Biological Vision and Applications
Module 07-04: Knowledge representation for visual cognition

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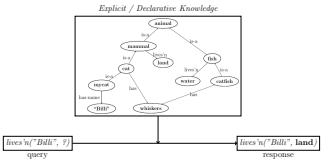
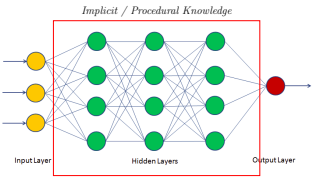
Dual Process Theory

Two processing paradigms

- Knowledge-driven approach (top-down)
  - Motivated by AI research
    - Examples: Logic systems, frame systems, ...
  - Symbolic Systems



- Data-driven approach (bottom-up)
  - Motivated by neuro-sciences / ML research
    - Examples: Learnt classifiers, Neural networks
  - Emergent Systems



Symbolic approach is traditionally known as the "cognitive approach"

Comparison of symbolic and emergent system approaches

Symbolic Systems	**Emergent Systems**
Formal representation: sharable - Human understandable / creatable	Informal representation: private - Not human understandable
Structured: can cominatorially generalize	Monolithic: cannot generalize
Inflexible: cannot discover new concepts	Flexible: can find new patterns in data
Deliberative reasoning: formal methods, slow	Intuitive Understand: informal methods, fast
Brittle: less tolerant to noisy data	Robust: more tolerant to noisy data
Explainable	Not explainable
Model-based	Model-less

See table 6.1 in textbook

How does the human mind work?

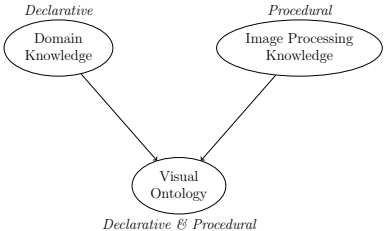
Dual process theory

- Symbolic approach: formal, knowledge driven, explainable, accurate, slow
  - More suitable for cognitive tasks
  - I need to go to the institute – how do I go?
- Emergent system approach: informal, data-driven, not explainable, inaccurate, fast
  - More suitable for perceptual processing
  - Is is an apple or a banana?
- Dual process theory: Human mind uses both the approaches
  - Parallel model: fast and slow thinking occur simultaneously
    - ... and may conflict
  - Default-Interventionist model: fast thinking generates intuitive responses
    - Subsequent slow thinking process may or may not deliberate on them

Dual process theory (short article)

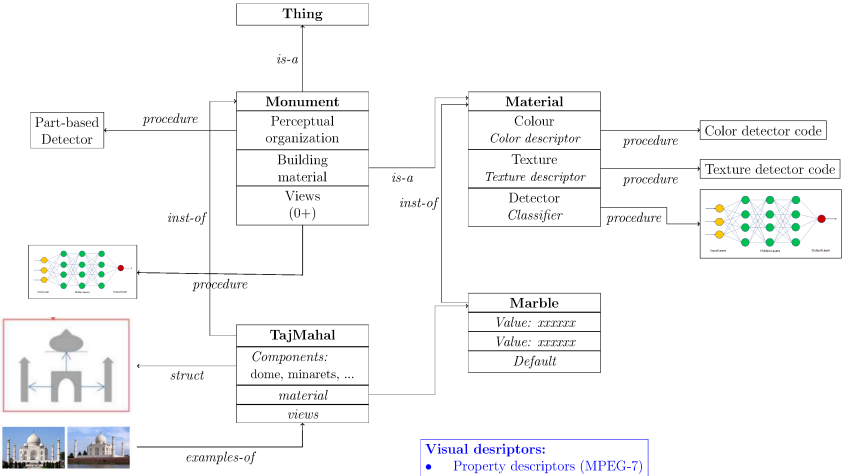
Framework of visual knowledge presentation

- Ontology =
  - A set of concepts C
  - A set of relations R
  - A set of axioms, e.g. transitivity, reflexivity, etc.
  - Two partial orders $\succ_C$ and $\succ_R$ define concept and relation hierarchies



Example of visual property specifications in a frame-based system

Multiple modes of specification in a unified framework



More of structural description

Point events and their relations

Temporal:
$\mathbf{R}$ *before* $\mathbf{B}$

Spatial:
$\mathbf{R}$ *north* / *above* $\mathbf{B}$
$\mathbf{R}$ *west* / *left* $\mathbf{B}$

Inverse relations:
$\mathbf{R}$ *before* $\mathbf{B} \equiv$
$\mathbf{B}$ *after* $\mathbf{R}$

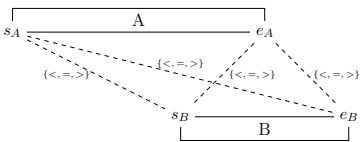
$\mathbf{R}$ *north* $\mathbf{B} \equiv$
$\mathbf{B}$ *south* $\mathbf{R}$

- The relations are normative
  - based on convention ... lacks semantics
- Events are seldom point events
  - finite spatial and temporal extension

Temporal relations between finite events

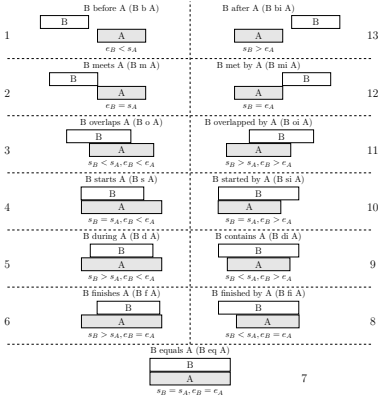
Allen's temporal relations

- An event A spans a finite interval of time
  - Start and end points: s_A, e_A
  - Finite and positive duration: $s_A < e_A$
- Two point events x and y can be has three possible unambiguous relations
  - $x < y$, $x = y$ and $x > y$
- Temporal relation between two interval events A and B can be represented as
  - Comparison 4-tuple of $(s_A, e_A) \times (s_B, e_B)$
  - Are there 3^4 possible values ?



Allen's temporal relations

13 feasible distinct relations

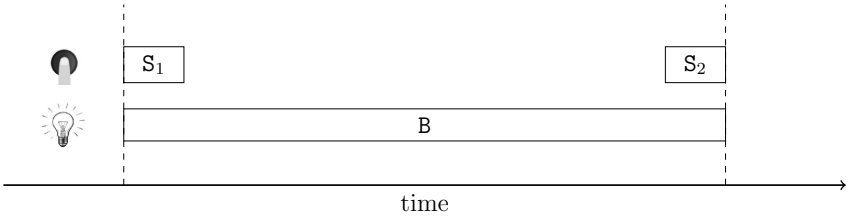


1. $e_B < s_A$: B *before* A
2. $e_B = s_A$: B *meets* A
3. $s_B < s_A, e_B < e_A$: B *overlaps* A
4. $s_B = s_A, e_B > e_A$: B *starts* A
5. $s_B > s_A, e_B < e_A$: B *during* A
6. $s_B > s_A, e_B = e_A$: B *finishes* A
7. $s_B = s_A, e_B = e_A$: B *equals* A

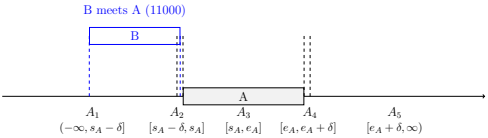
Allen's temporal relations

Example

(a) $\mathtt{S}_1$ *before* $\mathtt{S}_2$
(b) $\mathtt{S}_1$ *starts* B
(c) $\mathtt{S}_2$ *finishes* B



Binary encoding



B before A:	10000	B after A:	00001
B meets A:	11000	B met by A:	00011
B overlaps A:	11100	B overlapped by A:	00111
B starts A:	01100	B started by A:	01111
B during A:	00100	B contains A:	11111
B finishes A:	00110	B finished by A:	11110
B equals A:	01110		

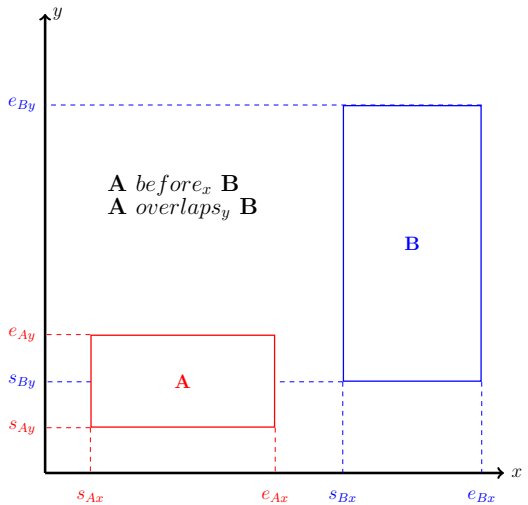
- There can be small error in determining the exact boundaries of an event
  - "B meets A" may be confused with "B before A" or "B overlaps A"
- Hamming distance between the binary strings signify closeness of the relations

Papadias. Approximate Spatio-temporal Retrieval

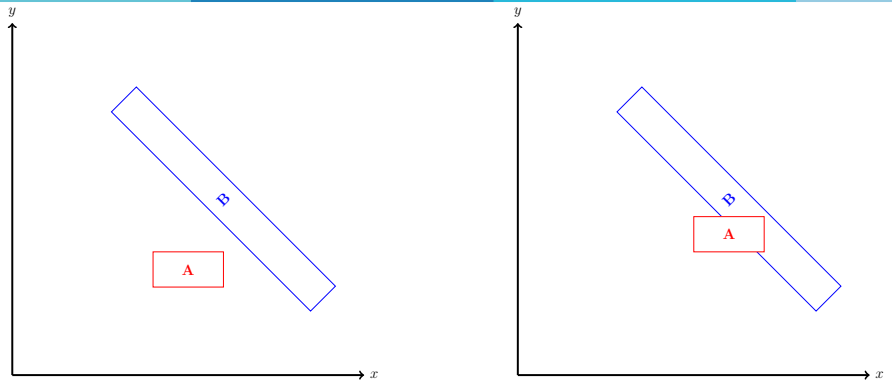
Allen's relations

Extension to spatial dimensions

- Can be applied to spatial dimensions as well
  - "before" $\rightarrow$ "left-of" / "below"
- Express spatio-temporal relations as a tuple of allen relations
  - (A b_x B, A o_y B)



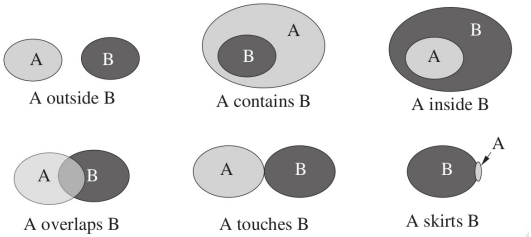
Ambiguity: Allen's relations extended to multi-dimensional space



- In both the cases, (A d_x B, A d_y B)
  - Left: A does not intersect B
  - Right: A intersects B

Containment relations (multi-dimensional)

To resolve ambiguity



- In multi-dimensional space
  - Spatio-temporal relations unambiguously defines with
    1. The Allen's relations on projections on each axis
    2. The containment relations (in multiple dimension)

Quiz

Quiz 07-04

End of Module 07-04