Lecture 34
Hidden Markov Models
ECEN 5283 Computer Vision

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The Distinguished Seminar Series of the School of Electrical and Computer Engineering (ECE) presents the work of internationally recognized researchers. This seminar series is intended to provide an open platform for the faculty and students, to have a dialog with leading researchers in various fields of ECE, and to build-up a dynamic and vibrant culture of research and academic exchange in the ECE department. All seminars are free and open to the public.
Person-Centered Multimedia Computing: A New Paradigm Inspired by Assistive and Rehabilitative Applications
4:00 - 5:00 p.m. Wednesday, April 11 | ENG North 107
Dr. Sethuraman "Panch" Panchanathan - Executive Vice President, ASU Knowledge Enterprise Development
Chief Research and Innovation Officer, Director, Center for Cognitive Ubiquitous Computing (CUbiC), Foundation Chair in Computing and Informatics
Panchanathan was the founding director of the School of Computing and Informatics and was instrumental in founding the Biomedical Informatics Department at ASU. He also served as the chair of the Computer Science and Engineering Department. He founded the Center for Cognitive Ubiquitous Computing (CUbiC) at ASU. CUbiC's flagship project iCARE, for individuals who are blind and visually impaired, won the Governor's Innovator of the Year-Academia Award in November 2004. In 2014, Panchanathan was appointed by President Barack Obama to the U.S. National Science Board (NSB) and is Chair of the Committee on Strategy. He was appointed by former U.S. Secretary of Commerce Penny Pritzker to the National Advisory Council on Innovation and Entrepreneurship (NACIE). Panchanathan is a Fellow of the National Academy of Inventors (NAI), a Fellow of the American Association for the Advancement of Science (AAAS), and a Fellow of the Canadian Academy of Engineering. He is also the Fellow of the IEEE and SPIE. He is currently serving as the Chair of the Council on Research (CoR) within the Association of Public and Land-grant Universities (APLU) . His research interests are in the areas of human-centered multimedia computing, haptic user interfaces, person-centered tools and ubiquitous computing technologies for enhancing the quality of life for individuals with disabilities, machine learning for multimedia applications, medical image processing, and media processor designs.
Seminar Abstract
Human-centered multimedia computing (HCMC) focuses on a tight engagement of humans in the design, development and deployment of multimedia solutions. Today's multimedia technologies largely cater to the needs of the "able" population, resulting in HCMC solutions that mostly meet the needs of that community. However, individuals with disabilities have specific requirements that necessitate a personalized, adaptive approach to multimedia computing. In addition, individuals with disabilities have largely been absent in the design process, and have to adapt themselves (often unsuccessfully) to available solutions. To address this challenge, we recently introduced the concept of person-centered multimedia computing (PCMC), where the emphasis is on understanding the individual user's needs, expectations and adaptations towards designing, developing and deploying effective multimedia solutions. In this talk, PCMC will be discussed from two application viewpoints: (i) social interaction assistant to enrich the interaction experience of individuals with visual impairments and (ii) cyber-physical systems for stroke rehabilitation. Both these applications embody person-centeredness as the underlying methodology. Our research not only demonstrates the significant potential in using person centered multimedia solutions to enrich the lives of individuals with disabilities, but also the criticality of using a person centered approach to effectively address complex signal processing challenges in designing real-world solutions.
Refreshments and drinks will be offered after each seminar.
COLLEGE OF Engineering, Architecture and Technology
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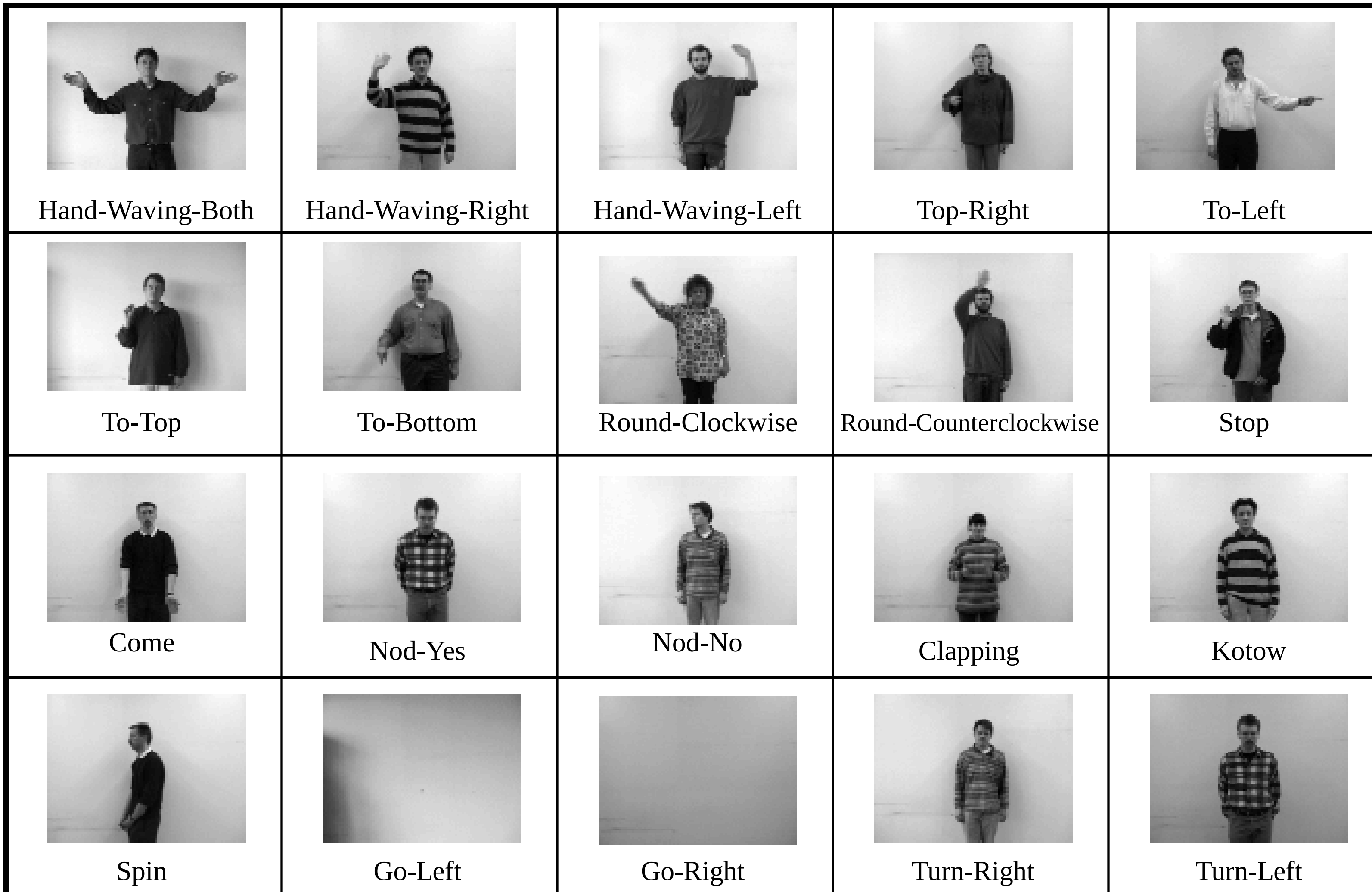
Goals

- To introduce hidden Markov models for high-level vision tasks on video sequences.
- To introduce three basic issues of HMMs.

Why do we need HMMs?



http://www.fb9-ti.uni-duisburg.de/projekte/video/video_e.html

Teacher HMM: Example

Teacher

Situation:

- Your school teacher gave three different types of daily homework assignments:

  A: took about 5 minutes to complete

  B: took about 1 hour to complete

  C: took about 3 hours to complete

- Your teacher did not reveal openly his mood to you daily, but you knew that your teacher was either in a bad, neutral, or a good mood for a whole day.
- Mood changes ocurred only overnight.

Question:

- How were his moods related to the homework type assigned that day?

Courtesy by Dr. Konrad Schlude, Institute of Theoretical Computer Science, ETH Zurich

Teacher HMM: Questions

Questions Teacher

One week, your teacher gave the following homework assignments:

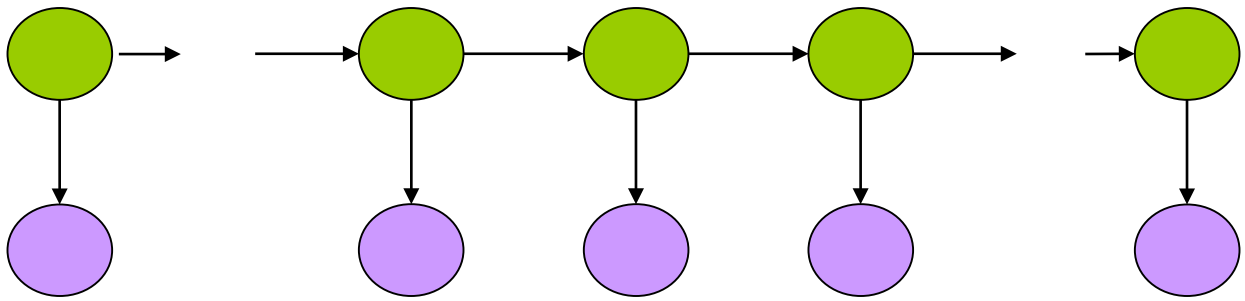
Monday:	A
Tuesday:	C
Wednesday:	B
Thursday:	A
Friday:	C

Questions:

- What did his mood curve look like most likely that week?
- What is the probability that he would assign this order of homework assignments?
- What is the probability that he was in a good mood on Thursday?

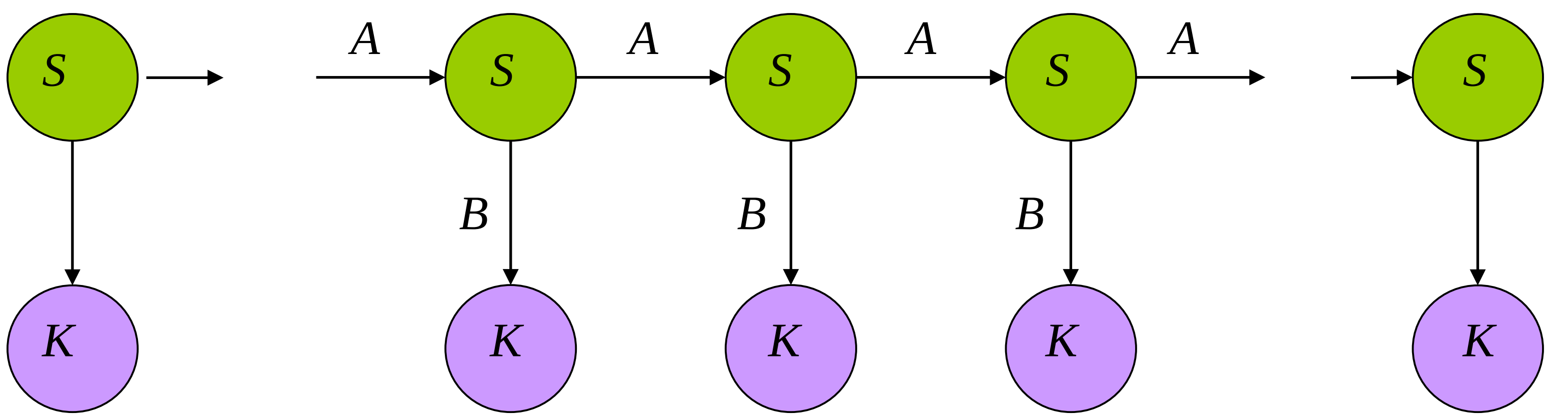
Hidden Markov Models (HMMs)

- **Graphical Model**
  - Circles indicate states or observations
  - Arrows indicate probabilistic dependencies between states and between state/observation
- **Green circles** are ***hidden states***
  - Dependent only on the previous state
  - The past is independent of the future given the present
- **Purple nodes** are ***observed data***
  - Dependent only on their corresponding hidden state



HMM Parameterization

- $\mu=\{S, K, P, A, B\}$
- $S : \{s_1 \ldots s_N\}$ are the values for the hidden states
- $K : \{k_1 \ldots k_M\}$ are the values for the observations
- $P = \{p_i\}$ are the initial state probabilities
- $A = \{a_{ij}\}$ are the state transition probabilities
- $B = \{b_{ik}\}$ are the observation state probabilities.



Inferences in HMMs

- **Evaluation:** Compute the probability of a given observation sequence **O** for a HMM parameterized by μ as

$$P(\mathbf{O} \mid \mu) = ?$$

- **Decoding:** Given an observation sequence **O** and a HMM μ, compute the most likely hidden state sequence

$$X_{\{1,\ldots T\}} = \max_{x_1 \ldots x_T} P(X|\mathbf{O}, \mu)$$

- **Learning:** Given an observation sequence **O** and set of possible models, which model most closely fits the data?

$$\mu = \arg\max_{\mu} P(\mathbf{O} \mid \hat{\mu})$$

Teacher HMM: Questions Revisited

Questions Teacher

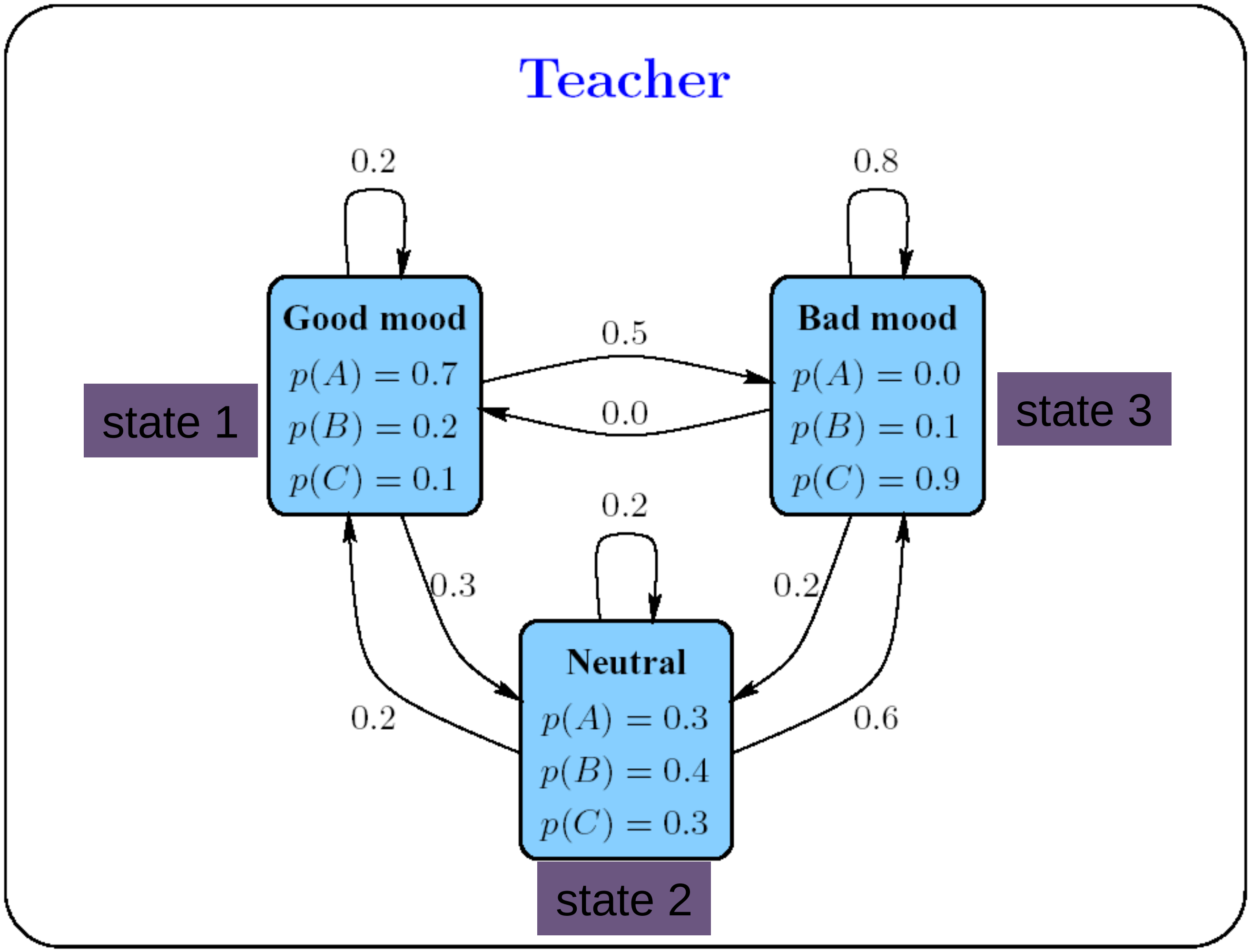
One week, your teacher gave the following homework assignments:

Monday:	A
Tuesday:	C
Wednesday:	B
Thursday:	A
Friday:	C

Questions:

- What did his mood curve look like most likely that week?
- What is the probability that he would assign this order of homework assignments?
- What is the probability that he was in a good mood on Thursday?

Teacher HMM: Parameterization



$$\pi_g = \pi_n = \pi_b = 1/3$$

$$A = \begin{bmatrix} 0.2 & 0.3 & 0.5 \\ 0.2 & 0.2 & 0.6 \\ 0 & 0.2 & 0.8 \end{bmatrix}$$

$$b_1(A) = 0.7$$
$$b_1(B) = 0.2$$
$$b_1(C) = 0.1$$

$$b_2(A) = 0.3$$
$$b_2(B) = 0.4$$
$$b_2(C) = 0.3$$

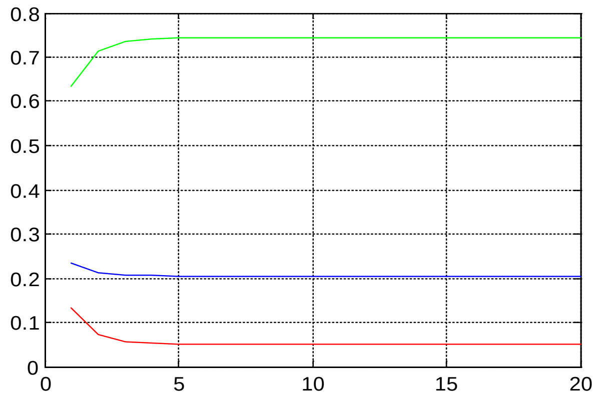
$$b_3(A) = 0.0$$
$$b_3(B) = 0.1$$
$$b_3(C) = 0.9$$

What kind of teacher he is?

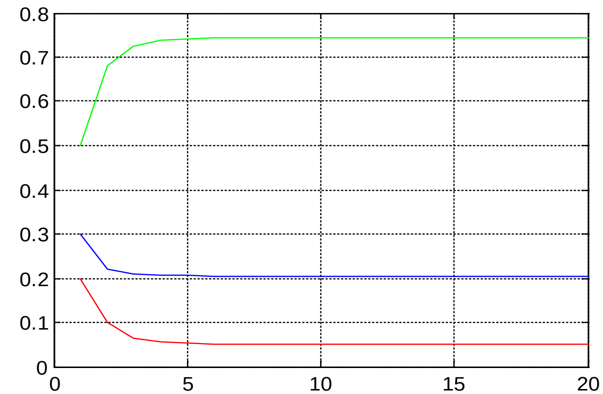
$$\mathbf{A} = \begin{bmatrix} 0.2 & 0.3 & 0.5 \\ 0.2 & 0.2 & 0.6 \\ 0 & 0.2 & 0.8 \end{bmatrix}$$

$$\boldsymbol{\rho}^n = \boldsymbol{\pi}\mathbf{A}^n$$

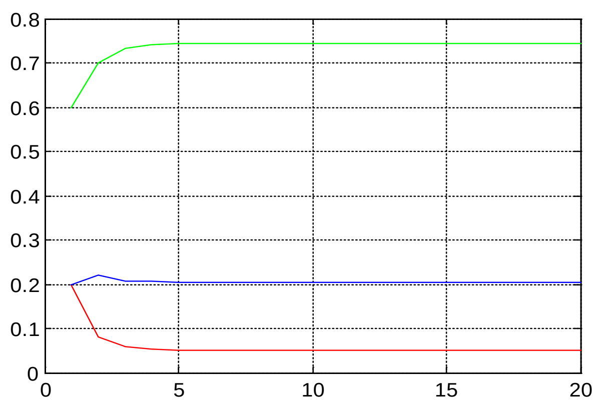
$$\pi_g = \pi_n = \pi_b = 1/3$$



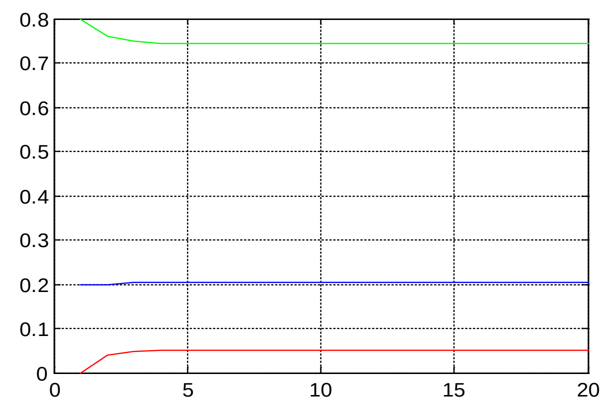
$$\pi_g = 1, \pi_n = \pi_b = 0$$



$$\pi_g = 0, \pi_n = 1, \pi_b = 0$$



$$\pi_g = 0, \pi_n = 0, \pi_b = 1$$



Good
Natural
Bad

Let's take a look of another teacher....

$$\mathbf{B} = \begin{bmatrix} 0.6 & 0.3 & 0.1 \\ 0.4 & 0.3 & 0.3 \\ 0.3 & 0.4 & 0.3 \end{bmatrix}$$

$$\boldsymbol{\rho}^n = \boldsymbol{\pi}\mathbf{B}^n$$

$\pi_g = \pi_n = \pi_b = 1/3$

$\pi_g = 1, \pi_n = \pi_b = 0$

$\pi_g = 0, \pi_n = 1, \pi_b = 0$

$\pi_g = 0, \pi_n = 0, \pi_b = 1$