan as execution proceeds
- Models plans as Disjunctive Temporal Pro
  - Constraint satisfaction approach
  - Payoff function



## COACH

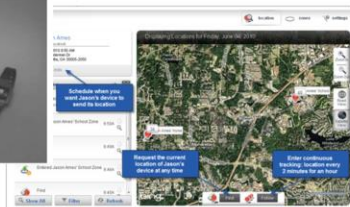
- COACH: Monitoring hand-washing activity and prompting [Mihailidis 2007, U Toronto]
- Vision
- Detecting current state
  - Markov Decision process (MDP)
- Prompting



## Outdoor Stray Prevention

- Opportunity Knocks (OK): public transit assistance [Patterson 2004]
- iRoute: Learns walking preference of dementia patients [Hossain 2011]
- Commercial
  - GPS shoes
  - **ComfortZone**

Bracelet for tracking patients

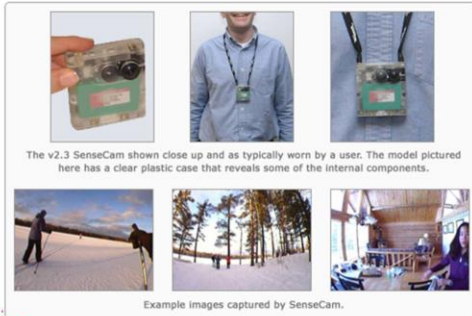


ComfortZone  MASTER OF DIGITAL MEDIA



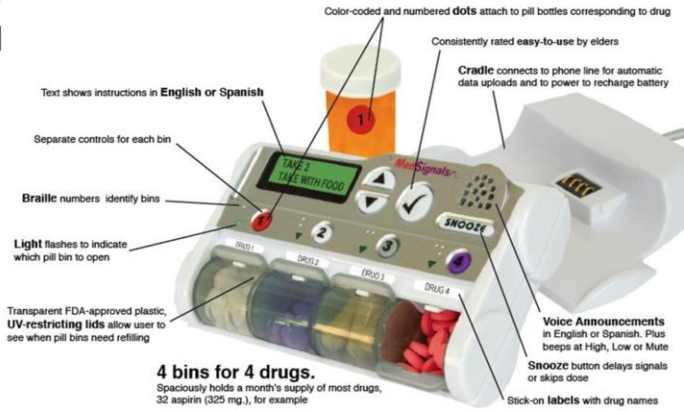
## Memory Aid

- SenseCam
  - Microsoft Research, Cambridge, UK, 2004-2011
  - Now commercially available as REVUE



# Medication Management

- MedSignale
- MI



**4 bins for 4 drugs.**  
 Spaciously holds a month's supply of most drugs, 32 aspirin (325 mg.), for example



MedSignals





# “CASAS SMART HOME”

## Case Studies:



## CASAS Project

- Center for Advanced Studies in Adaptive Systems
- One of the large-scale smart home projects in the nation
  - A couple of on campus testbeds
  - Dozens of real home deployment
- A smart home data repository



Data  
Repository

<http://ailab.eecs.wsu.edu/casas>



# On-campus Testbeds

Camera



sensor ID	date / time	reading
12048146000000B2	2008-02-12 10:50:45.673225	ON
12027E460000000D	2008-02-12 10:50:48.903745	ON
12048146000000B2	2008-02-12 10:50:49.339849	OFF
2084A30D0000003908	2008-02-12 10:50:53.27364	0.0459382
2084A30D0000003908	2008-02-12 10:51:05.6252	0.158401

## Actual Deployments

- Patients with mild form of dementia
- Noninvasive deployment
- Prompting systems



# Prompting Technology



- Context-based
- Prompt only if task not initiated
- Prompt can be re-issued



I will do it now



I will do it later



I've done this task



I won't do this task





# DESIGN ISSUES





## Wearable & Mobile Design Issues

- Issues:
  - Physical interference with movement
  - Difficulty in removing and placing
  - Weight
  - Frequency and difficulty of maintenance
    - Charging
    - Cleaning
  - Social and fashion concerns
- Suggestions:
  - Use common devices to avoid stigmatization
  - Lightweight
  - Easy to maintain



## User Interface Design Issues

- Simple Interface
- Limit possibility of error
- Avoid cognitive overload
  - Limit options
  - keep dialogs linear
  - Avoid parallel tasks
- Consider all stakeholders
  - Patient, formal onsite/offsite caregivers, informal onsite/offsite caregivers, technical personnel



## Privacy & Ethics

- Ethics
  - Perfect transparency
  - Control over the system
  - Fight laziness
- Privacy
  - Encrypt data
  - Patient authentication (Owner aware)





# CHALLENGES & FUTURE



## Are they ready to adopt?

- Healthy older adults use technology more often\*
  - “Not being perceived as useful” \*
- Better a known devil than an unknown god
- Privacy Concerns
  - Big brother
  - Stigmatization



## Smart Home Challenges

- Smart homes
  - Location detection
    - Privacy/unobtrusiveness vs. accuracy
    - Difficulty with multiple residents
    - PIR sensor proximity is important
  - Reliability
    - Distinguishing anomalies from normal changes
  - Become more context aware
  - Standard protocol



## Wearable & Mobile Challenges

- Wearable & mobile
  - Power harvesting
  - Size
- Smart fabrics
  - Limitations when skin is dry or during intense activity
  - Still hybrid



## Assistive Robotics Challenges

- Assistive robotics
  - Marketing and price
  - Lack of reliable technology
  - A robot fully capable of helping with all ADLs
  - Adaptive robots
  - More user studies





## Legal & Ethical Challenges

- Legal, ethical
  - Telemedicine
    - Lack of regulations
      - Which state regulations? Patient's or Physician?
      - Who is responsible for malpractice?
    - Risk of fake physicians
    - Physician out-of-state competition
  - Insurance & reimbursement
  - Patient confidentiality



## Future

- Technology
  - Device interoperability
- Legal issues
- Patient centric
- Integrate all
  - Robots + smart home + wearable/mobile sensors + e-textile
- Technology transfer, go beyond prototype





# RESOURCES



## Assistive Robotics

- 2011 technical report on “robot assistance for older adults”
  - Understanding the potential for robot assistance for older adults in the home environment (HFA-TR-1102). Smarr, C. A., Fausset, C. B., Rogers, W. A. (2011). Atlanta, GA: Georgia Institute of Technology, School of Psychology, Human Factors and Aging Laboratory.
- 2009 review article on “Assistive social robots in elderly care”
  - Broekens J., Heerink M., Rosendal H. *Assistive social robots in elderly care: a review. Gerontechnology 2009; 8(2):94-103*
- 2011 technical report on “Robot acceptance”
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## Vision

- **Human Activity Analysis Survey**

- J.K. Aggarwal and M.S. Ryoo. 2011. Human activity analysis: A review. ACM Comput. Surv. 43, 3, Article 16.

- **Survey: Recognition of Human Activities**

- Turaga, P.; Chellappa, R.; Subrahmanian, V.S.; Udrea, O.; , "Machine Recognition of Human Activities: A Survey," Circuits and Systems for Video Technology, IEEE Transactions on , vol.18, no.11, pp.1473-1488, Nov. 2008.

- **CVPR 2011 Tutorial on Human Activity Recognition: Frontiers of Human Activity Analysis**

- <http://cvrc.ece.utexas.edu/mryoo/cvpr2011tutorial/>



## Wearable Sensors

- **Wearable monitoring systems book**
  - Bonfiglio, Annalisa; De Rossi, Danilo, *Wearable Monitoring Systems*, Springer, 2011.
- **On-board data mining book**
  - S. Tanner et al., *On-board data mining*, *Scientific Data Mining and Knowledge Discovery*, Volume . ISBN 978-3-642-02789-5. Springer-Verlag Berlin Heidelberg, 2009, p. 345
- **Excellent tutorial on time series**
  - Eamonn Keogh's VLDB06 Tutorial



## Activity Recognition

- Activity Recognition Book

- Chen, Liming, Nugent, CD, Biswas, J and Hoey, J. "Activity Recognition in Pervasive Intelligent Environments", 2011, Springer.

- Context Aware Modeling Survey

- Claudio Bettini, et al., "A survey of context modeling and reasoning techniques", Pervasive and Mobile Computing, Volume 6, Issue 2, April 2010, Pages 161-180.

- HMM Tutorial

- Rabiner, L.R.; , "A tutorial on hidden Markov models and selected applications in speech recognition," Proceedings of the IEEE , vol.77, no.2, pp.257-286, Feb 1989.



## Smart Homes

- **Intelligent Environments Book**

- Monekosso, Dorothy; Kuno, Yoshinori. "Intelligent Environments: Methods, Algorithms and Applications", 2011, Springer.

- **Smart Environments Book**

- Diane J. Cook, Sajal K. Das. Smart environments: technologies, protocols, and applications. John Wiley and Sons, 2005.

- **Smart Home Survey**

- Marie Chan, Daniel Estve, Christophe Escriba, and Eric Campo. 2008. A review of smart homes-Present state and future challenges. *Comput. Methods Prog. Biomed.* 91, 1 (July 2008)





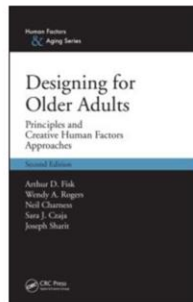
## Legal, Ethical

- Legal and ethical issues in telemedicine and robotics
  - B.M. Dickens, R.J. Cook, Legal and ethical issues in telemedicine and robotics, Int. J. Gynecol. Obstet. 94 (2006) 73–78.
- Telemedicine: Licensing and Other Legal Issues
  - Gil Siegal, Telemedicine: Licensing and Other Legal Issues, Otolaryngologic Clinics of North America, Volume 44, Issue 6, December 2011, Pages 1375-1384
- Older adults: Are they ready to adopt health-related ICT?
  - Tsipi Heart, Efrat Kalderon, Older adults: Are they ready to adopt health-related ICT?, International Journal of Medical Informatics, ISSN 1386-5056, 2011.



## Design

- **Designing for Older Adults**
  - Arthur D. Fisk, Wendy A. Rogers, Neil Charness, Joseph Sharit. Designing Displays for Older Adults. CRC Press, 26.3.2009.
- **Design meets disability**
  - Graham Pullin. "Design meets disability", 2009, MIT Press.



## General Resources

- **Gerontechnology Journal:** International journal on the fundamental aspects of technology to serve the ageing society
  - <http://www.gerontechnology.info/Journal/>
- **Assistive Technology: Journal of Assistive Technologies**
  - <http://www.emeraldinsight.com/journals.htm?issn=1754-9450>
- **Ambient Assisted Living Joint Programme of EU**
  - <http://www.aal-europe.eu/>



## Datasets

- Washington State University CASAS dataset
  - <http://ailab.eecs.wsu.edu/casas/datasets/index.html>
- My collection of links
  - <http://www.cise.ufl.edu/~prashidi/Datasets/ambientIntelligence.html>
- PAIR datasets
  - <http://homepages.inf.ed.ac.uk/cgeib/PlanRec/Resources.html>



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2. Emmanuel Munguia Tapia, Tanzeem Choudhury and Matthai Philipose, Building Reliable Activity Models Using Hierarchical Shrinkage and Mined Ontology. *Lecture Notes in Computer Science*, 2006, Volume 3968/2006.
3. Latfi, Fatiha, and Bernard Lefebvre. Ontology-Based Management of the Telehealth Smart Home , Dedicated to Elderly in Loss of Cognitive Autonomy. *Management* 258: 12-12, 2007.
4. Chen, Luke, Nugent, Chris D., Mulvenna, Maurice, Finlay, Dewar and Hong, Xin (2009) *Semantic Smart Homes: Towards Knowledge Rich Assisted Living Environments*. In: *Intelligent Patient Management, Studies in Computational Intelligence*. Springer Berlin / Heidelberg, pp. 279-296. ISBN 978-3-642-00178-9.
5. A.K. Dey, et al. "A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of ContextAware Applications", *Human-Computer Interaction Journal*, Vol. 16(2-4), pp. 97-166, 2001.



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