Spatio-Temporal Reasoning and Context Awareness

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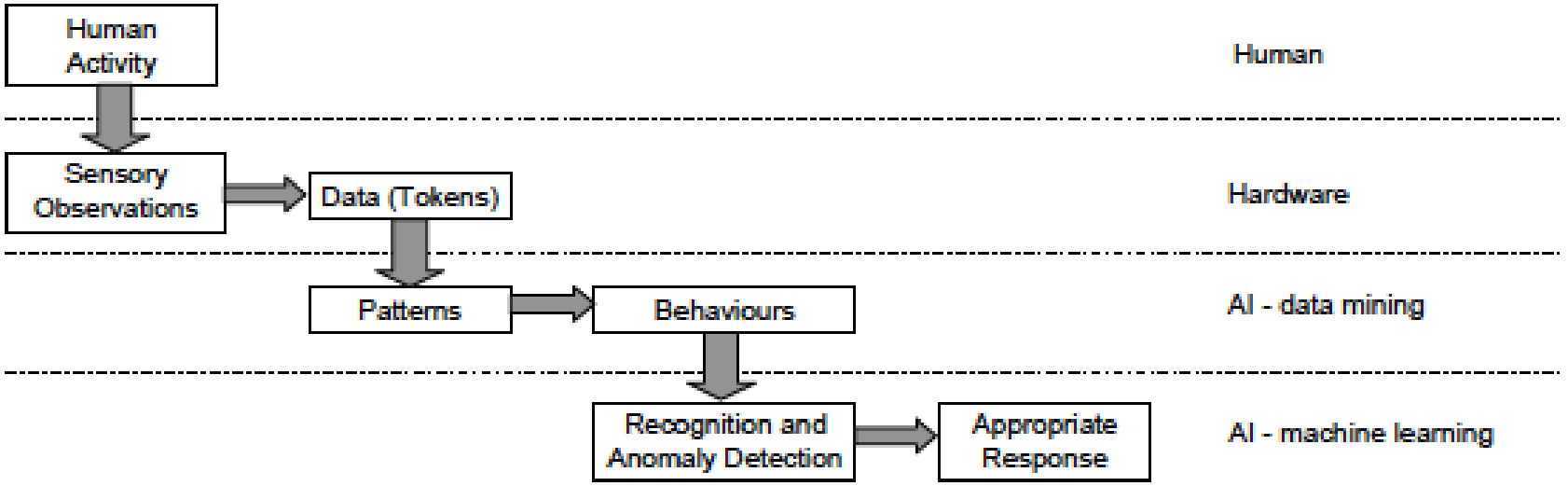
Overview

- Concerned with “smart” homes
- How best to represent sensor info?
- Not interested in:
  - What the sensors are, how they are processed
- How then to interpret that info?
- How to use those interpretations?
- Exploration of various reasoning (AI) techniques
  - Pros and Cons of each

“Smart” Homes



- Their “Smart” in Smart home means AI
- Use AI to learn human behavior then interpret it

Use Case

- Driving use case for paper
  - Aging population wanting to stay in home
  - Stress on spousal caregiver, or cost of hired caregiver
  - Smart Home can notify caregiver of abnormal behavior
  - Use of “unobtrusive” monitoring

Issues

- How to learn/define normal behaviors?
- How to adapt to changing behaviors?
  - Time of day, time of year, age, slight modification (tea vs. coffee)
- Identify abnormal behaviors
  - Difficult to “learn” due to infrequency
- Key issue: Avoid false positives
  - “False positives are a major reason why genuine emergencies are missed” - no corroboration

How to define normal behaviors?

- Break all sensor info into “tokens” – sensor started or stopped
  - Sensors – motion detector, coffee maker, stove, etc
- Patterns of tokens define behaviors
  - Sensors know where they are and when they change state

Formal Methods

- Human Behaviors are inherently Spatio-Temporal
  - Qualitative location - “in the kitchen” as opposed to at point x,y
  - Qualitative time – at lunchtime, not at 12:07
- Temporal
  - Allen's temporal logic
    - Time intervals and their relationships (Allen's composition table)
  - Point Algebra
    - Time points rather then intervals
- Spatial
  - Can be also applied to spatial – replace time

Topological

- Determined to be most important – the author's premise

  "We argue that the topological aspects of space are the most relevant ones for modelling human behaviour in an ambient intelligence."

- Topological reasoning calculus
  - Region Connection Calculus – 8 possible relationships
    - Given two relationships between regions, determine a third relationship
      - Example: if the region that the person is standing in (**R**1) is disconnected from the region occupied by the box (**R**2) and if the region taken up by the book (**R**3) is a tangential proper part of **R**2 , then we can conclude that **R**1 and **R**3 are disconnected

AI Symbolic Approaches

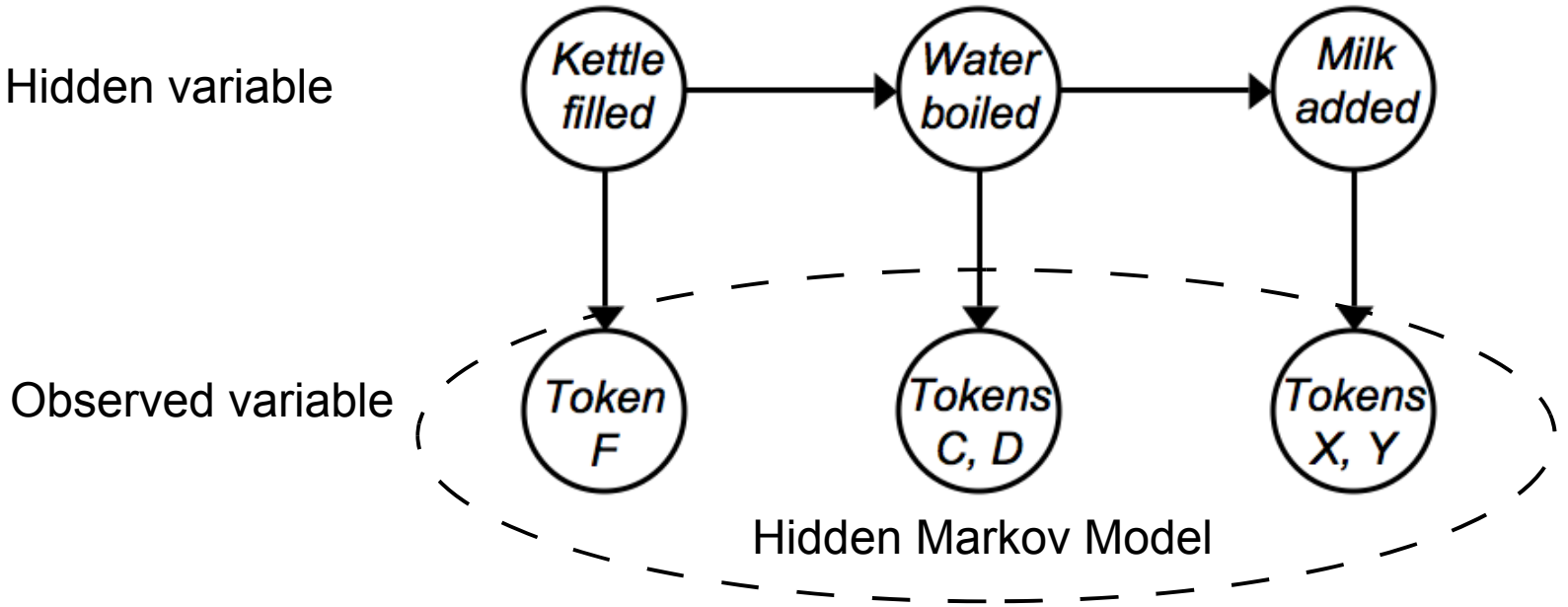
- Situation Calculus
  - Logic based on states - effects (state changes) from actions
  - Generally used to assemble actions to meet a task
  - This use case is the inverse – given a set of actions what will be the result?
    - Database of actions → outcomes – problem variation
    - No time and space associations
  - Can be used to identify abnormal behavior
    - Reasoning engine must be developed
      - ON *event* IF *action* THEN *action*

Machine Learning Topics

- Frequent Pattern Data Mining
  - Record sequence of operations in a time interval
  - Extract combinations that appear together – FP Tree approach
  - Define the longest possible repeated patterns
  - Problems
    - Patterns not necessarily contiguous – eg. Wash dishes while waiting for tea water to boil
    - Not necessarily in same order – pour water then put in tea bag or vice versa

Machine Learning Topics

- Graphical models
  - Variables=nodes, edges=relationships
  - Previously identified a sequence of tokens to equal a behavior
  - Use these to identify normal or abnormal behavior in real time



Tea Making - non-trivial

Novelty Detection

- Neural network
  - Novelty detection overcomes problem of always giving an answer
  - If behavior does not match training set – termed 'novel'

> "...the novelty of the wife in the best friend's bed lies neither in the wife, nor the friend, nor the bed, but in the unfamiliar conjunction of the three."

  - Habituation – reduction in reaction to commonly seen stimuli
    - Use two models with different characteristics
      - Both respond = new
      - Neither respond = common
      - Seen before, but not recently = short memory one responds
      - New behavior occurring suddenly occurring = long memory responds

Final Thoughts

- “The chapter has most certainly fallen short of presenting one homogeneous solution to the problem of classifying complex human behavior.”

- Paper covered many different possible reasoning techniques
  - None perfect
  - Good – detect abnormal behavior without explicit human modeling – just by learning common behaviors or sequences of tokens
  - Use of nonintrusive simple sensors

The more we have looked into the data that is presented in smart home problems, the more important context awareness and spatio-temporal reasoning have seemed to us.

Backup

Allen's Composition Table

- Given relationships between O1r1O2 and O2r2O3 then...

  < before,

  > after

  m meets

  mi met by

  o overlaps

  oi overlaped by

  s starts

  si started by

  d during

  di contains

  f finishes

  fi finished by

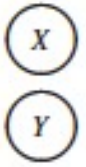
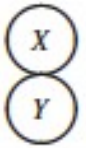
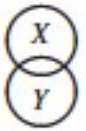
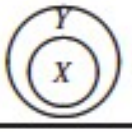
  = equals

	<	m	o	fi	di	si	=	s	d	f	oi	mi	>
<	<	<	<	<	<	<	<	<	<, m o, s d	<, m o, s d	<, m o, s d	<, m o, s d	<, m o, s d f, =, fi di, si, oi mi, >
m	<	<	<	<	<	m	m	m	o, s d	o, s d	o, s d	f, = fi	di si, oi mi, >
o	<	<	<, m o	<, m o	<, m o fi, di	o fi, di	o	o	o, s d	o, s d	o, s d, f, = fi, di si, oi	di si, oi	di si, oi mi, >
fi	<	m	o	fi	di	di	fi	o	o, s d	f, = fi	di si, oi	di si, oi	di si, oi mi, >
di	<, m o fi, di	o fi, di	o fi, di	di	di	di	di	o fi, di	o, s d, f, = fi, di si, oi	di si, oi	di si, oi	di si, oi	di si, oi mi, >
si	<, m o fi, di	o fi, di	o fi, di	di	di	si	si	s, = si	d, f oi	oi	oi	mi	>
=	<	m	o	fi	di	si	=	s	d	f	oi	mi	>
s	<	<	<, m o	<, m o	<, m o fi, di	s, = si	s	s	d	d	d, f oi	mi	>
d	<	<	<, m o, s d	<, m o, s d	<, m o, s, d f, =, fi di, si, oi mi, >	d, f oi, mi >	d	d	d	d	d, f oi, mi >	>	>
f	<	m	o, s d	f, = fi	di si, oi mi, >	oi mi, >	f	d	d	f	oi mi, >	>	>
oi	<, m o fi, di	o fi, di	o, s d, f, = fi, di si, oi	di si, oi	di si, oi mi, >	oi mi, >	oi	d, f oi	d, f oi	oi	oi mi, >	>	>
mi	<, m o fi, di	s, = si	d, f oi	mi	>	>	mi	d, f oi	d, f oi	mi	>	>	>
>	<, m o, s, d f, =, fi di, si, oi mi, >	d, f oi, mi >	d, f oi, mi >	>	>	>	>	d, f oi, mi >	d, f oi, mi >	>	>	>	>

Point Algebra relations

Relation	*Illustration*	*Interpretation*
$P_1 < P_2$		P_1 precedes P_2
$P_1 = P_2$		P_1 same as P_2
$P_1 > P_2$		P_1 follows P_2

Region Connection Calculus

Relation	*Illustration*	*Interpretation*
DC(X,Y)		X disconnected from Y
EC(X,Y)		X externally connected to Y
PO(X,Y)		X partially overlaps Y
EQ(X,Y)		X identical with Y
TPP(X,Y)		X tangential proper part of Y
TPPi(X,Y)		Y tangential proper part of X
NTPP(X,Y)		X nontangential proper part of Y
NTPPi(X,Y)		Y nontangential proper part of X