DePaul University
College of Computing and Digital Media

Casey Bennett, PhD

Mar.4, 2019

Last Week

- HW4 due today
- Final Projects

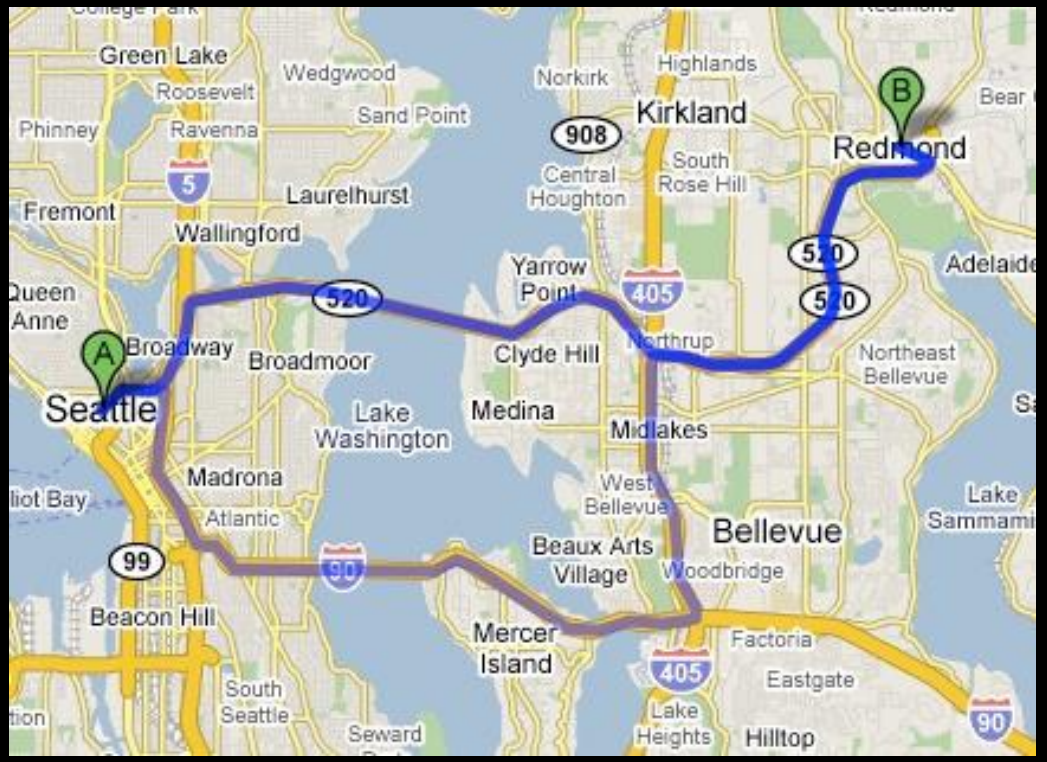
Pecha Kucha

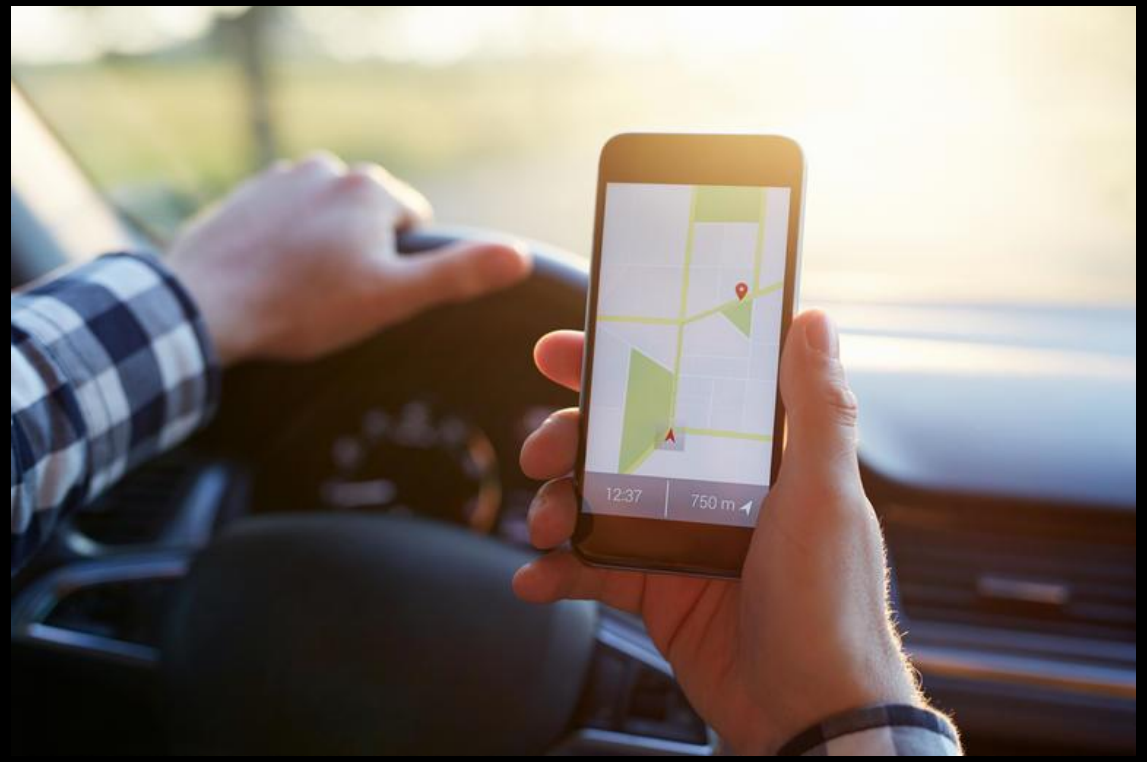
- 20 slides, 20 seconds each

Markov Models and Temporal Modeling

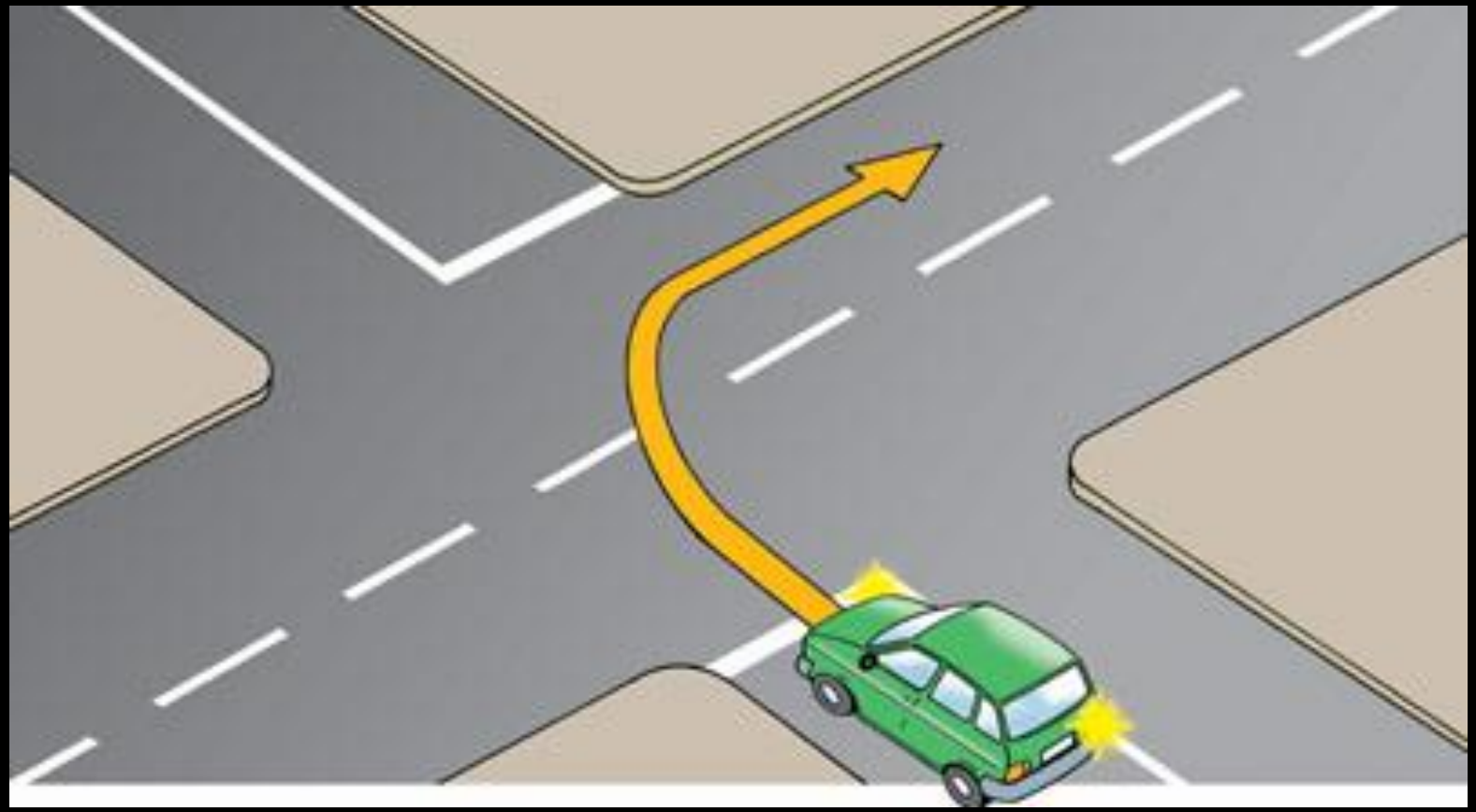
https://pollev.com/caseybennett801

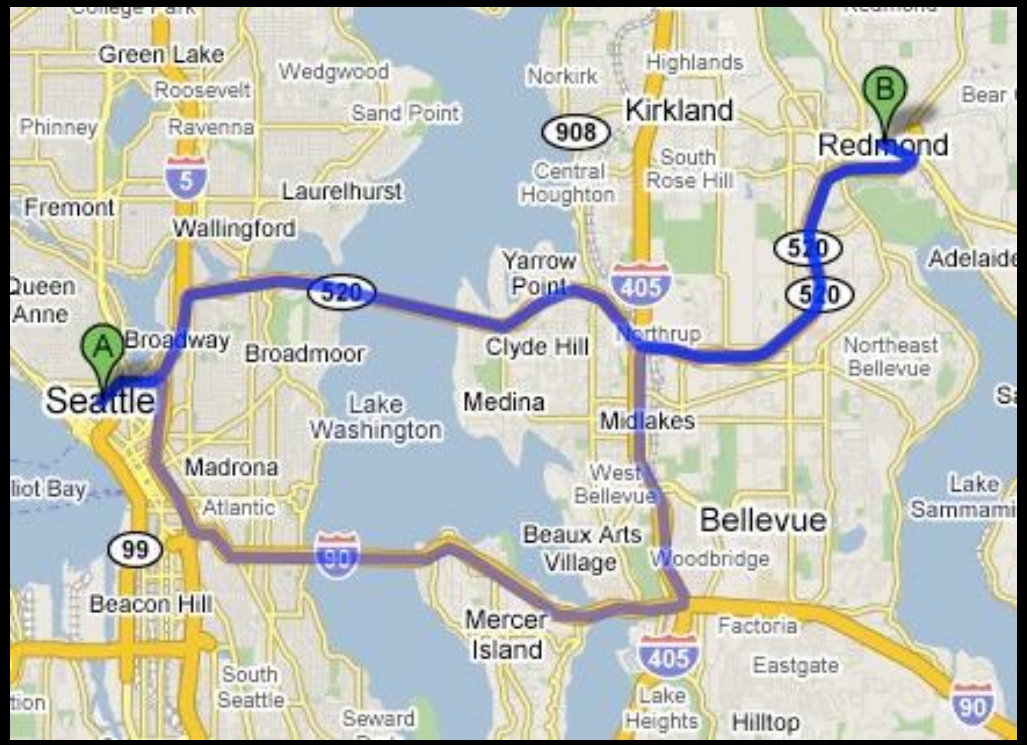
or text “caseybennett801” to 37607

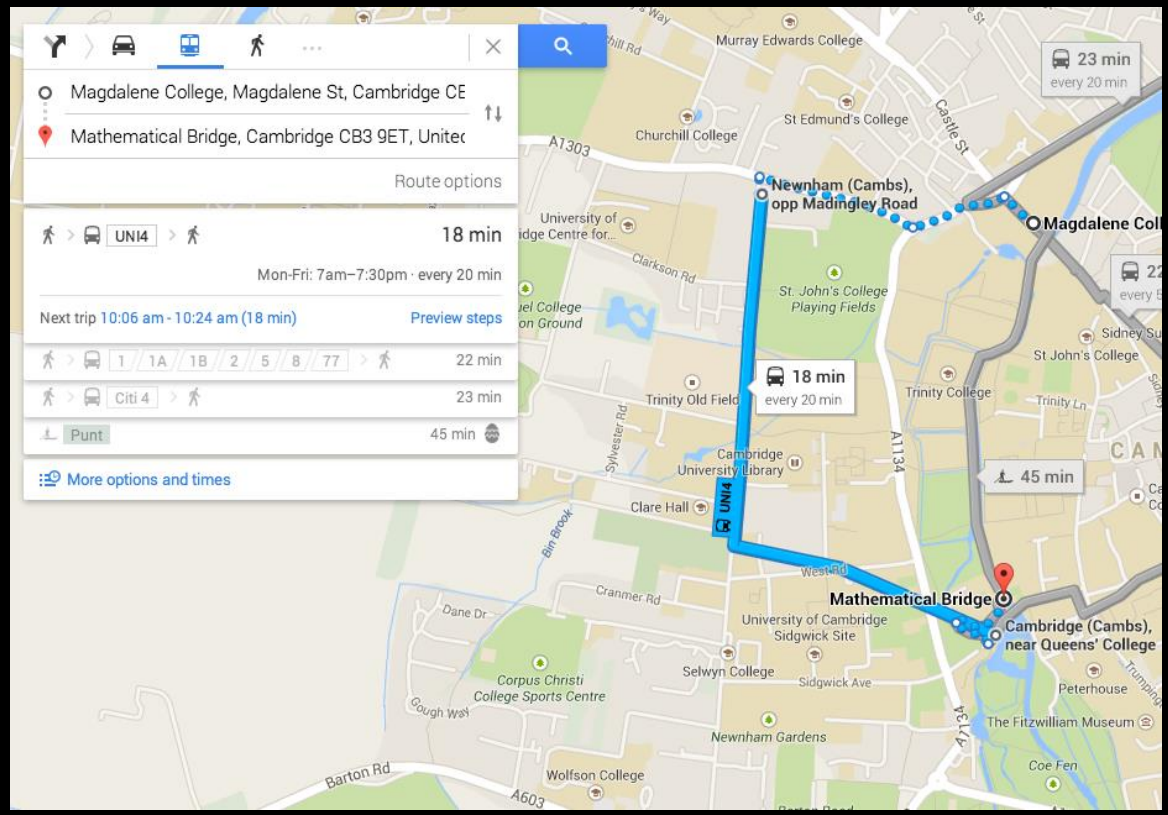




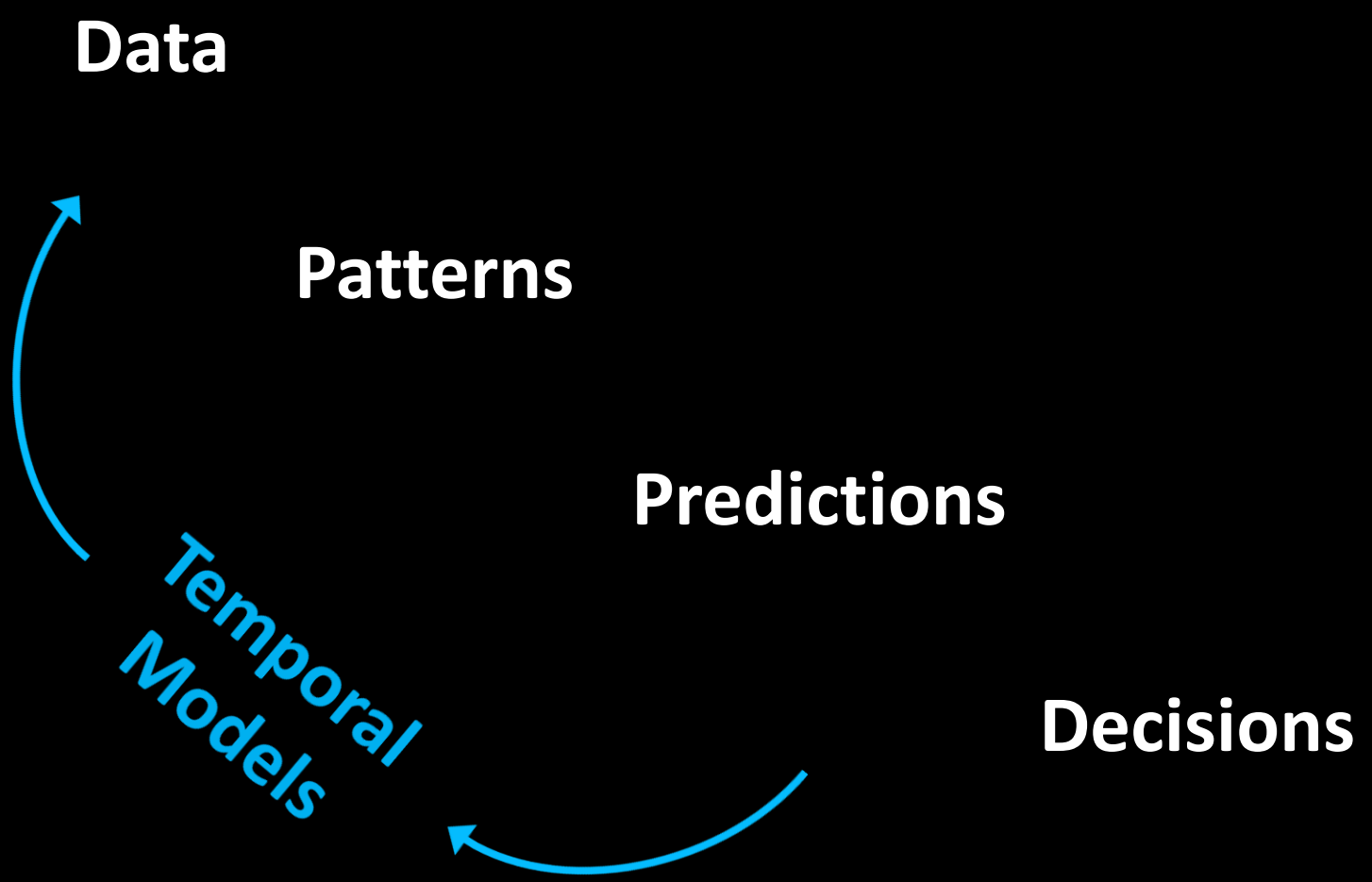
How does GPS find the best route from here to the airport?




Green Lake
Wedgwood
Roosevelt
Norkirk
Highlands
Kirkland
Redmond
Phinney
Ravenna
Sand Point
908
Central Houghton
South Rose Hill
Fremont
Laurelhurst
Wallingford
5
520
Yarrow Point
405
Adelaide
Queen Anne
Broadway
Broadmoor
Clyde Hill
Northrup
Northeast Bellevue
Seattle
Lake Washington
Medina
Midlakes
Madrona
West Bellevue
Lake Sammamish
Atlantic
Bellevue
Beaux Arts Village
Woodbridge
99
90
Beacon Hill
Mercer Island
Factoria
Eastgate
South Seattle
Lake Heights
Seward
Hilltop


Magdalene College, Magdalene St, Cambridge CB
Mathematical Bridge, Cambridge CB3 9ET, United
Route options
UNI4
18 min
Mon-Fri: 7am–7:30pm · every 20 min
Next trip 10:06 am - 10:24 am (18 min)
Preview steps
1
1A
1B
2
5
8
77
22 min
Citi 4
23 min
Punt
45 min
More options and times
Murray Edwards College
23 min
every 20 min
Churchill College
St Edmund's College
A1303
Newnham (Cambs), opp Madingley Road
Magdalene Coll
University of
Clarkson Rd
St. John's College Playing Fields
18 min
every 20 min
Trinity Old Field
Trinity College
St John's College
Cambridge University Library
A1134
45 min
Clare Hall
UNI4
Bin Brook
Cranmer Rd
Mathematical Bridge
Cambridge (Cambs), near Queens' College
Dane Dr
University of Cambridge Sidgwick Site
Selwyn College
Sidgwick Ave
Corpus Christi College Sports Centre
Peterhouse
Gough Way
The Fitzwilliam Museum
Newnham Gardens
Coe Fen
Barton Rd
Wolfson College
A603

Building a Pipeline



Step 1

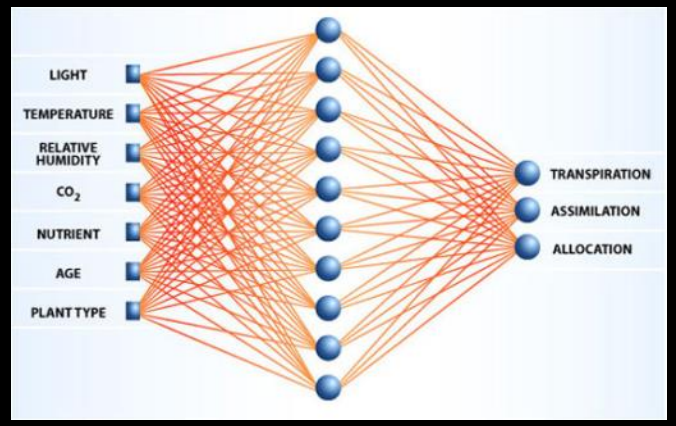
Make Predictions

Clinical Indicators

Socio-demographic

Genetic Data

Etc.



Patterns

Machine Learning/Statistical Techniques – predict risk stratification, treatment response , survival, re-hospitalization, LOS, etc.

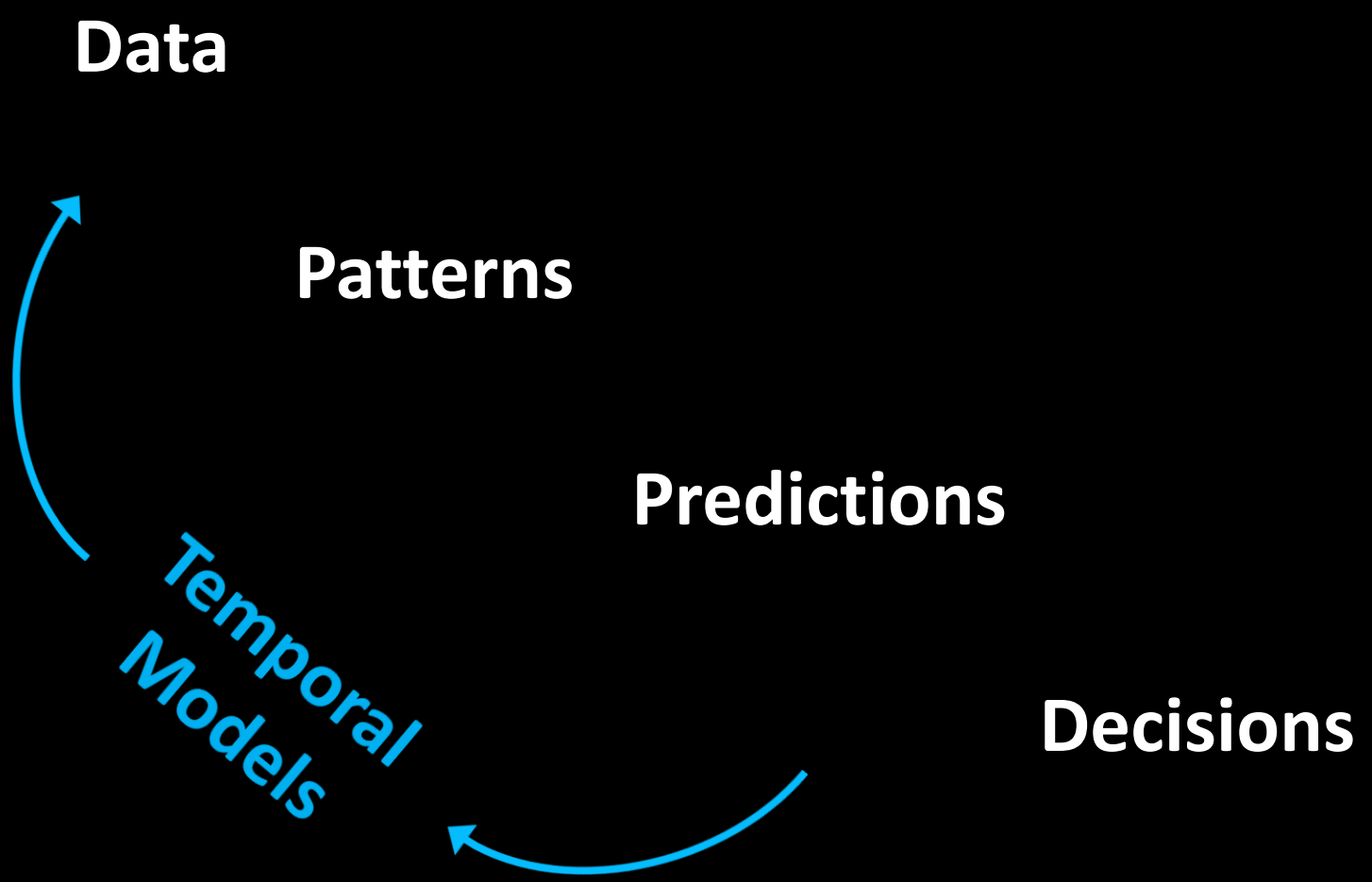
The basic assumption is that the pattern is *stationary*

But sometimes this happens …

How could you avoid a *random* traffic jam or wreck?

The things we do *now* constrain what we can do in the *future*

Building a Pipeline



Step 3

Make Predictions

Clinical Indicat

Socio-demog

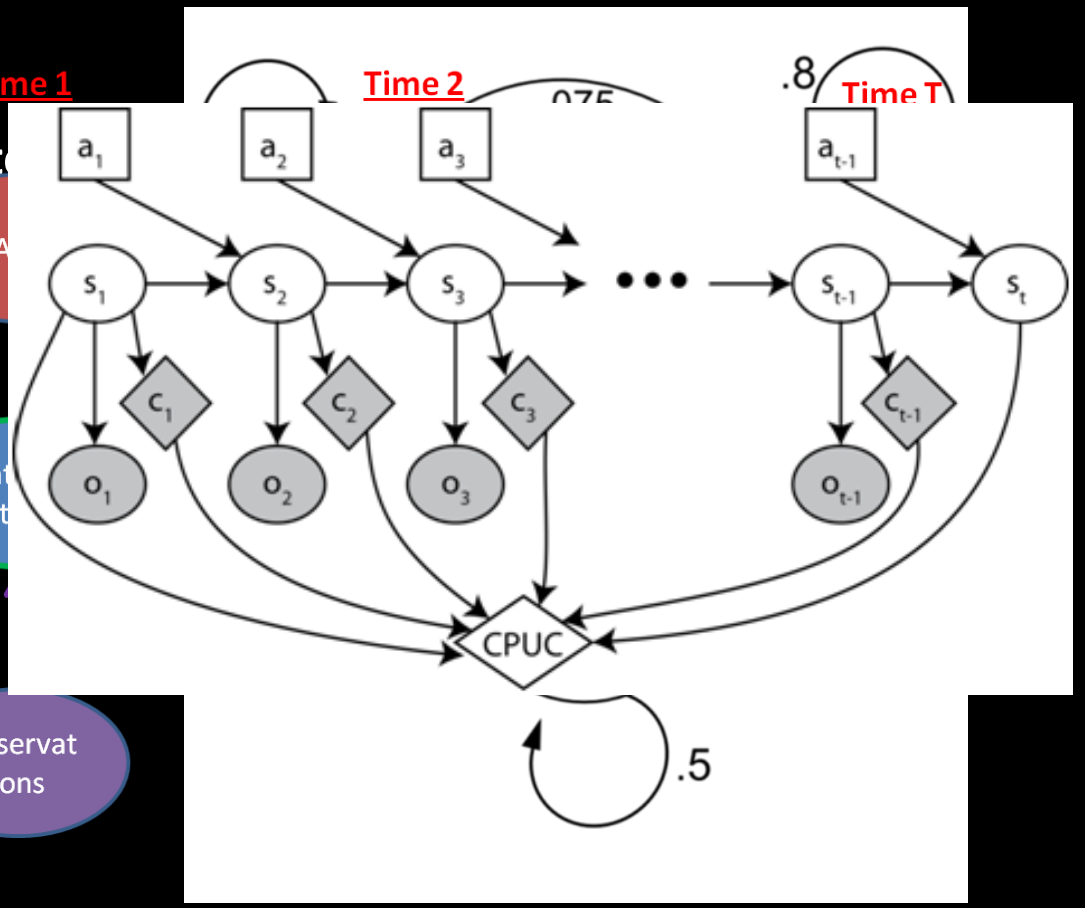
Genetic Data

Etc.

Tx A

Pat
St

Observat
ions



Patterns

a = Action/Treatment
s = Patient State
o = Observation
c = Costs
r = Rewards
cpuc = Utility

Patterns

Predictions

Transition Models

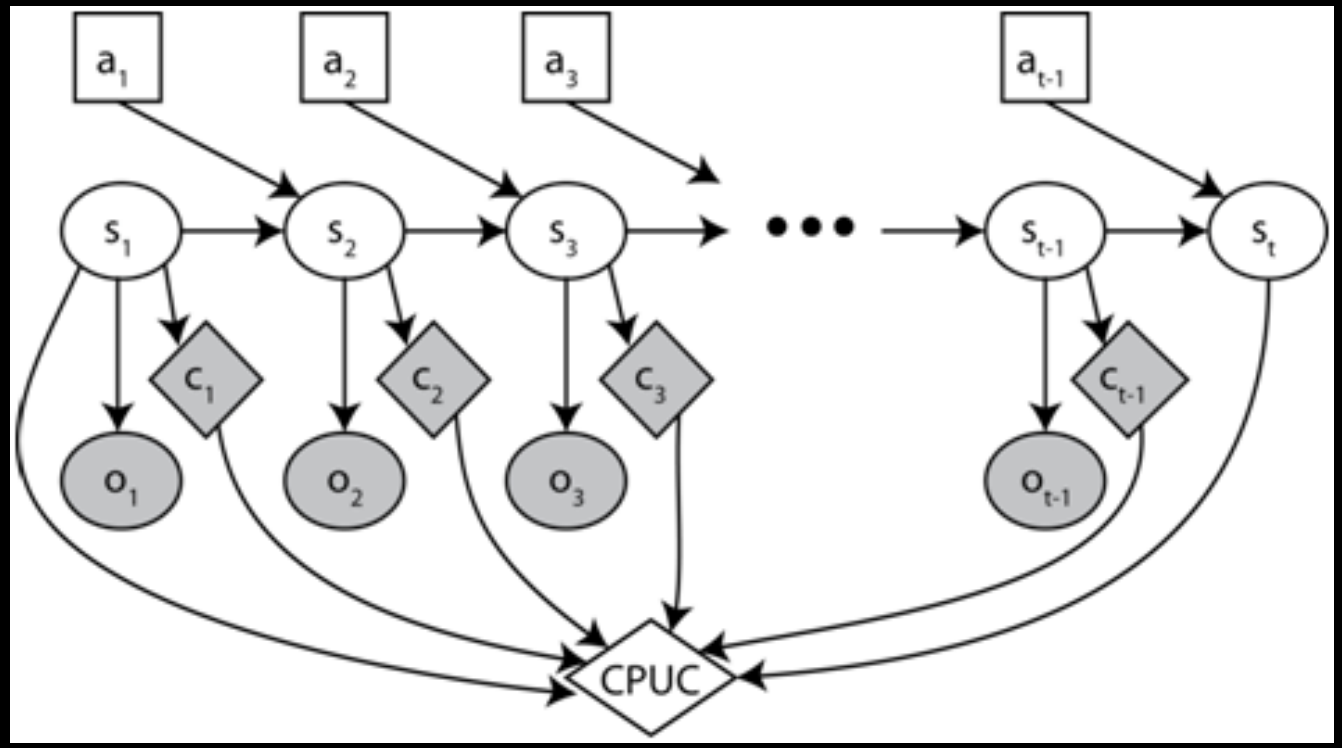
Markov Decision Processes (MDPs)

Machine Learning/Statistical Techniques – predict risk stratification, treatment response, survival, Decision Analysis, OR, etc.

Dynamic Decision Networks (DDNs)

Step 3

Make Decisions



a = Action/Treatment
s = Patient State
o = Observation
c = Costs
t = Time
cpuc = Utility

Belief States

Plan over Time

Plan/re-plan

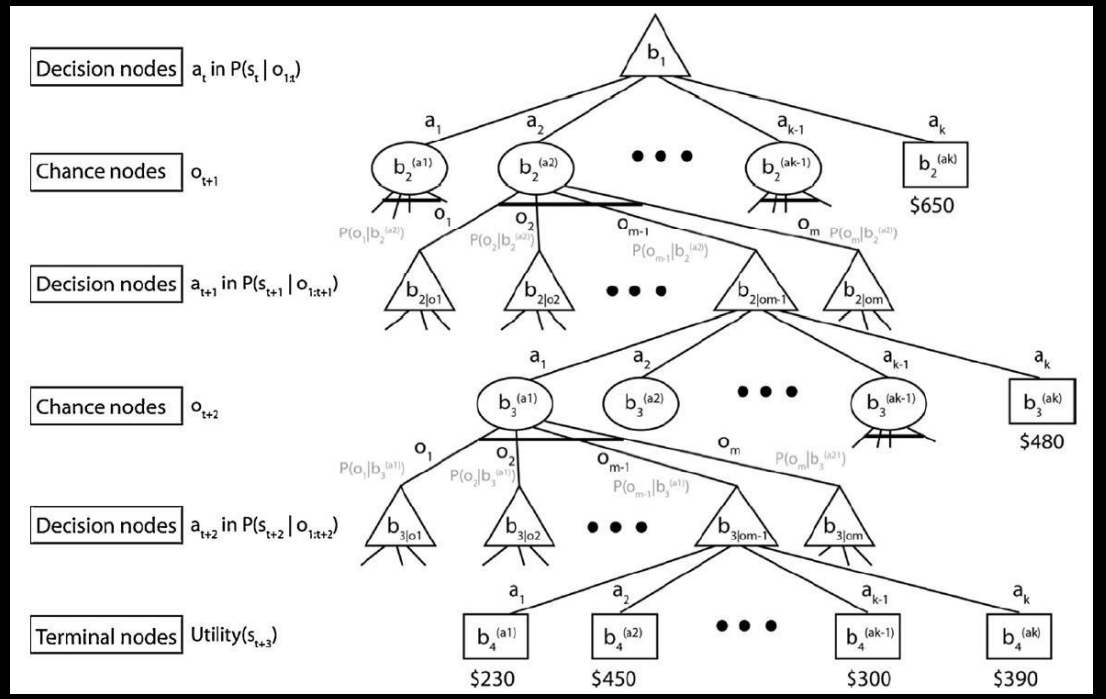
Markov Models

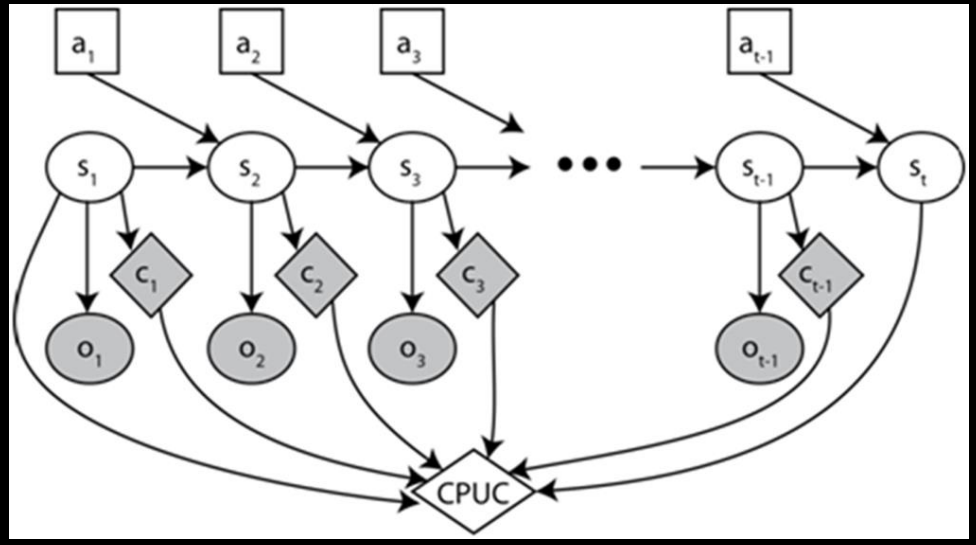
- Based on the Markov property
- How far we go back in time to get information is called the order of the Markov model
- We also usually have some time horizon to which we limit predicting
- Markov model = chain = process

Solving an MDP

- Bellman Equations
- These are used to produce a “policy”

What might be a problem with producing a “policy” for the way the world works?





a = Action/Treatment
b= Probabilities
s = Patient State
o = Observation
c = Costs
t = Time
CPUC = utility

Patient 1

- 50-year old patient, primary depression diagnosis, Physician Referral
- "Arranging Mental Health Visit" makes **no difference** in chance of improvement, <10% either way
- Main risk factors included: lower overall historical costs, referral reason, and higher GAD score

Patient 2

- 21-year old cancer patient with depression, referred via ER Admission
- "Arranging Mental Health Visit" would **double** chance of improvement, 33.1% vs. 64.5%
- Main risk factors included: higher historical drug costs and young age

52.89.63.101:8000/Faros_app/FarosAPI/

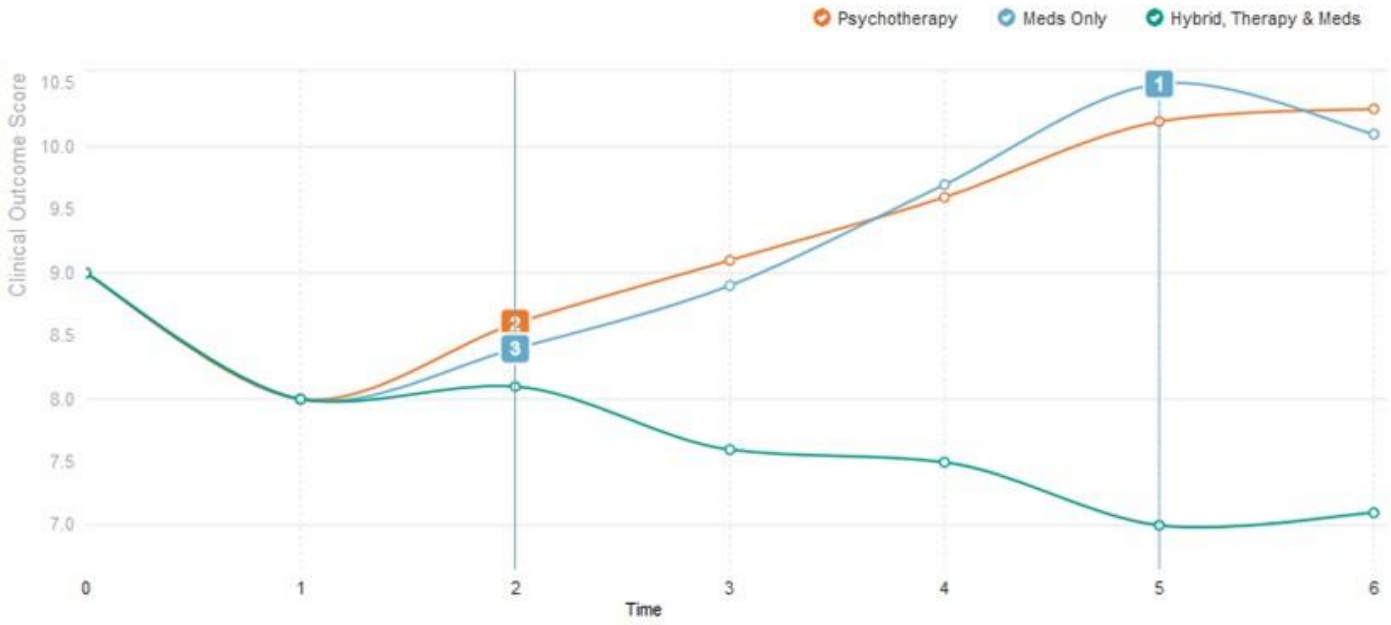
Search

Treatments Clinical Outcome Score

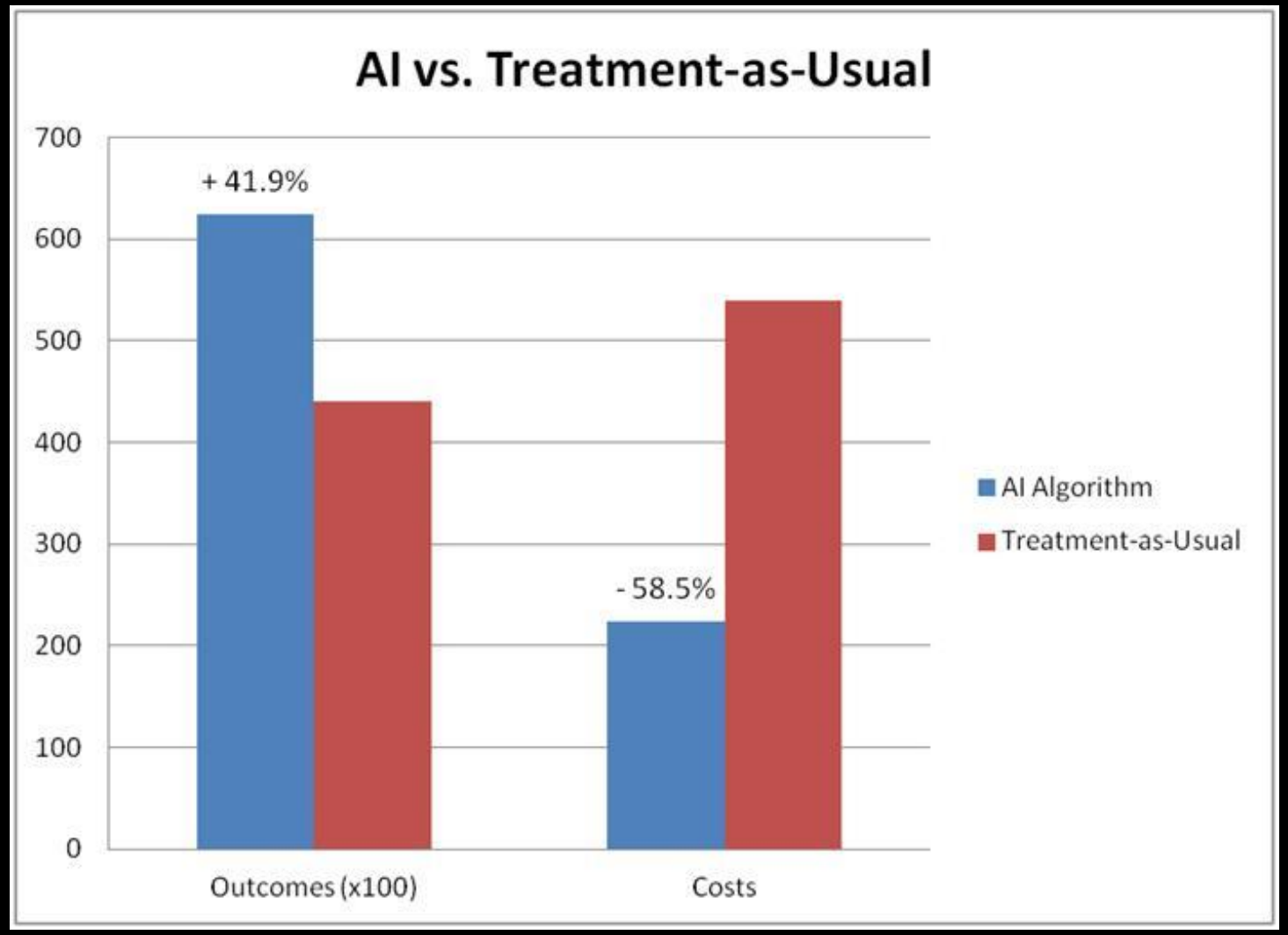
Patient #47

Maximal Treatment Plans

1st Plan		2nd Plan		3rd Plan	
Meds Only		Psychotherapy		Meds Only	
CPUC	$221.33	CPUC	$239.99	CPUC	$256.54
Raw Cost	$331.99	Raw Cost	$88.14	Raw Cost	$83.00
Outcome Score	10.5	Outcome Score	8.6	Outcome Score	8.4



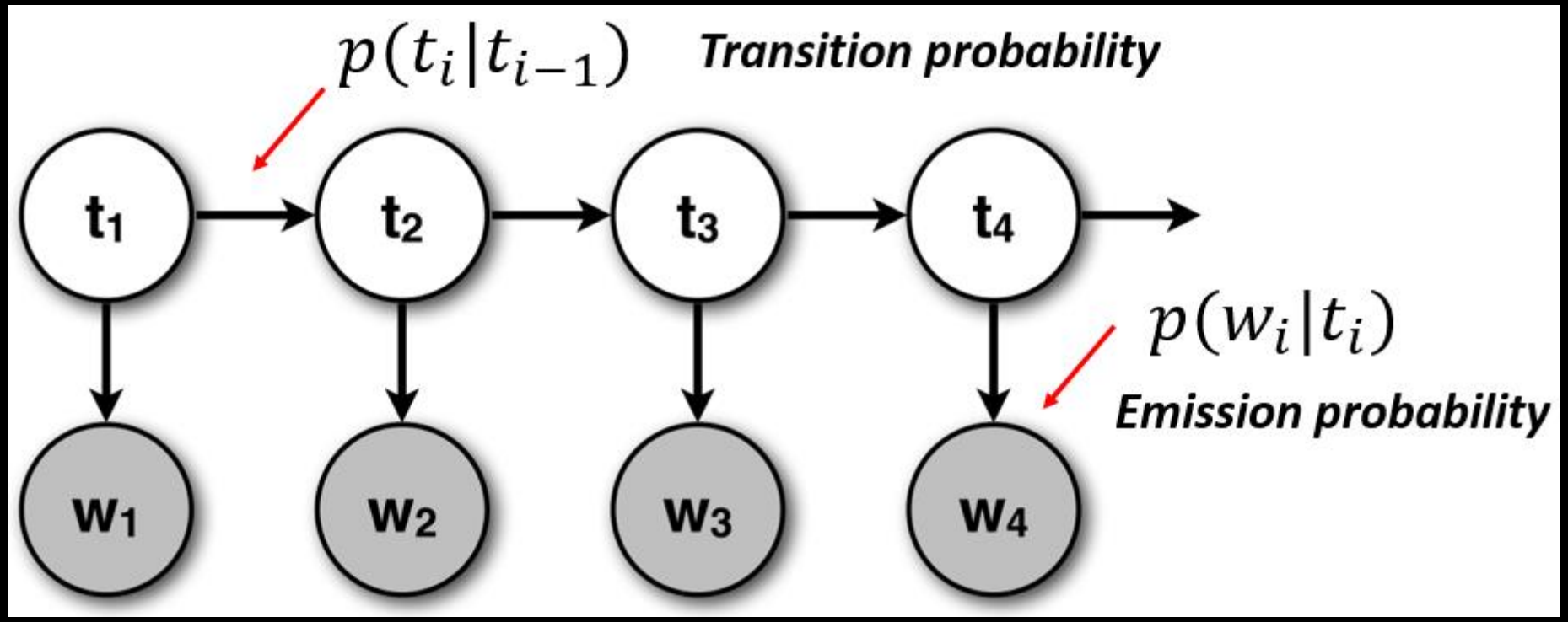
Results with Real Patient Data



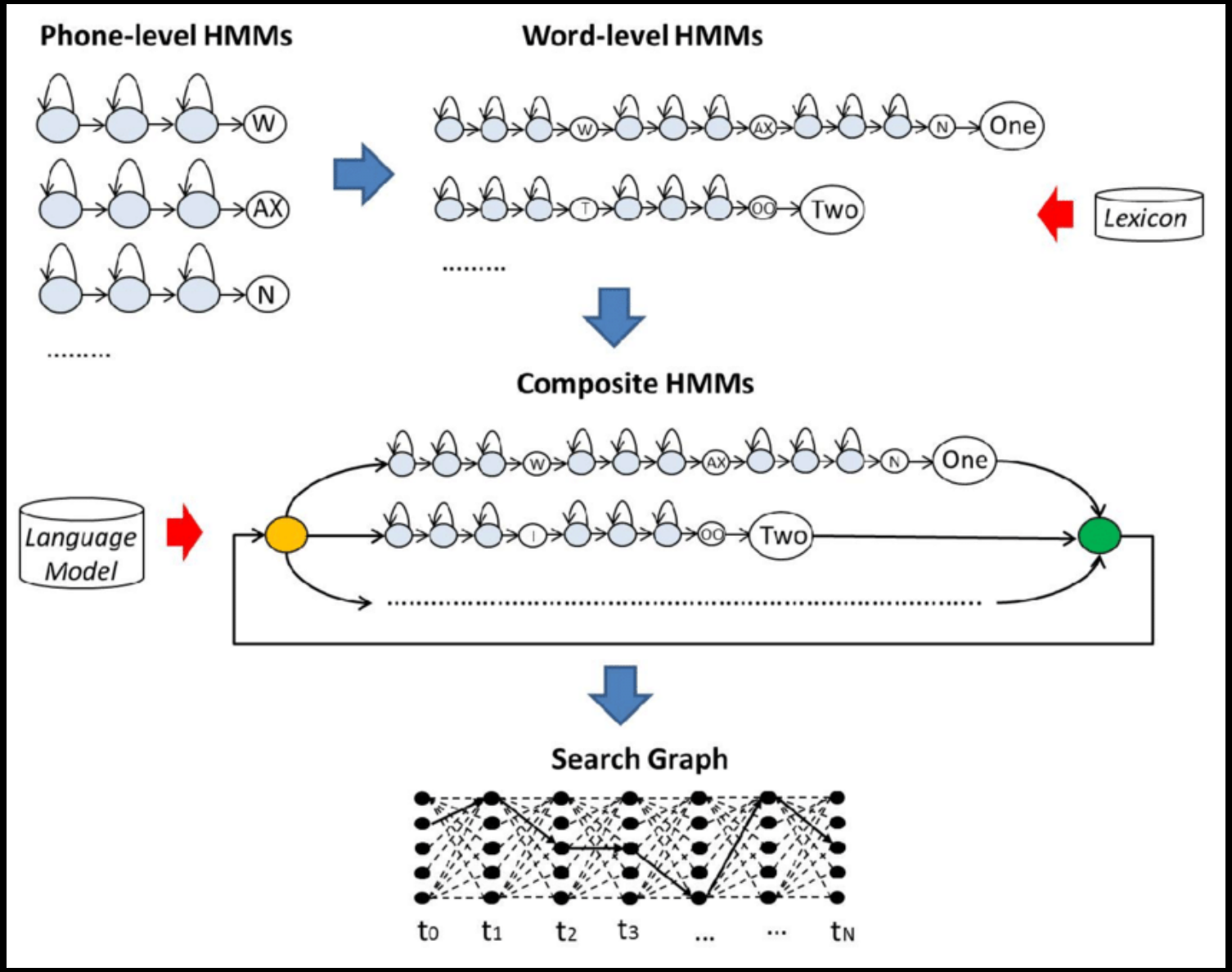
Bennett CC and K Hauser (2013) "Artificial Intelligence Framework for Simulating Clinical Decision-Making: A Markov Decision Process Approach." *Artificial Intelligence in Medicine*. 57(1): 9-19.

How could I figure out if I've seen this sequence before?

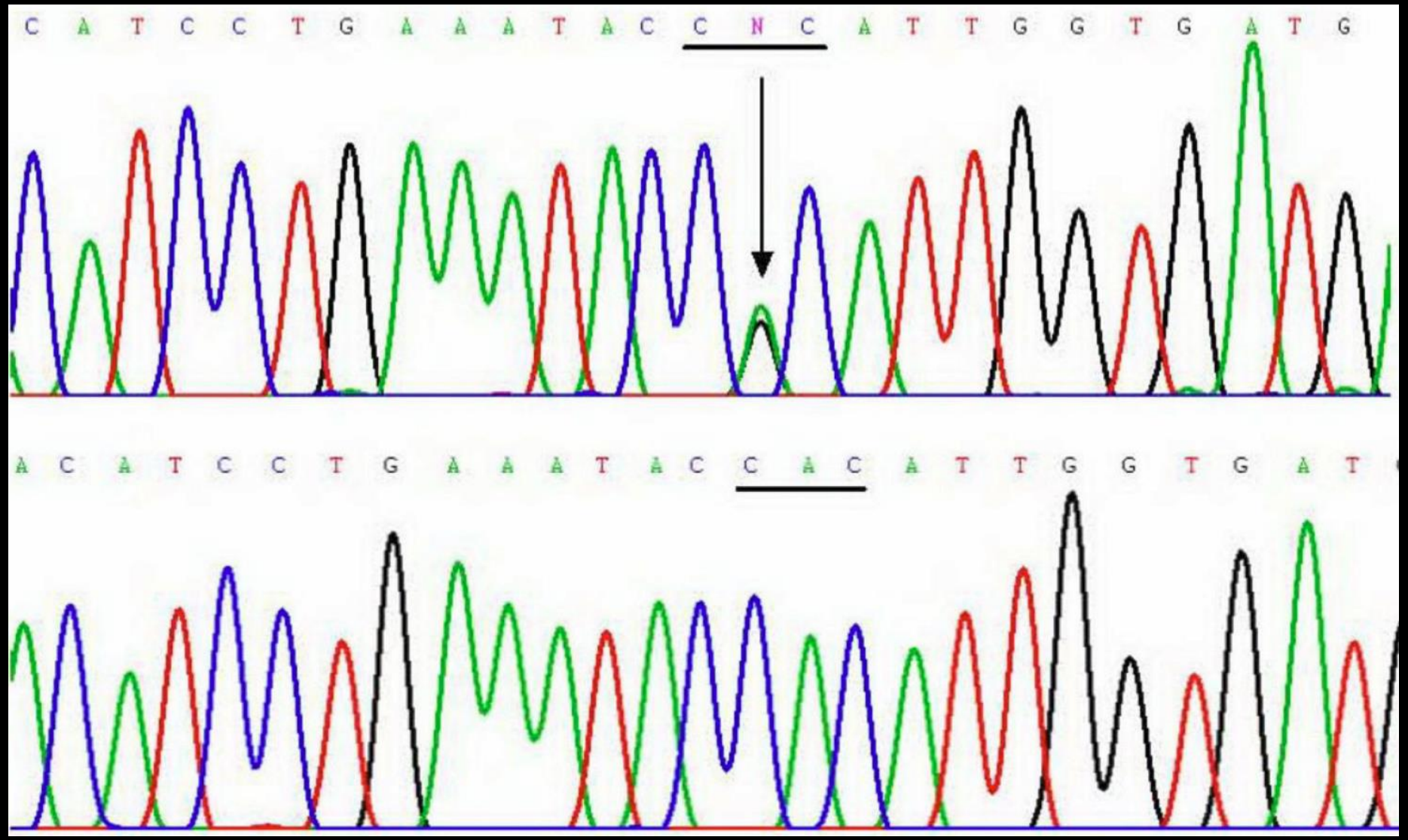
Hidden Markov Models



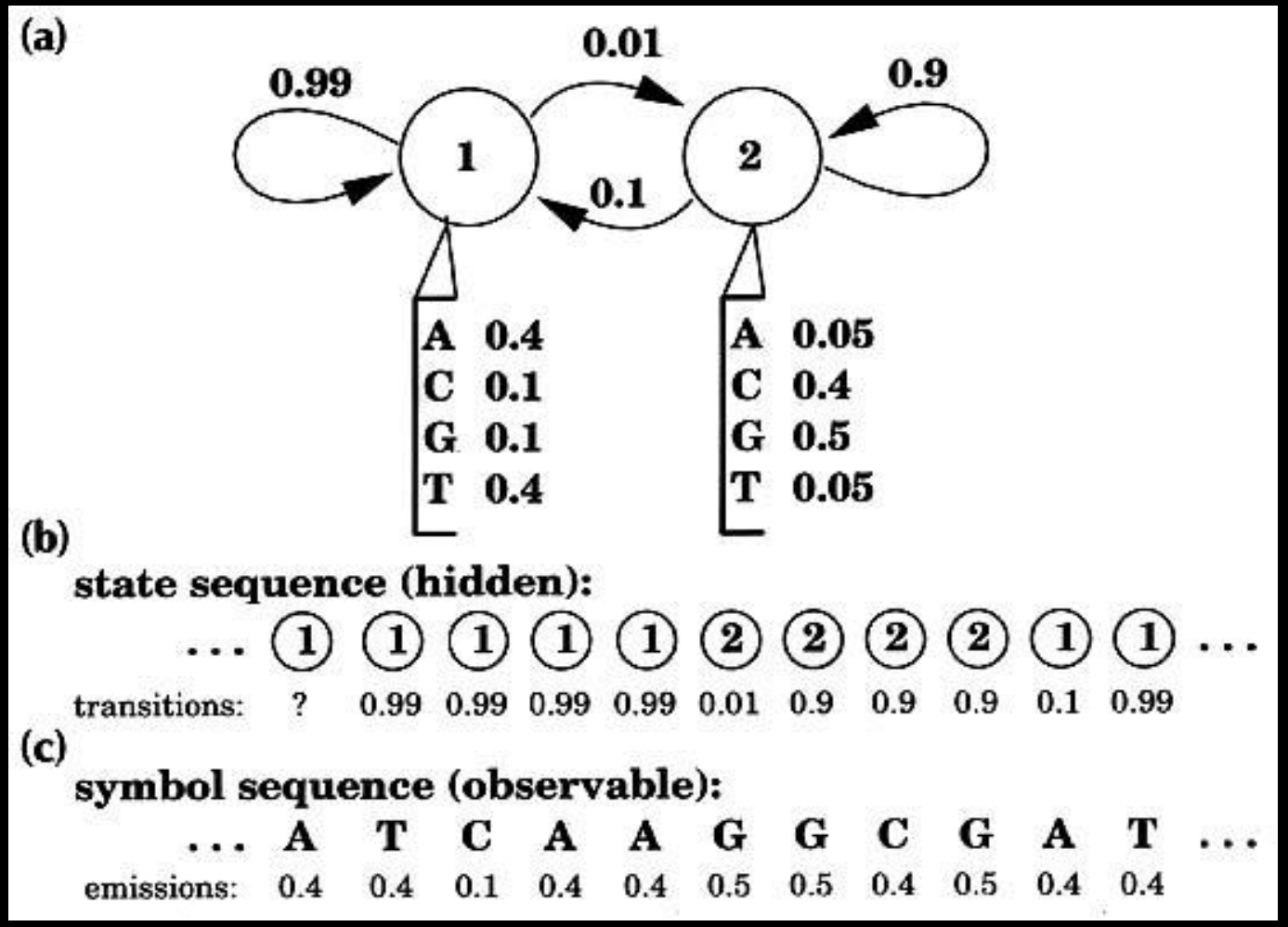
HMMs and Speech Recognition



HMMs and DNA Sequencing



HMMs and DNA Sequencing




```
A C A - - - A T G
T C A A C T A T C
A C A C - - A G C
A G A - - - A T C
A C C G - - A T C
```

Solving an HMM

- Viterbi Algorithm

- This is used to find the “most probable” sequence given the observations

Many kinds of Markov Models

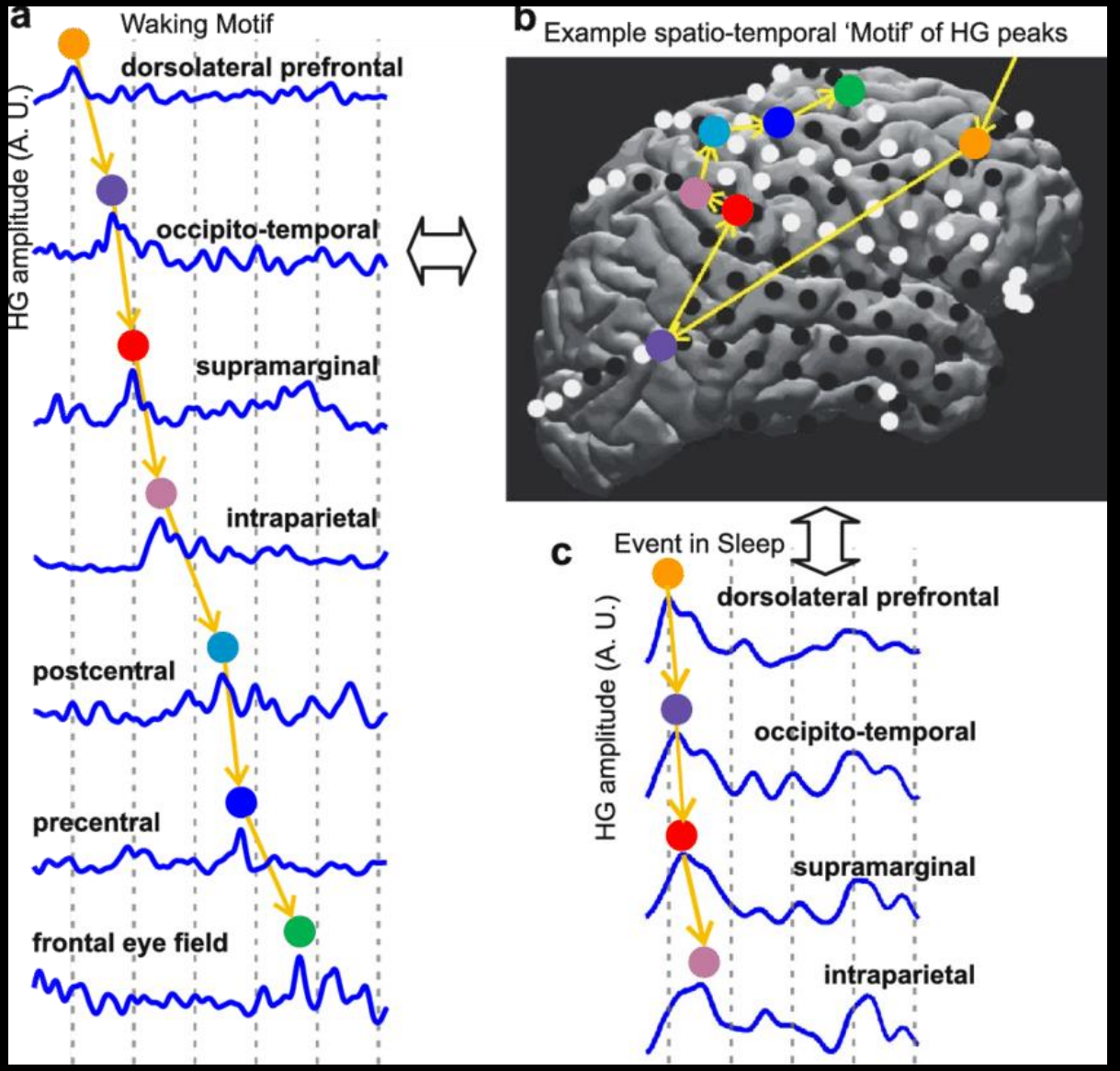
- Markov Decision Processes (MDPs)
- Partially-Observable MDPs (POMDPs)
- Hidden Markov Models (HMMs)
- Markov Random Fields
- Markov Logic Networks

Other Topics in Temporal Modeling

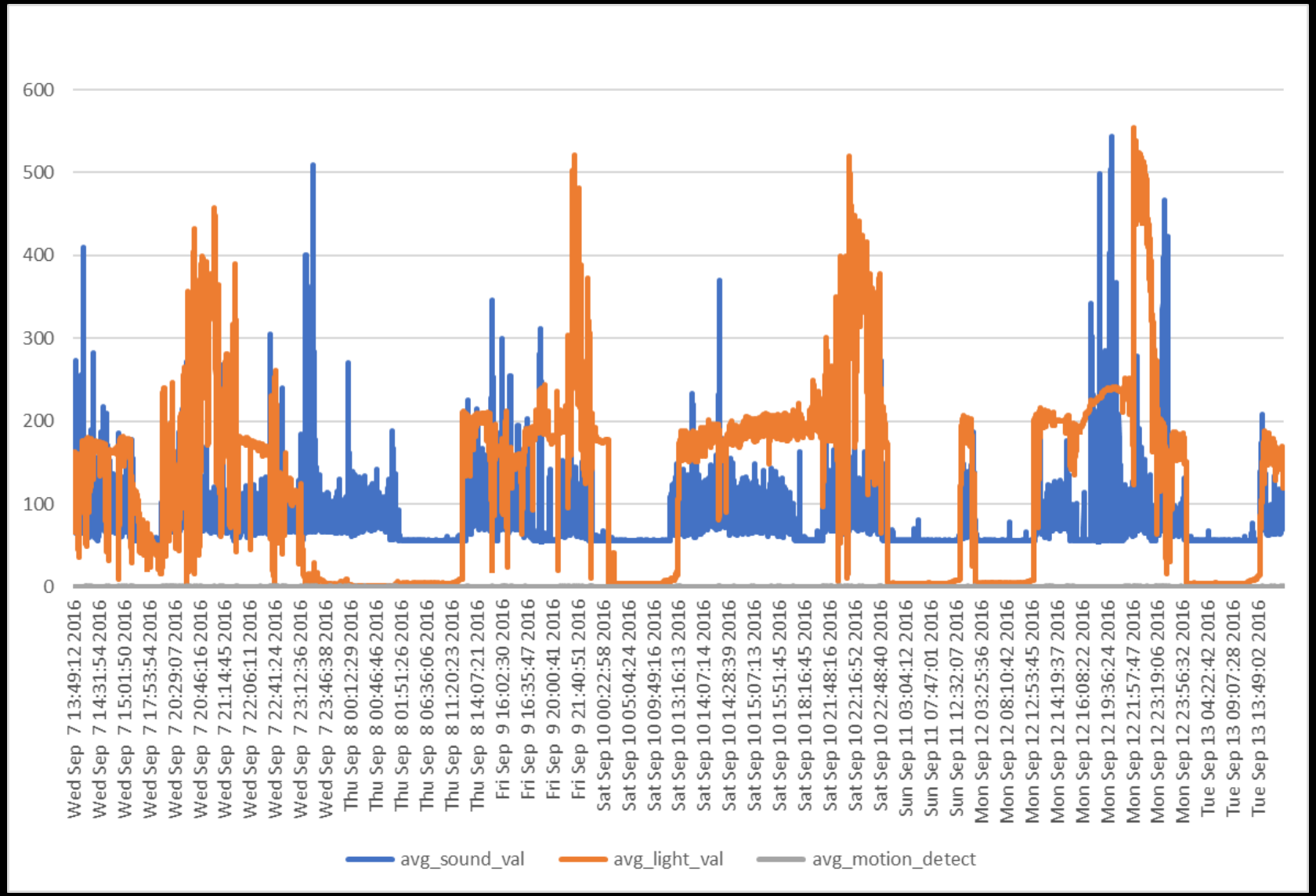
Other Temporal Models

- Temporal Motifs
- Sequential Pattern Mining and Event Prediction
- Change Point Detection

Temporal Motifs

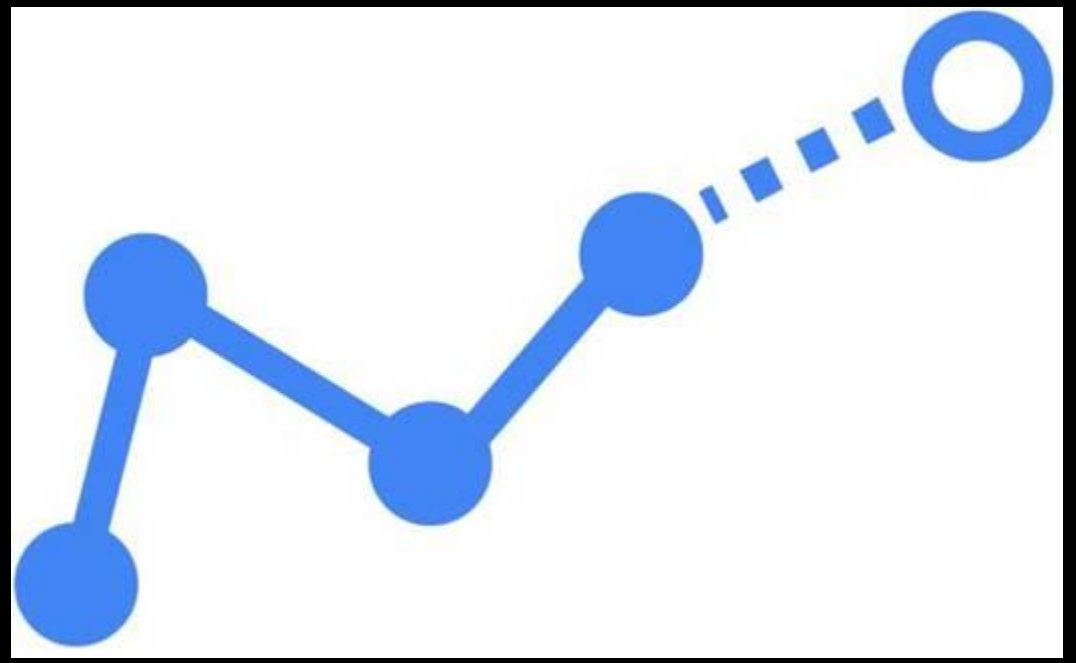


Temporal Motifs

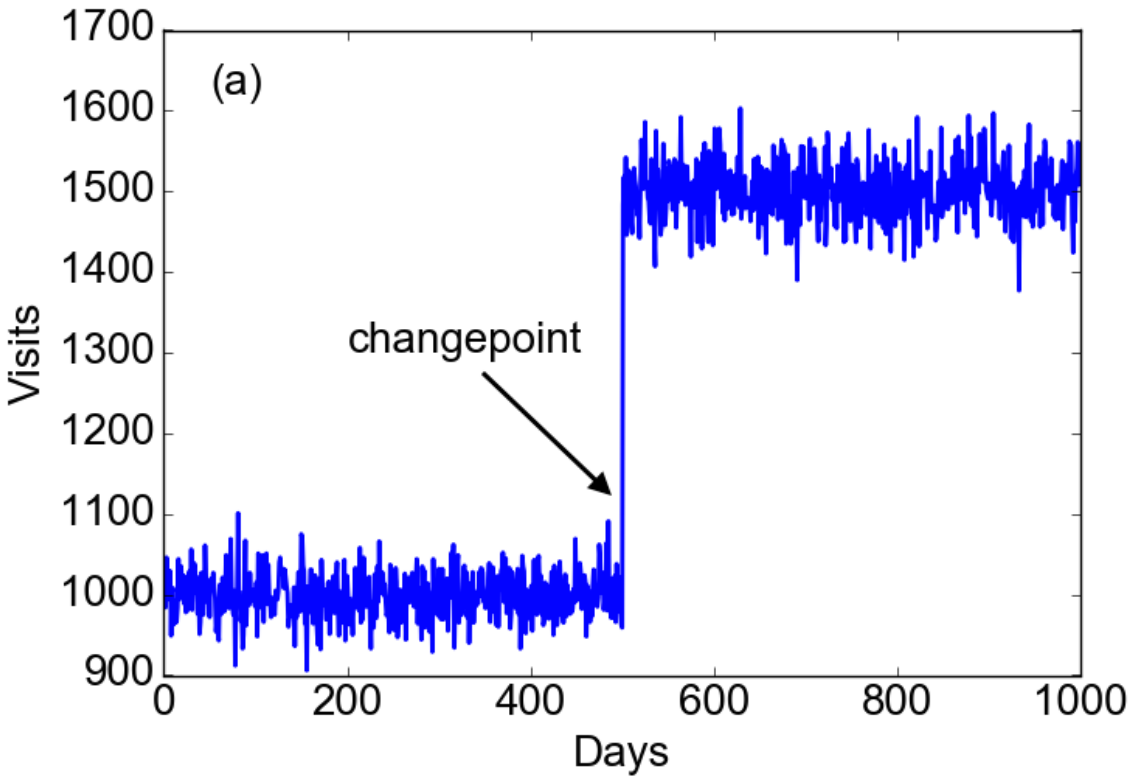


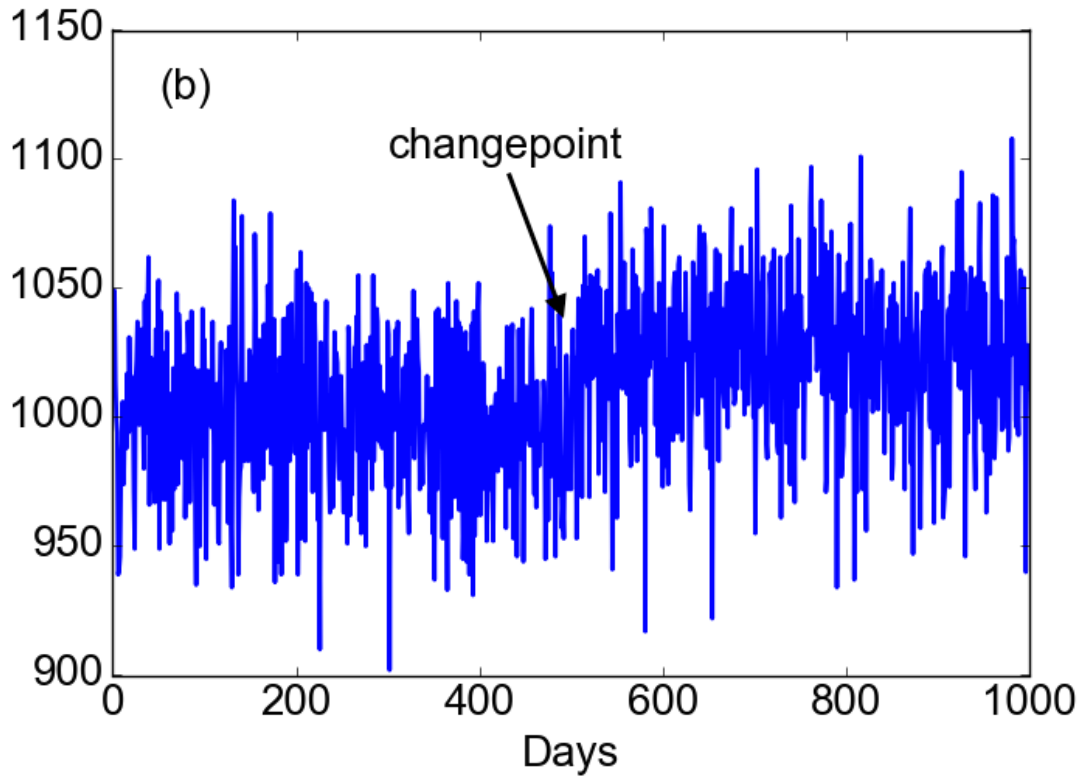
Sequential Pattern Mining

SeqID	Sequence
S1	<a,b,b,d,c>
S2	<a,c,d>
S3	<a,c,c,d>

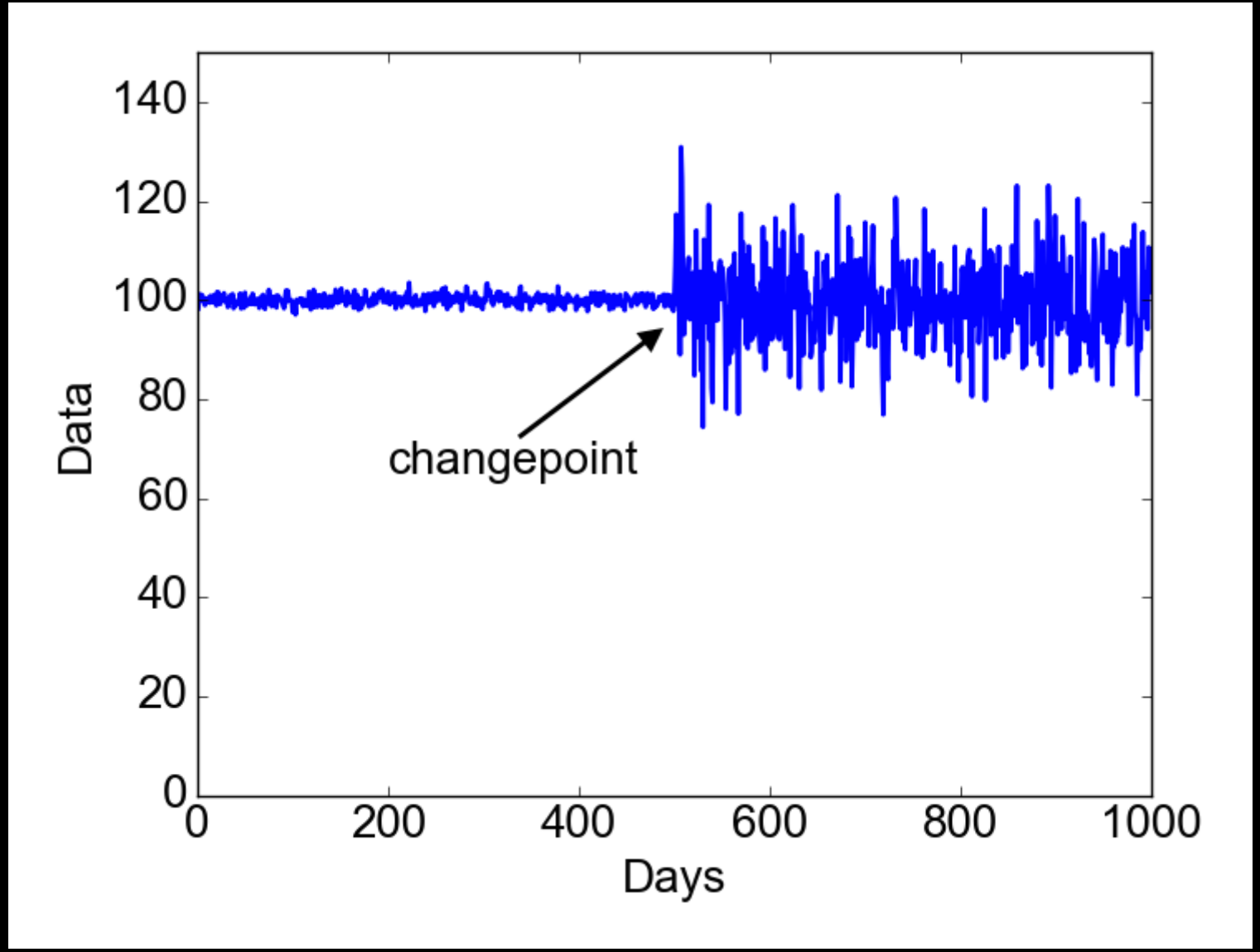


Change Point Detection

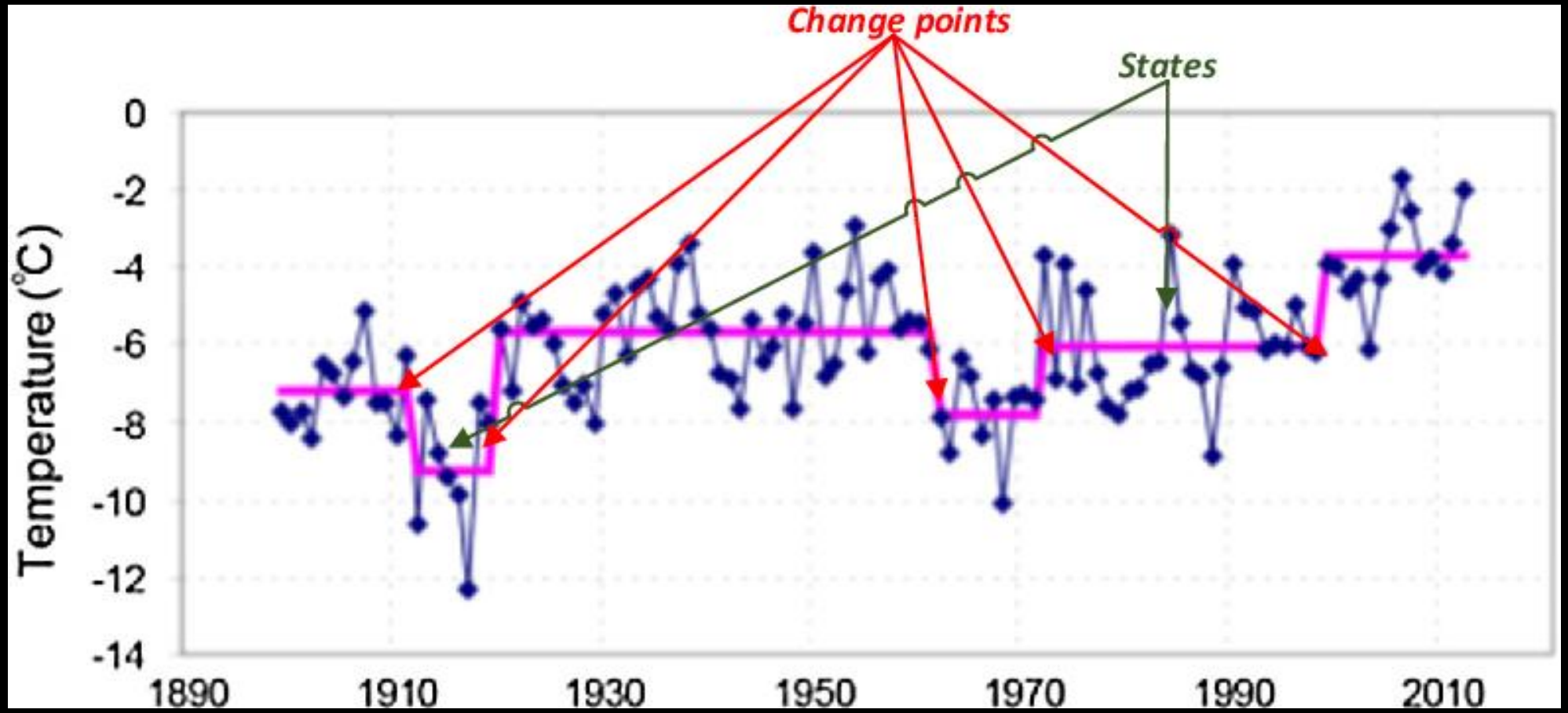




Change Point Detection



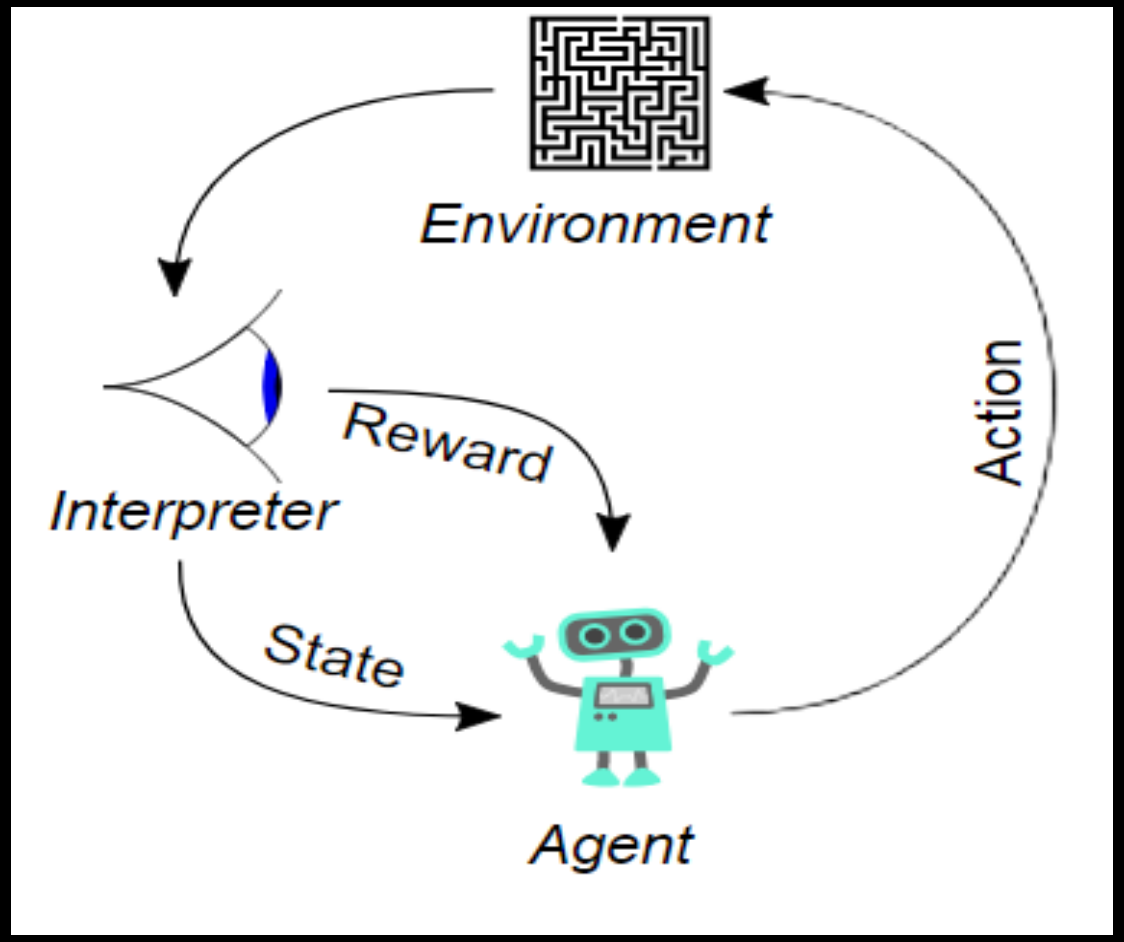
Change Point Detection



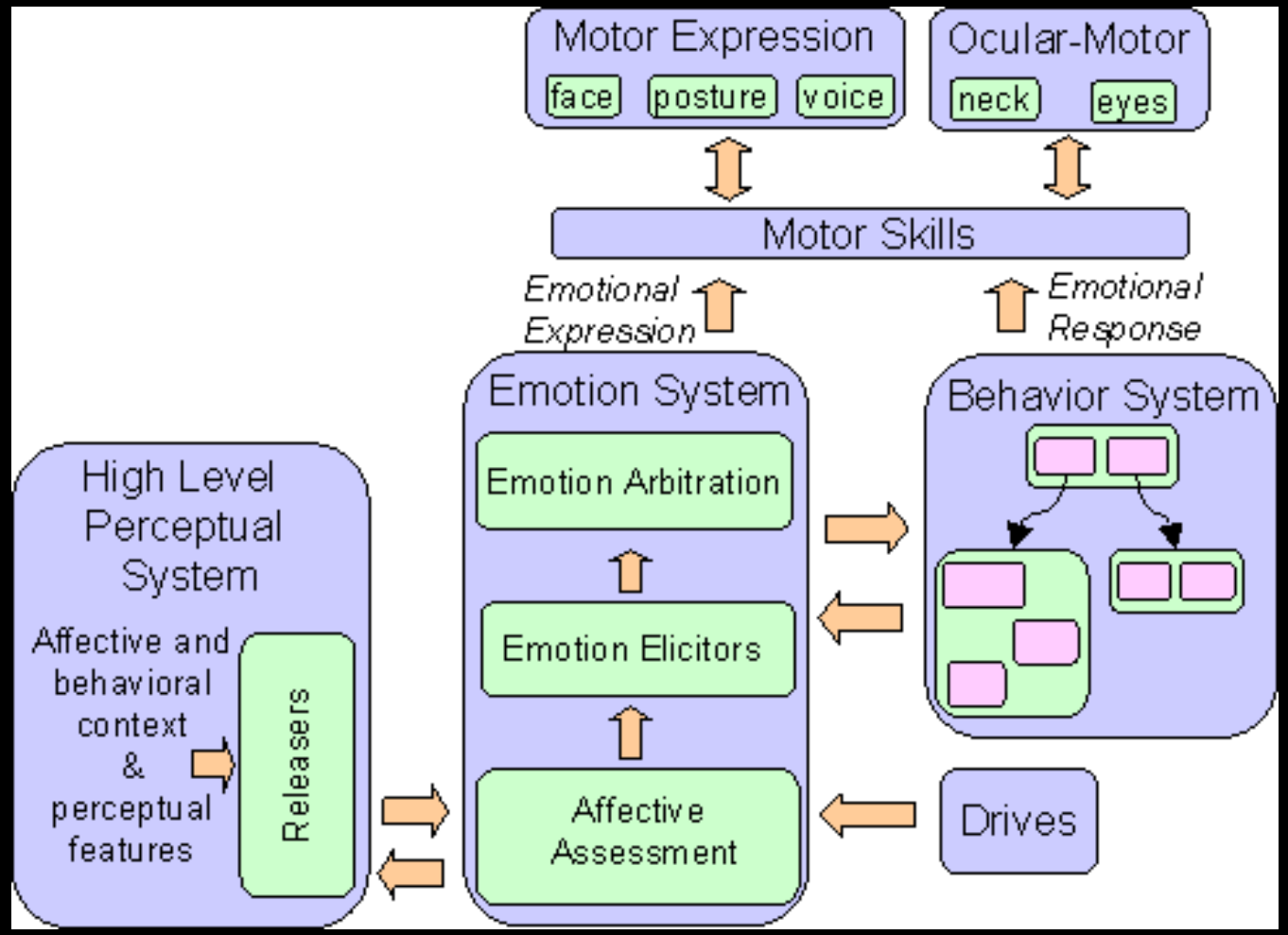
Special Topic: Machine Learning and Robotics

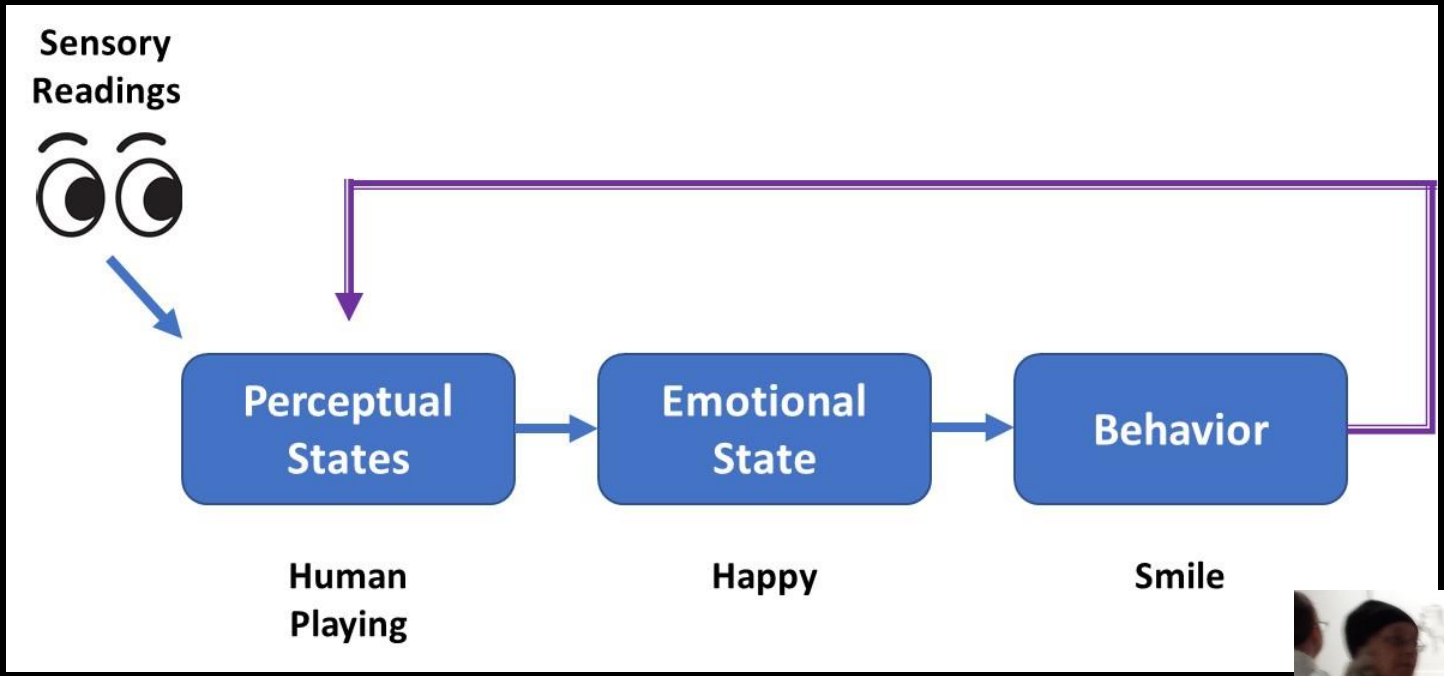
What if I don’t have GPS, and I’ve never been to the airport … how could I find the optimal route?

Reinforcement Learning



Reinforcement Learning




Sensory
Readings
Perceptual
States
Emotional
State
Behavior
Human
Playing
Happy
Smile

Merging of the Physical and Digital World

For next week

1) Project Presentations (13th and 20th)
2) Project write-up due Nov 21