Context-Aware Computing 2

Context Representation and Reasoning

Mobile Computing

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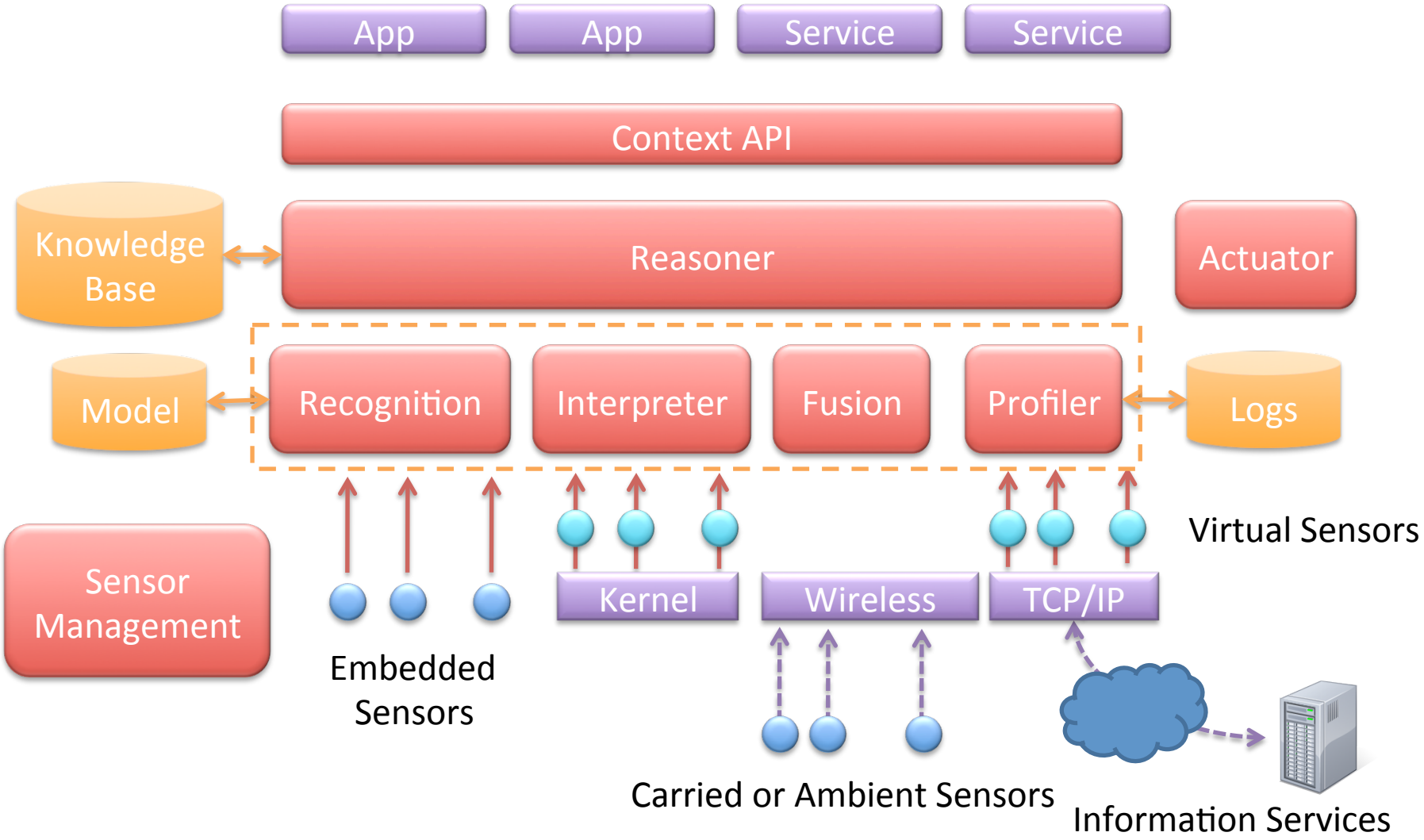
Definitions

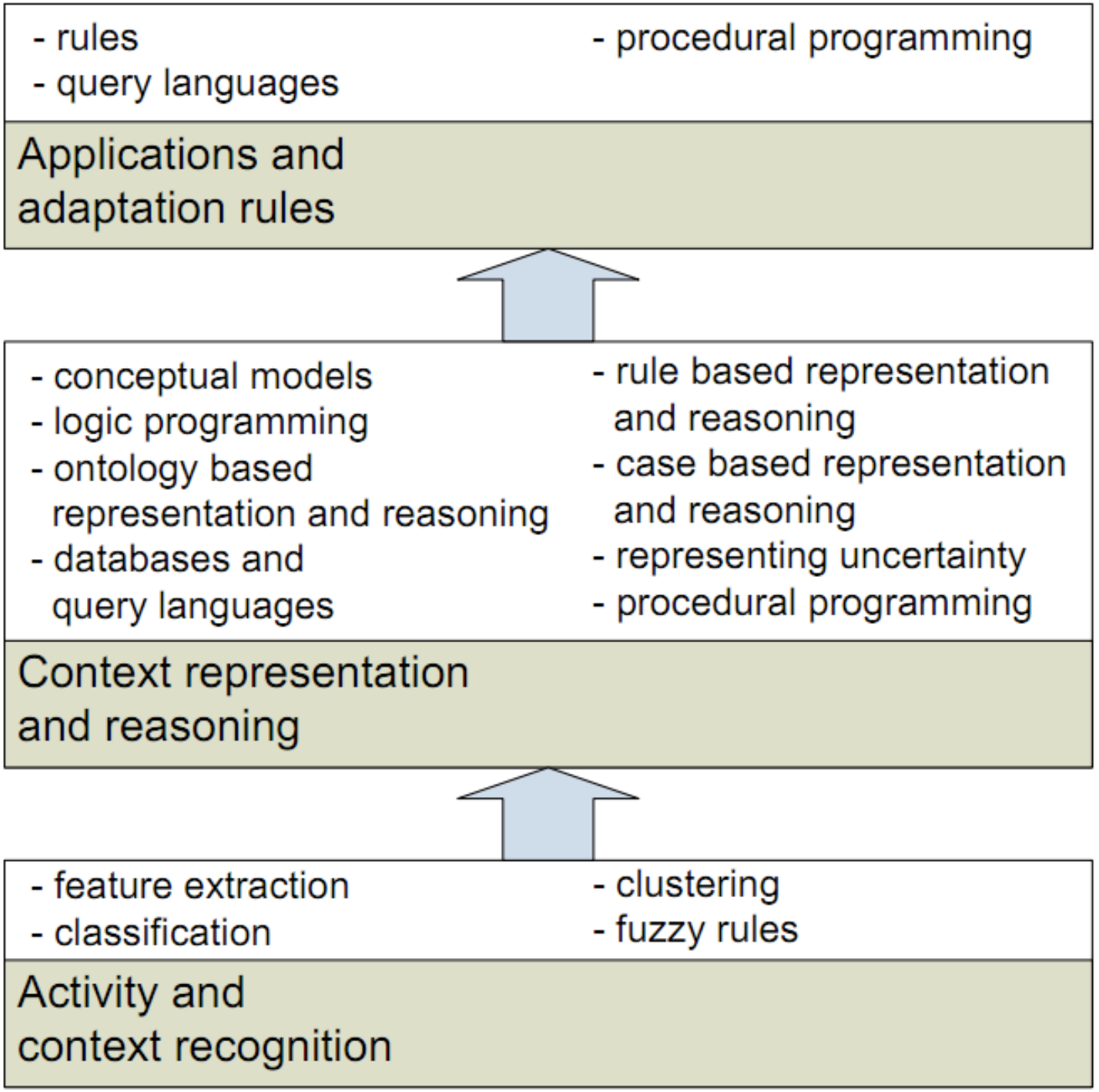
- Dey
  - Context is any information that can be used to characterize the situation of an entity.
  - An entity is a person, place, or object that is considered relevant to the interaction
  - between a user and an application, including the user and applications themselves

Context Awareness

- Computers can both sense, and react based on their environment.
- Context aware systems are concerned with
  - acquisition of context (e.g. using sensors to perceive a situation),
  - abstraction and understanding of context (e.g. matching a perceived sensory stimulus to a context),
  - application behavior based on the recognized context (e.g. triggering actions based on context).

System Architecture for Context-Aware Computing




- rules
- query languages
- procedural programming
Applications and adaptation rules
- conceptual models
- logic programming
- ontology based representation and reasoning
- databases and query languages
- rule based representation and reasoning
- case based representation and reasoning
- representing uncertainty
- procedural programming
Context representation and reasoning
- feature extraction
- classification
- clustering
- fuzzy rules
Activity and context recognition

Context Representation & Reasoning

- How can we make inferences on the user context based on lower context data?
  - Logic programming
  - Ontology-based
  - Case-based
- Knowledge Representation & Reasoning

LOGIC PROGRAMMING FOR CR&R

Logic Programming Approach

- Express variety of contexts by first order logic

Background: First-order logic

- Propositional Logic
  - No quantifiers ($\exists$ or $\forall$)
  - $p \rightarrow q$
- First-order logic
  - Statement expressed as a function: P(x)
    - Human(x)
  - Quantifiers allowed
    - $\forall$*people x P(x)* $\rightarrow$ *Q(x)*
  - No predicates or functions as arguments
- Higher-order logic
  - Predicates or funcations can be arguments

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Context Model

- Represent context as first-order predicates
- Name of predicate is type of context
  - Location(…), Temperature(…), Time(…), …
- Examples:
  - *Location (chris, entering, room 3231)*
  - *Temperature (room 3231 , ‘‘=’’, 98 F)*
  - *Sister (venus, serena)*
- Arguments in Subject-Verb-Object (SVO) format
  - *ContextType(<subject>, <verb>, <object>)*
  - *Location (<person or object>, {entering, leaving, in}, <location>)*
- Each argument can take any types: string, integer, list, …
- Each context type corresponds to a class in ontology

Operations on Contexts

- Contruct complex context expressions by Boolean operations:
  - Conjunction($\wedge$), Disconjunction($\vee$), Negation($\neg$)
- Examples
  - *Location (Manuel , Entering, Room 3211)*
    $\wedge$ SocialActivity(Room 3211, Meeting)
    - "Manuel is entering Room 3211 and that there is a meeting going on in that room."
  - *Lighting(Room 3234, Off) $\vee$ Lighting(Room 3234, Dim)*
    - "The lighting in Room 3234 is either off or dim."
  - *$\neg$Location (Manuel , In, Room 3211)*
    - "Manuel is not in Room 3211."

Existential & Universal Quantification

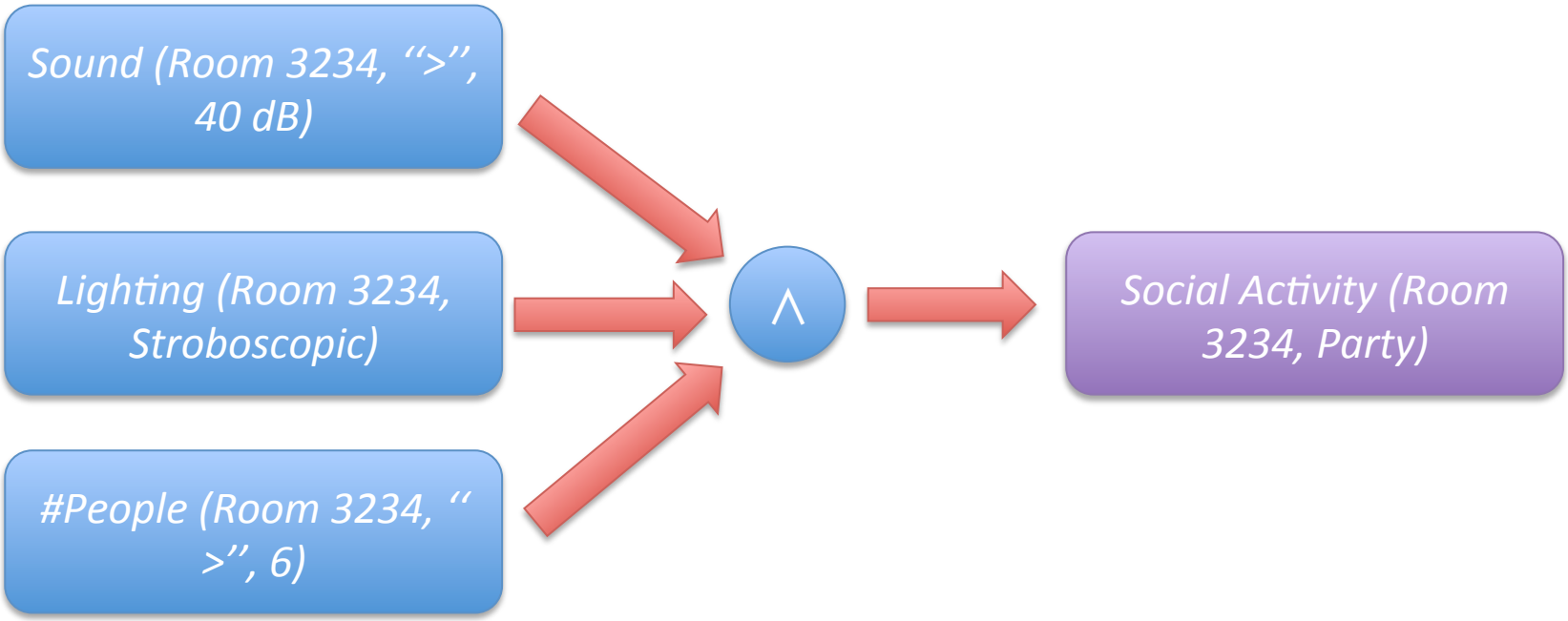
- Existential quantifier (“there exists”)
  - True for at least one value
  - $\exists_{Location}\, y$ *Location(Chris, In, y).*
    - “Chris is in some location”
- Universal quantifier (“for all”)
  - true for all values
  - $\forall_{People}\, x$ *Location(x, In, Room 3231)*
    - all people are in room 3231

Rules

- Can derive a new context from other (sensed) contexts
  - <existing context> => <new context>
  - *Sound (Room 3234, ‘‘>’’, 40 dB) ∧ Lighting (Room 3234, Stroboscopic) ∧ #People (Room 3234, ‘‘ >’’, 6) =>Social Activity (Room 3234, Party)*
  - “there is a party going on in a room if the level of sound in the room is high, stroboscopic lights are on and the number of people in the room is greater than some threshold value.”

Rules

- Derive a new context from other contexts
  - <existing context> => <new context>



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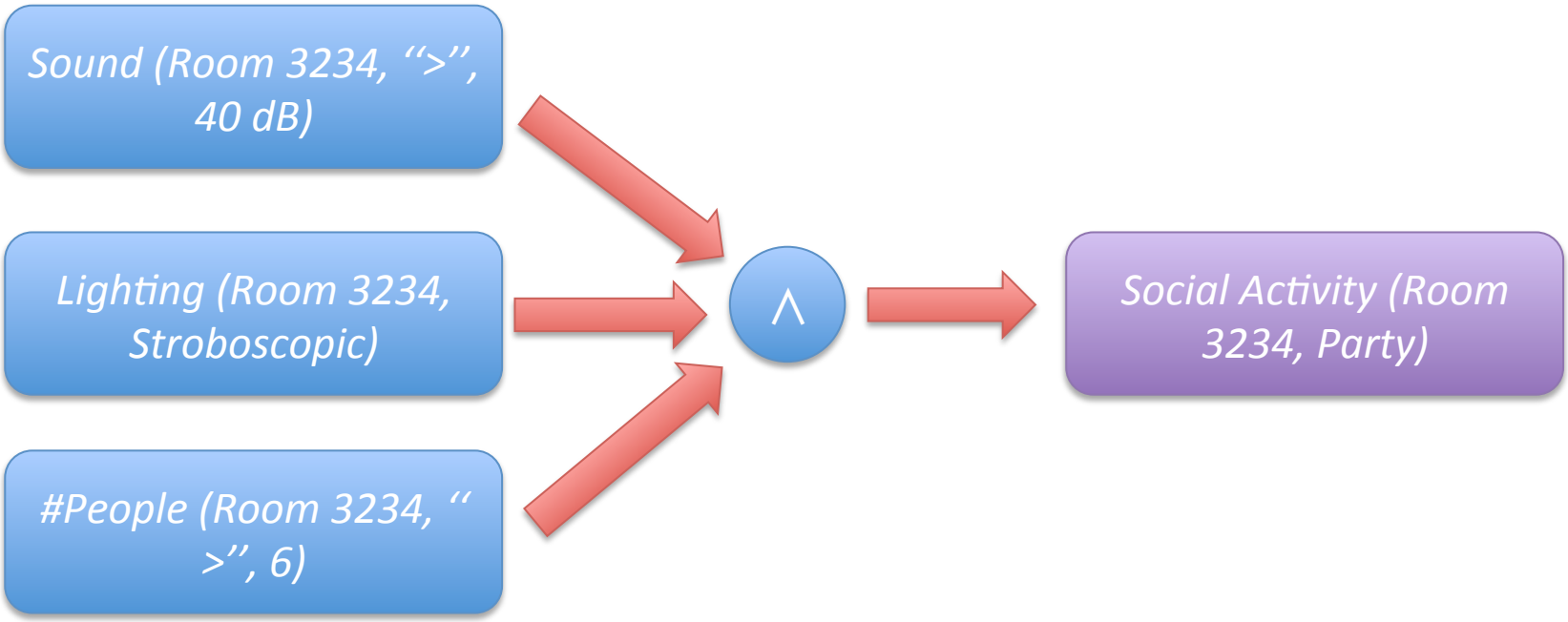


Methods for Providing Context

- How can an application obtain a context of interest from the *context engine*?
- Context Query
  - Application sends a query to the context engine
- Subscribe-Notify
  - Subscribe for certain contexts and get notified whenever that context becomes true.

Methods for Providing Context

- Context Query
  - Application sends a query to the context engine
  - In a query, one or more arguments of the predicate is replaced by a variable (say X) to indicate that the application would like values of the variable to make the predicate true.
  - Ex: “Who is in room 3231?”
    - Query: *Location(X, in, room 3231)*

Methods for ProvidingContext

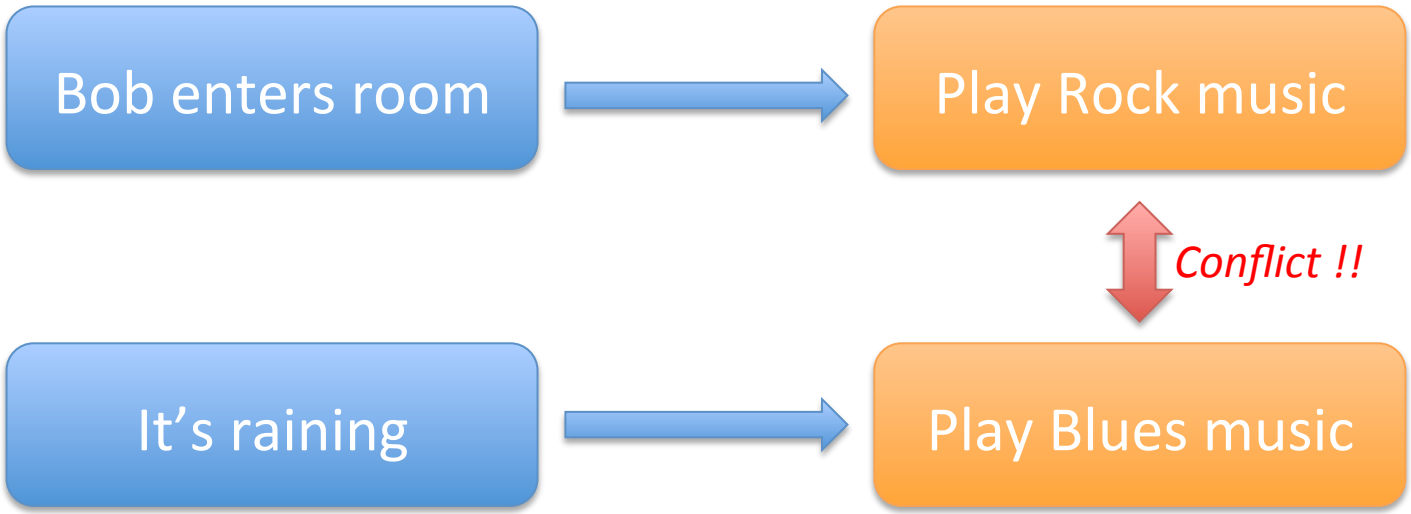
- Subscribe-Notify
  - Subscribe for certain contexts and get notified whenever that context becomes true.
  - For example, an application wants to receive notifications when outside temperature is below 5°C
    - Temperature(outside, “<“, 5°C)

Context-Sensitive Behavior

- A context-aware jukebox App could specify that whenever Bob enters his room, the playMusic() method must be invoked.
- Configuration file defines rules that associate certain contexts with an action

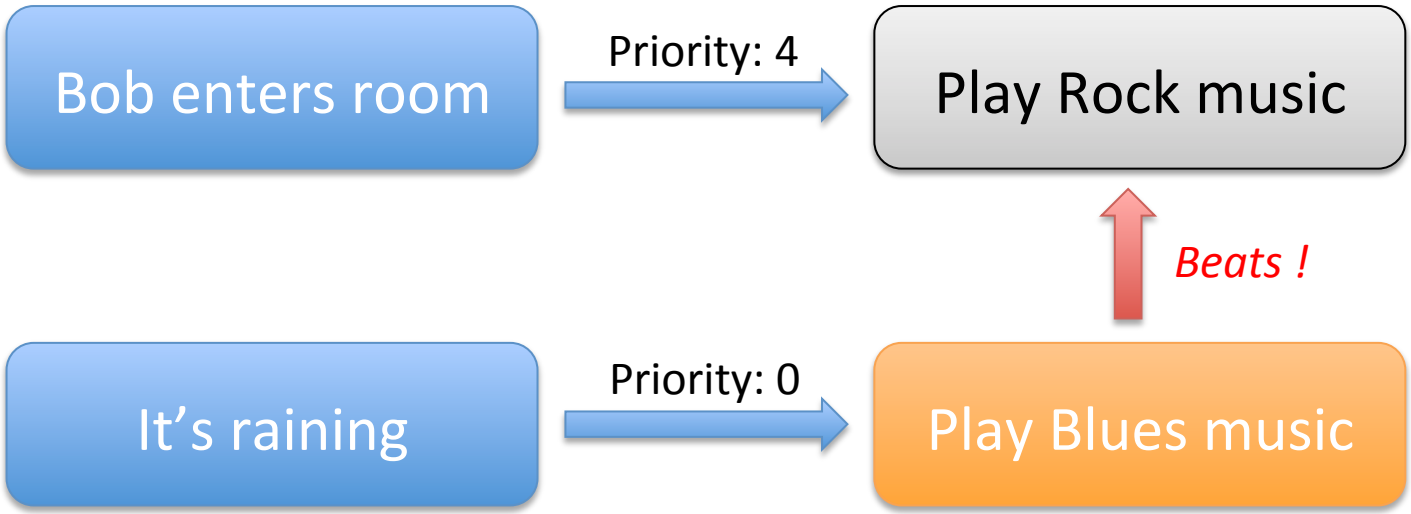
Challenge: Conflicts

- Two rules may cause a conflict in actions



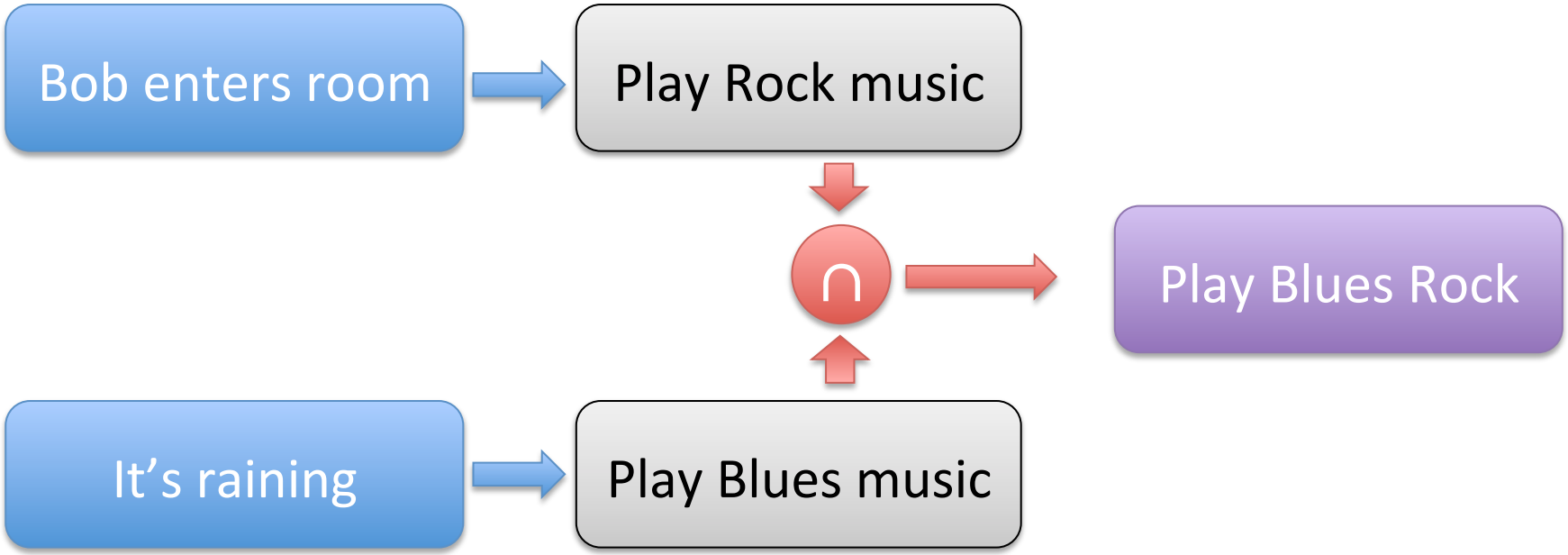
Conflict Resoultion: Prioritized Rule

- Set priority to each rule



Conflict Resoultion: Compromise

- Come up with a compromised action (find intersection of two actions)



Conflict Resoultion: Learning

- Choose an action and get feedback from the user
- Or let the user choose?
- Then learn user's preference between conflicting actions

Challenge: Context Evaluation

- Suppose we have *n* rules in total
  - Either context-synthesize rules or action rules
- For each small changes in sensor values or lower contexts, we need to evaluate *n* rules, i.e., *n* contexts: O(n)
- How can we minimize the number of necessary context evaluation?

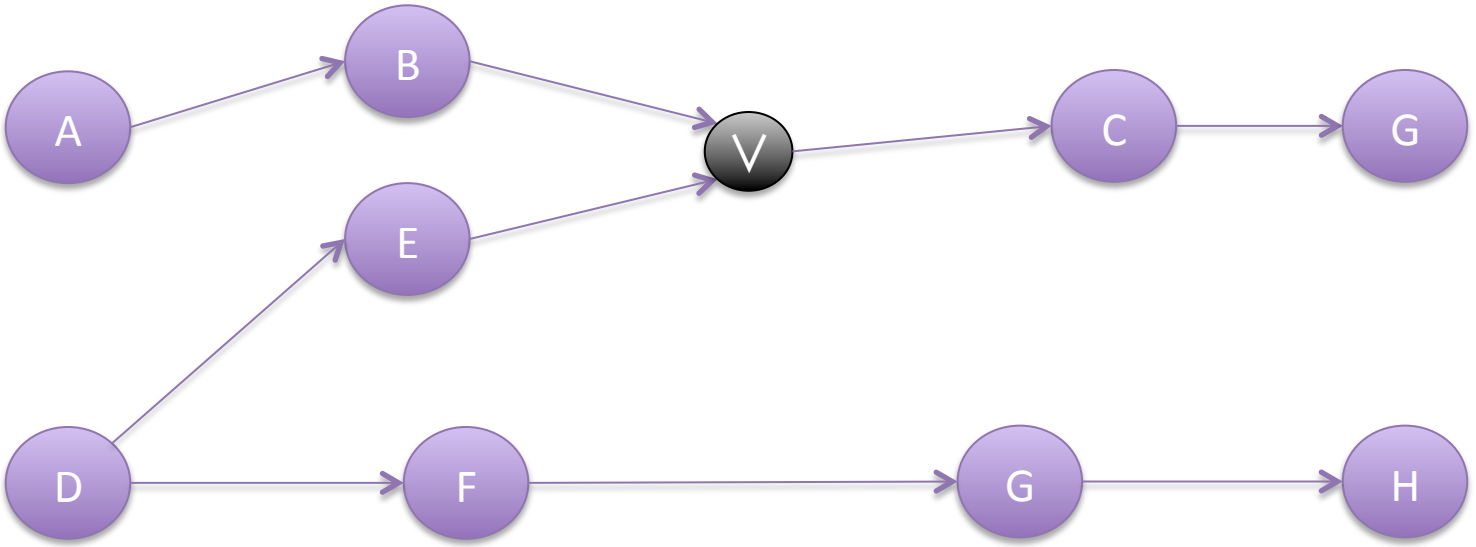
Optimization

- Optimize context evaluation

- If Context-A is true, then Context-B is true
- contrapositive:
- If Context-B is not, then Context-A is not
- So, if Context-B is found false, we don't need to evaluate Context-A (false)

POSET (Partially Ordered Set)

- With contexts, form a poset and evaluate from the right to left until false



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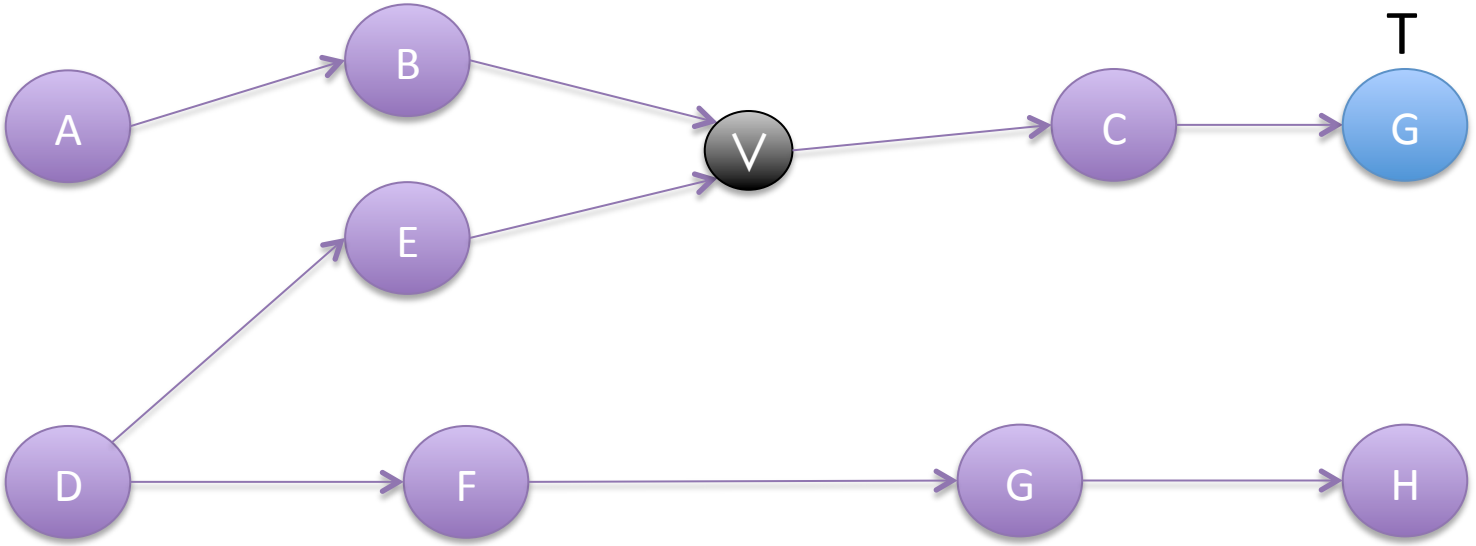

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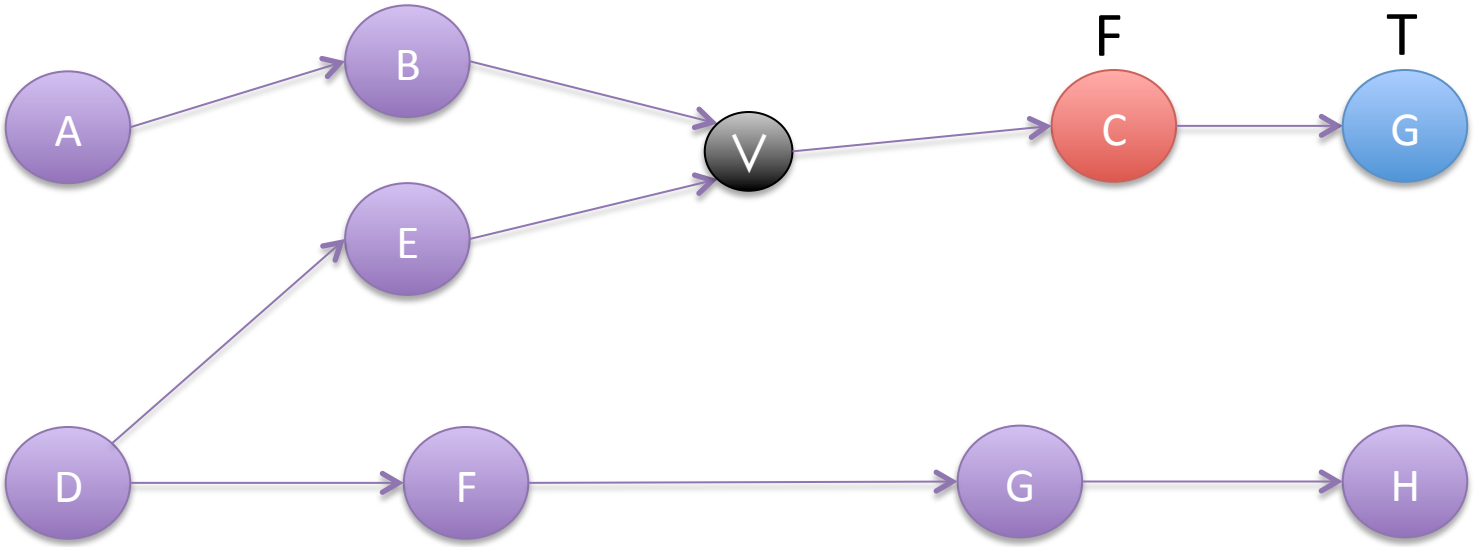

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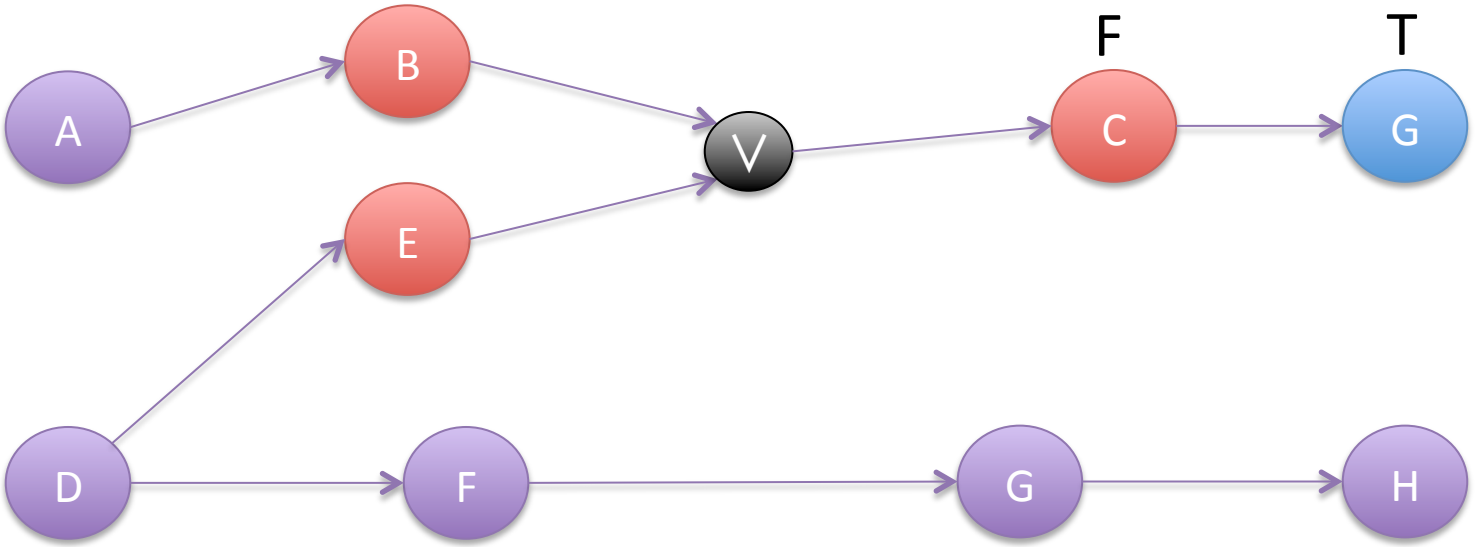

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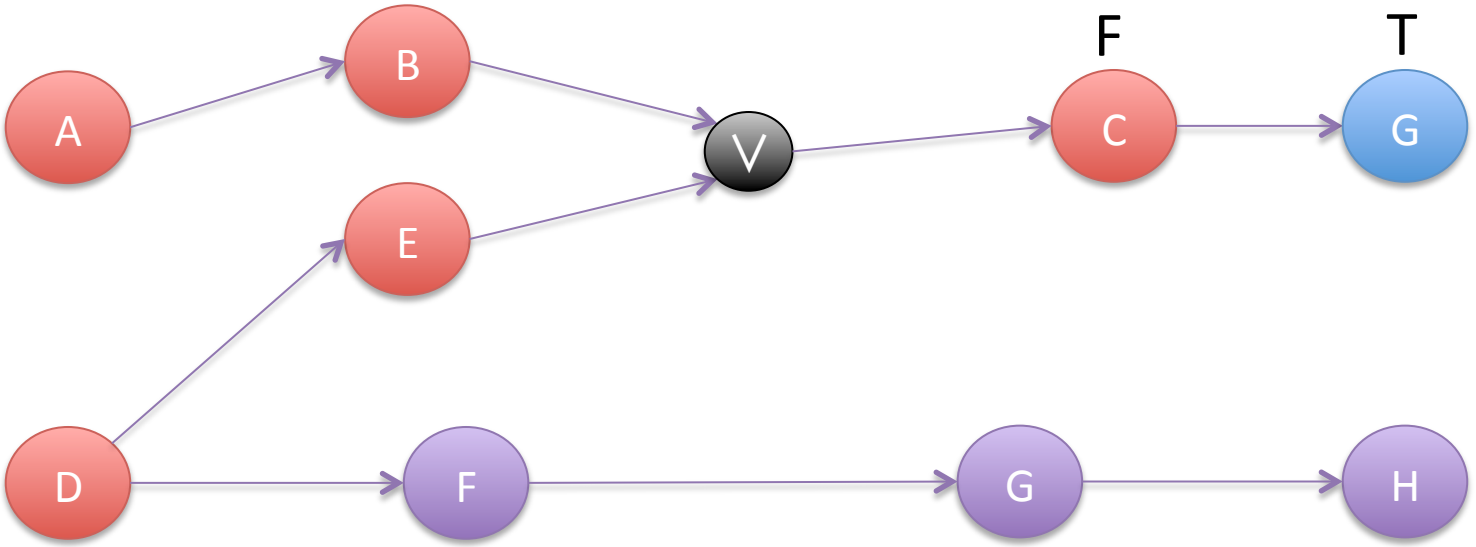

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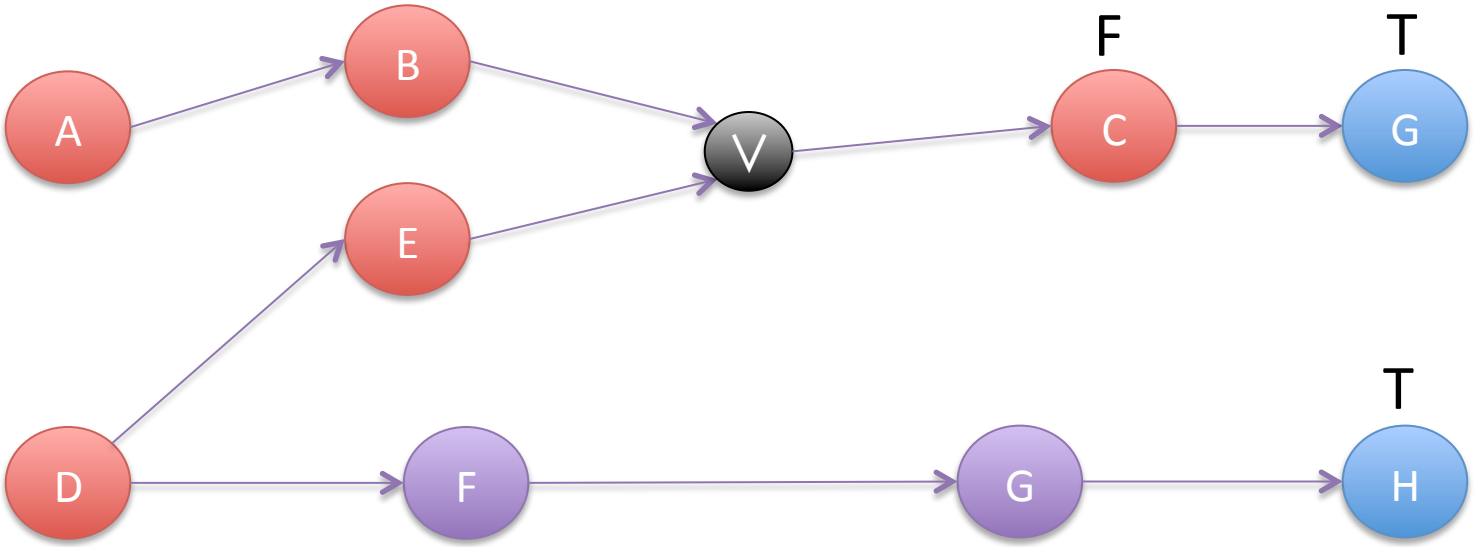

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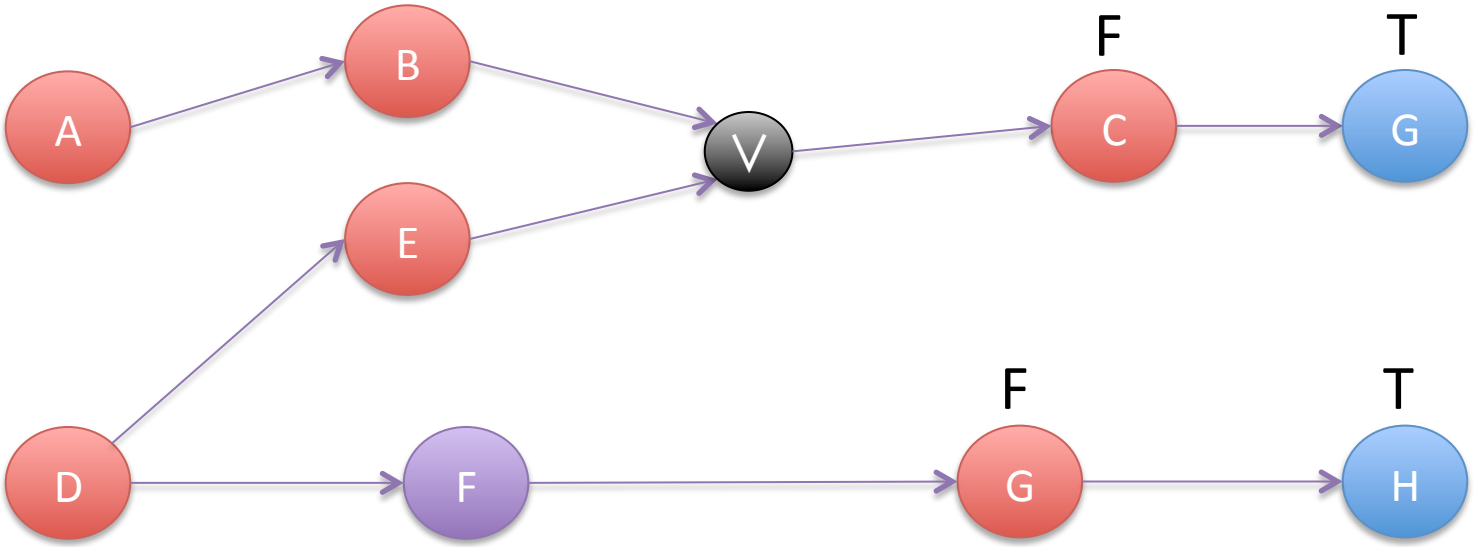

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