Knowledge and Computing

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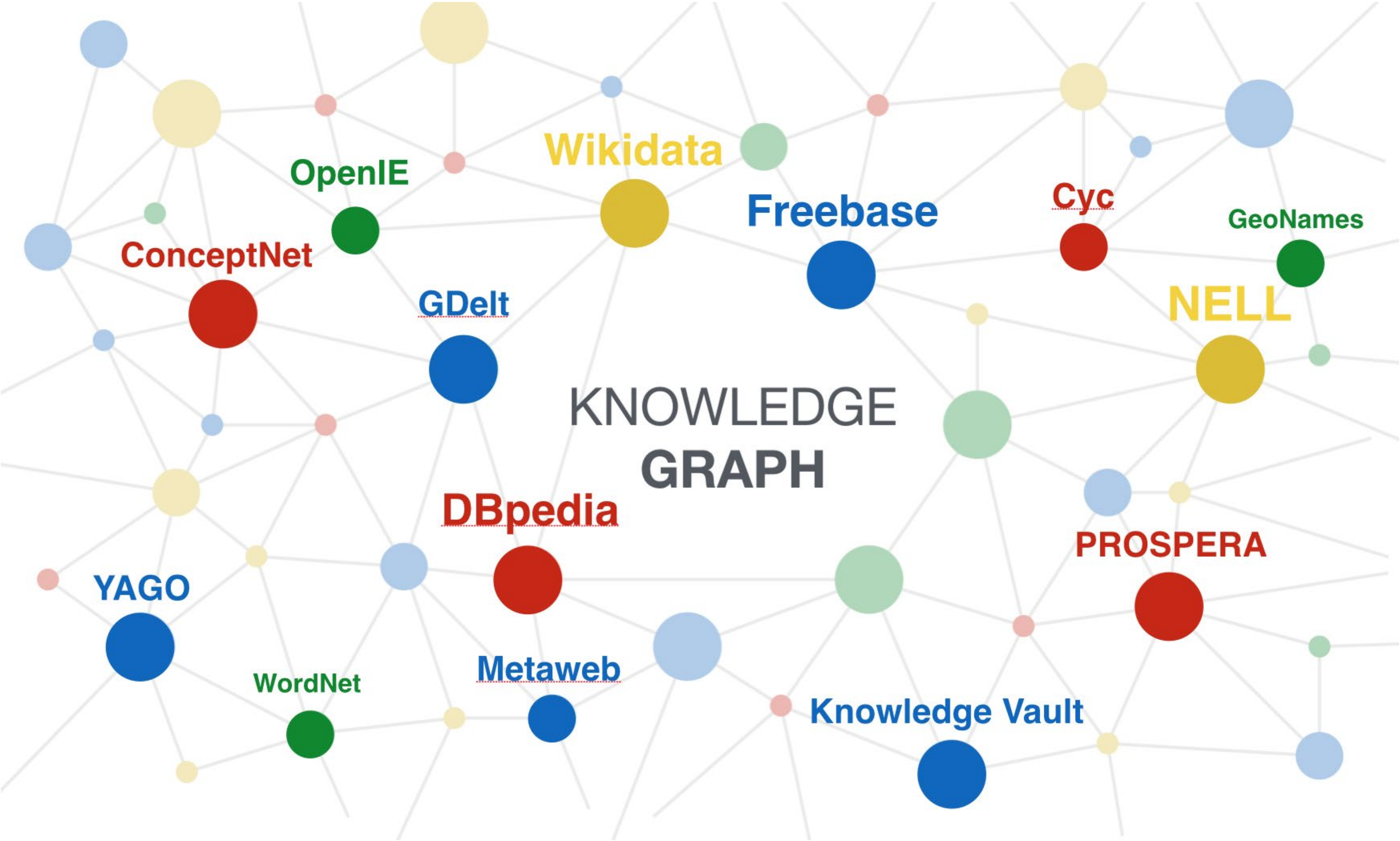
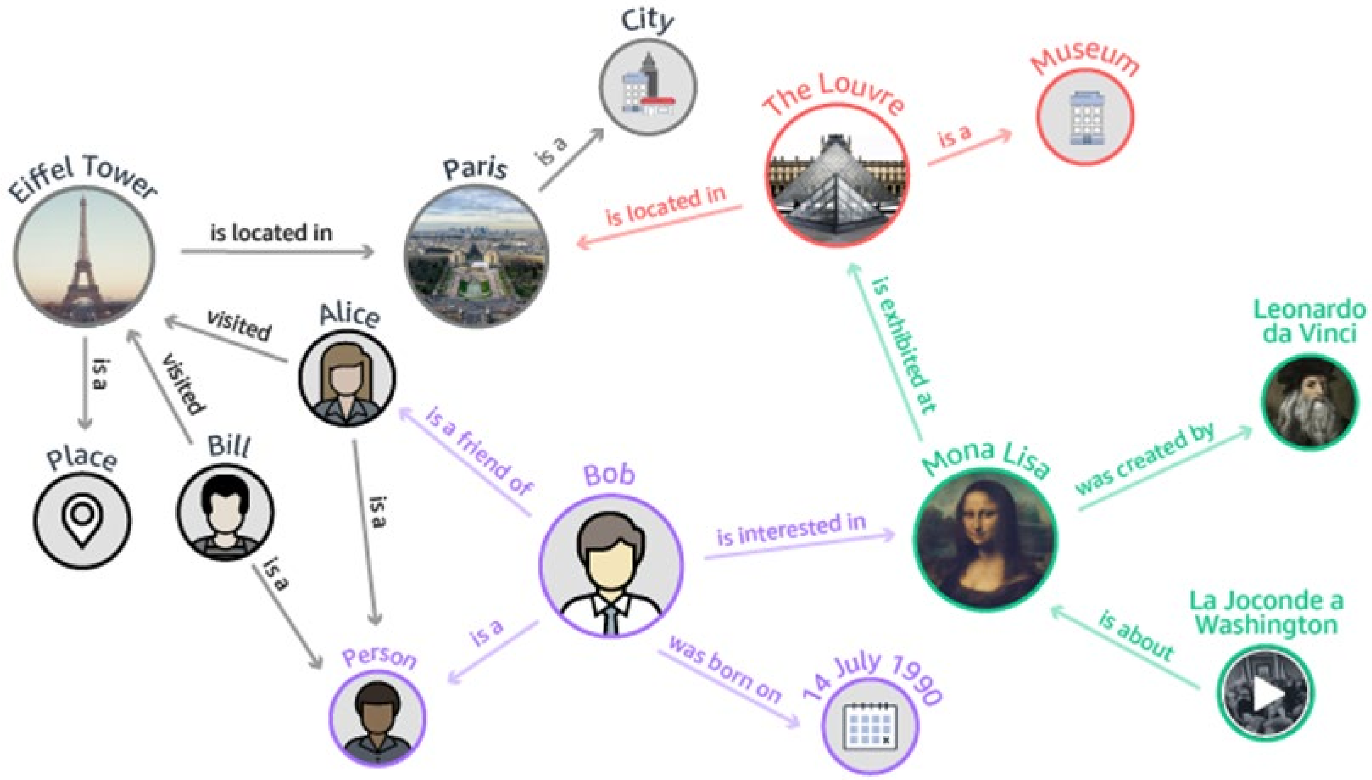
Knowledge and Computing

- Model World Knowledge - Linguistically Motivated Computational Processing
  - Meaning of words
  - Meaning of speech acts (including Presuppositions, Implicatures, Events, Temporal Logic)
  - Computational Models of World Knowledge / Common Sense in phenomena like Binding, Anaphora Resolution, Reasoning
    - “Take the knife, cut the lime in half, and put it down.” it = knife
    - “Take the knife, cut the lime in half, and squeeze it.” it = lime

Large Knowledge Graphs



Knowledge Graphs



Knowledge Representations

- Model (or Ontology) and Individuals (or Assertions of Facts)

- Model: Web Ontology Language (OWL) as a restrictive model/ontology specifying
  - Concepts (or entity types)
  - Relations (between entities, instances of concepts or entity types)
  - Properties of Concepts and Relations

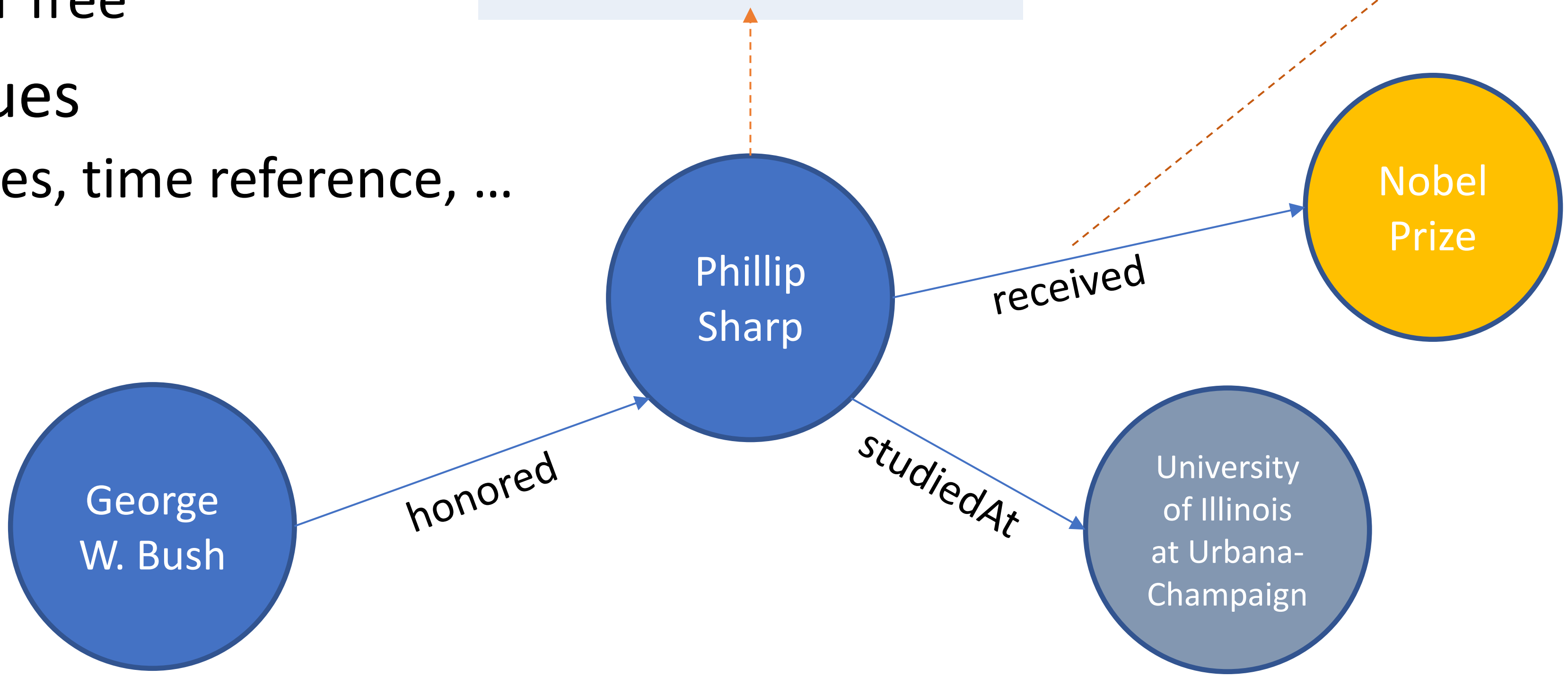
- Individuals
  - Concrete instances of concepts and relations

Knowledge Graphs

- Concepts and Relations
  - Mostly unconstrained
  - Domain specific or free
- Attributes and Values
  - encoding properties, time reference, …

Attribute	Value
Birth place	Falmouth, KY
DOB	06/06/1944
gender	male
…	

Attribute	Value
year	1993
…	



Knowledge Graphs

- No computation or interpretation of logic equations (e.g., no access to universal or existential quantifiers)
- Direct mapping of knowledge from language input is limited to Description Logic

- Description of Knowledge
  - Directed Graph: encoding concept, events, domain specific knowledge…
  - Attribute-Value encoded features like size and shape, but also event time references (start, end, duration), etc.

- Reasoning: OWL & Reasoner, Common Graph Algs.
- Prediction: Links, Class prediction, etc.
- Machine Learning of concepts and concept properties: node or edge embedding

Knowledge Graphs

- Static: Concept and Relation Properties
  - Even when dynamically growing or changing
- Problem to encode events or procedures
  - *Mary gave John a book*.
    - Event as a state change / transformation:
      - Mary owns a book, John does not → John owns a book, Mary does not
  - Peter was fetching his daughter from school.
    - Intermediate states:
      - Peter is at home, daughter at school → Peter is at school, daughter at school → Peter is at home, daughter at home

Temporal Relations

- Sequencing of events or sub-events
  - Wash the veggies, chop them, fry them.
    - Presentation and Temporal event sequence: 1 2 3
  - Before you fry the veggies, wash and chop them.
    - Presentation sequence: 3 1 2
    - Temporal event sequence: 1 2 3
- Duration of events
  - Clear reference: “for 30 minutes”
  - Common sense

Temporal Relations

- Duration of events
- Unfolding over time
    - Events relate to time
    - States are points in time

- Temporal sequencing relates to
    - Causal reasoning

Temporal Scope

- Simple temporal relations
  - Past tense: Tim Cook bought Google.
    - Assumptions: factive, true event
  - Future tense: Tim Cook will buy Google.
    - Assumptions: non-factive, hypothetical
- Complex relations: temporal scope
  - Reuters reported that
  - Reuters will report that

Tim Cook bought Google

NLP Extensions

- Implicatures:
  - John to Peter: I bought the blue car.
    - John and Peter talked about cars earlier.
    - There should be a set with at least one more car the John could have bought, but did not, and
    - None of the cars in the set is blue.
  - Clues: Definiteness of NP via the, and specificity of NP
- Presuppositions:
  - John fed his cat this morning.
  - Assumptions:
    - John owns/has a cat/pet.
    - John owned cat-food this morning.
  - Clues: Possessive pronoun as modifier of Direct Object.

Predicates

- Veridicality
  - Factive predicates: *know*, *regret*, *realize*, *notice*, …
    - *I regret that* … (X did something to Y)
    - Complements are assumed to be true
  - Non-factive predicates: *believe*, *think*, *claim*, …
    - *I believe that* … (X did something to Y)
    - Complements cannot be assumed to be true
  - Counter-factive predicates: *pretend*, …
    - *John pretends that he is ill.*
    - Complement cannot be true: *John is not ill*

- Question:
  - Cross-linguistic similarity = universal properties related to factivity

Semantic Mapping and Reasoning

- Type of Predicative Arguments: Typing
  - Named Entity Recognition
  - Closes possible Hypernym in a Taxonomy or Ontology of isA relations

- Identity of entity: Linking
  - Named Entity Recognition
  - Link to unique identifier of entity in some knowledge representation, Ontology, Wikipedia, Knowledge Graph

- Issues: Ambiguity

Graph Extraction and Linking

- Graph generation sample:
  - NLP pipelines
  - Graph extraction
  - Linking (conceptualization, language independent representation)

- Goal:
  - Extract predicate-argument tuples
  - Type the entities (e.g. NER, ontology lookup, Knowledge Graph linking)
  - Dynamically expand the knowledge graph and track weights (probabilities)

Pipeline

- NLP Pipelines
- Knowledge Graph Generation

Linguistic Bias

- Pragmatic effects in language use data (e.g. Sperber & Wilson's Relevance Theory, Grice's Maxims)
  - People communicate facts and information that is relevant, new, exciting
  - Observation:
    - Exciting information: purple carrots

Less exciting information: orange carrots

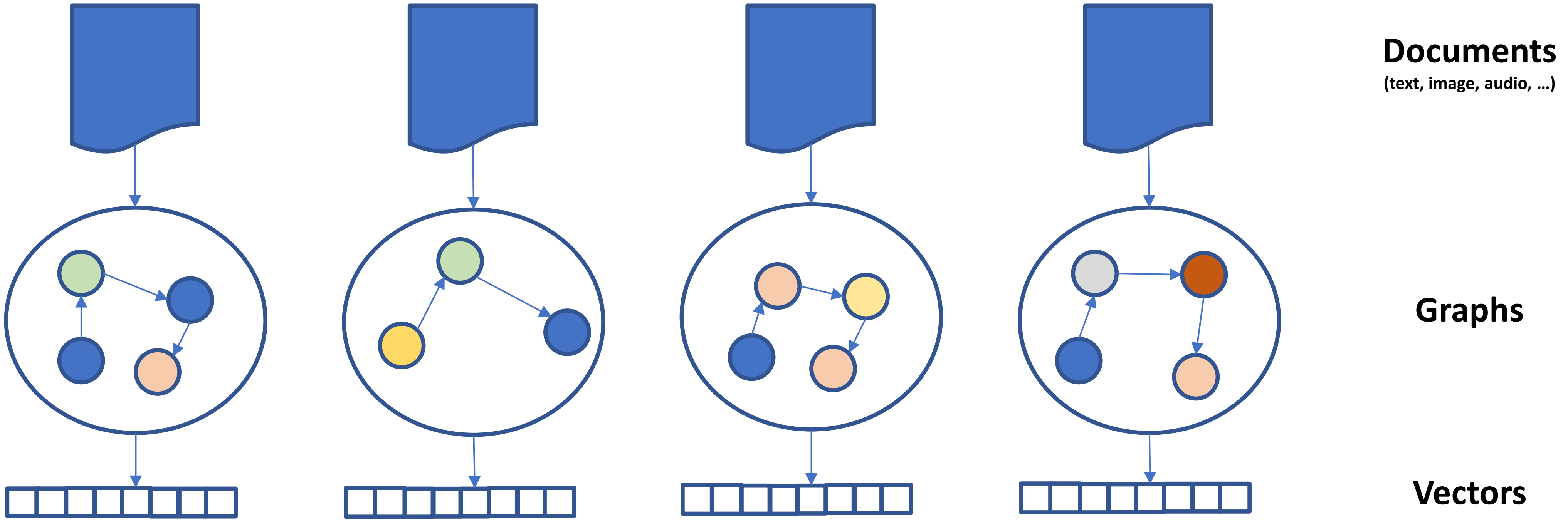
Solution

- Multi-modal information input to knowledge representation
  - Language input (speech and text)
  - Information in images
  - Haptic information
  - Secondary information: sound it makes, properties when shaking, tossing, etc.

- Graphs generated using:
  - General or common sense knowledge
  - Domain specific knowledge
  - Semantic restrictions over graphs: ontologies, taxonomies

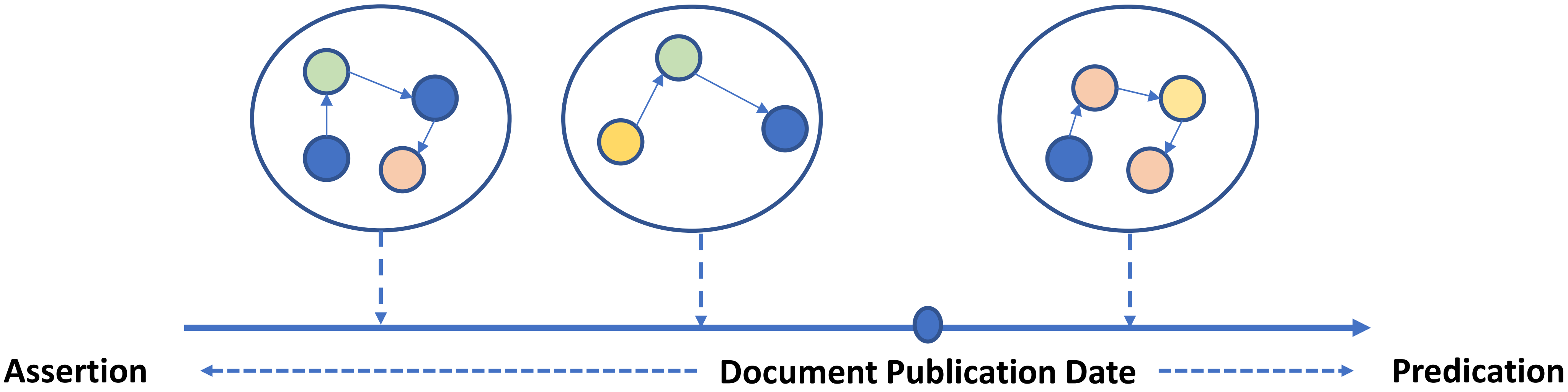
Document Graphs

- Concept/Knowledge Graph Document Representation

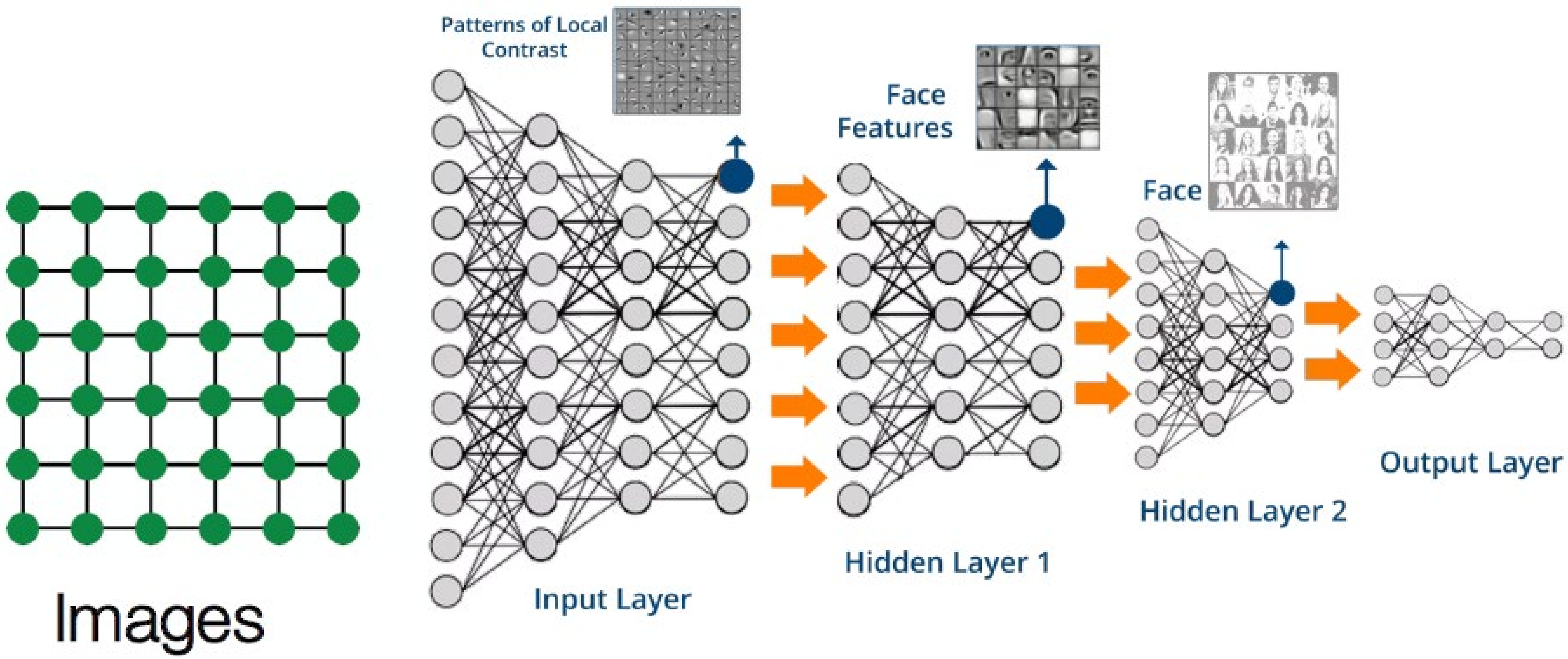


Event Graphs

- Arrangement of sub-events along time axis
  - Approximation of duration
  - Identification of geo-location
  - Linked entities and relations



Graph Neural Network Models



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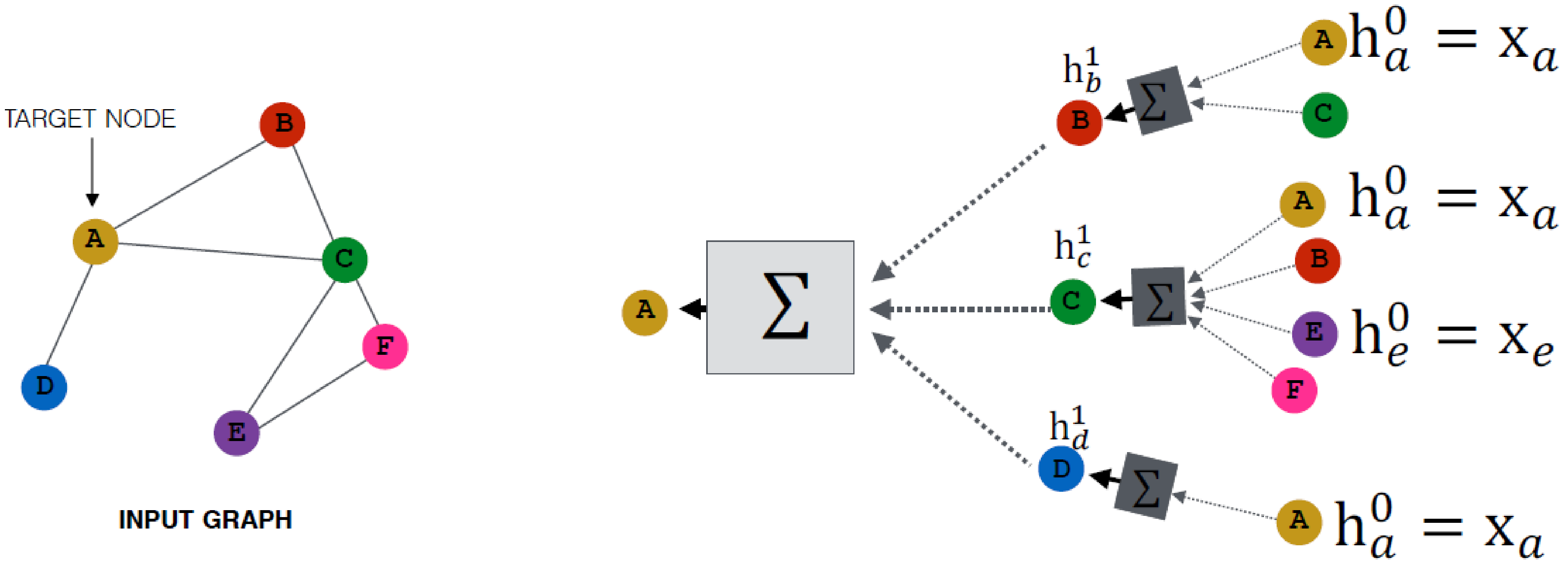

$$h_v^{(l+1)} = \sigma(W_l \sum_{u \in N(v)} \frac{h_u^{(l)}}{|N(v)|} + B_l h_v^{(l)})$$