

# First-Order Logic

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# Pokok Bahasan

- Mengapa FOL?
- Syntax dan semantics pada FOL
- Penggunaan FOL
- Wumpus world pada FOL
- Knowledge engineering pada FOL

# Logika Propositional

- ☺ Logika propositional adalah **declarative**
- ☺ Logika propositional mengizinkan informasi partial/disjunctive/negated
  - (tidak seperti struktur data dan database)
- ☺ Logika propositional merupakan **compositional**:
  - meaning of  $B_{1,1} \wedge P_{1,2}$  is derived from meaning of  $B_{1,1}$  and of  $P_{1,2}$
- ☺ Arti pada logika propositional **context-independent**
  - (tidak seperti natural language, dimana arti tergantung context)
- ☹ Logika propositional mempunyai kekuatan ekspresif terbatas
  - (tidak seperti natural language)
  - Misal: tidak bisa seperti kamliat "pits cause breezes in adjacent squares"
    - Kecuali dengan menulis satu kalimat pada setiap square

# First-order logic

- Logika propositional mengasumsikan dunia dengan **fakta-fakta**,
- First-order logic (seperti natural language) mengasumsikan dunia berisi
  - **Objects**: people, houses, numbers, colors, baseball games, wars, ...
  - **Relations**: red, round, prime, brother of, bigger than, part of, comes between, ...
  - **Functions**: father of, best friend, one more than, plus, ...

# Syntax pada FOL: Elemen dasar

- Constants     KingJohn, 2, NUS,...
- Predicates     Brother, >,...
- Functions     Sqrt, LeftLegOf,...
- Variables     x, y, a, b,...
- Connectives    $\neg, \Rightarrow, \wedge, \vee, \Leftrightarrow$
- Equality       =
- Quantifiers     $\forall, \exists$

# Kamliat Atom

Atomic sentence =  $\text{predicate} (term_1, \dots, term_n)$   
or  $term_1 = term_2$

Term =  $\text{function} (term_1, \dots, term_n)$   
or *constant* or *variable*

- Misal:  $\text{Brother}(\text{KingJohn}, \text{RichardTheLionheart}) >$   
 $(\text{Length}(\text{LeftLegOf}(\text{Richard})),$   
 $\text{Length}(\text{LeftLegOf}(\text{KingJohn})))$

# Kalimat Komplek

- Kalimat komplek dibuat dari kalimat atom menggunakan konektivitas

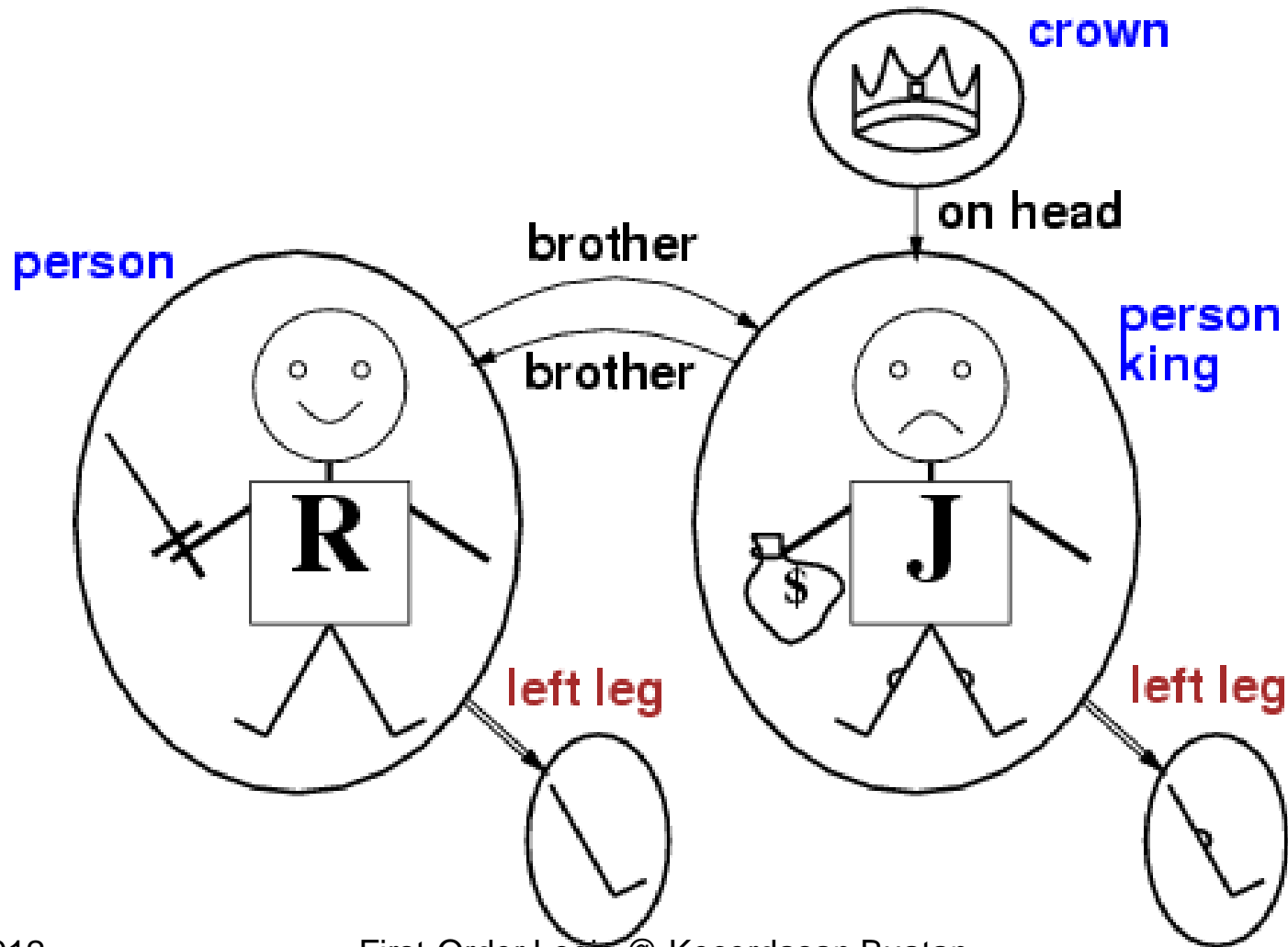
$$\neg S, S_1 \wedge S_2, S_1 \vee S_2, S_1 \Rightarrow S_2, S_1 \Leftrightarrow S_2,$$

Misal:  $Sibling(KingJohn, Richard) \Rightarrow$   
 $Sibling(Richard, KingJohn)$

$$>(1,2) \vee \leq (1,2)$$

$$>(1,2) \wedge \neg >(1,2)$$

# Contoh: Model untuk FOL





# Universal quantification

- $\forall \langle \text{variables} \rangle \langle \text{sentence} \rangle$

Everyone at NUS is smart:

$$\forall x \text{ At}(x, \text{NUS}) \Rightarrow \text{Smart}(x)$$

- $\forall x P$  bernilai true di sebuah model  $m$  iff  $P$  bernilai benar dengan  $x$  di setiap obyek pada model
- Equivalensi **conjunction** pada **instantiations** pada  $P$

$$\begin{aligned} & \text{At}(\text{KingJohn}, \text{NUS}) \Rightarrow \text{Smart}(\text{KingJohn}) \\ \wedge & \text{At}(\text{Richard}, \text{NUS}) \Rightarrow \text{Smart}(\text{Richard}) \\ \wedge & \text{At}(\text{NUS}, \text{NUS}) \Rightarrow \text{Smart}(\text{NUS}) \\ \wedge & \dots \end{aligned}$$

# Kesalahan umum yang harus dihindari

- $\Rightarrow$  adalah konektivitas utama dengan  $\forall$
- Kesalahan umum: menggunakan  $\wedge$  sebagai konektivitas utama dengan  $\forall$ :  
 $\forall x \text{ At}(x, \text{NUS}) \wedge \text{Smart}(x)$   
artinya “Everyone is at NUS and everyone is smart”

# Existential quantification

- $\exists \langle \text{variables} \rangle \langle \text{sentence} \rangle$
- Someone at NUS is smart:
- $\exists x \text{ At}(x, \text{NUS}) \wedge \text{Smart}(x)$
- $\exists x P$  bernilai benar pada sebuah model  $m$  iff  $P$  adalah benar dengan  $x$  di beberapa obyek pada model
- Equivalensi **disjunction** pada **instantiations** pada  $P$ 
  - $\text{At}(\text{KingJohn}, \text{NUS}) \wedge \text{Smart}(\text{KingJohn})$
  - $\vee \text{ At}(\text{Richard}, \text{NUS}) \wedge \text{Smart}(\text{Richard})$
  - $\vee \text{ At}(\text{NUS}, \text{NUS}) \wedge \text{Smart}(\text{NUS})$
  - $\vee \dots$

# Kesalahan umum yang harus dihindari

- $\wedge$  adalah konektivitas utama dengan  $\exists$
- Kesalahan umum: menggunakan  $\Rightarrow$  sebagai konektivitas utama dengan  $\exists$ :

$$\exists x \text{ At}(x, \text{NUS}) \Rightarrow \text{Smart}(x)$$

bernilai benar jika **ada seseorang yang tidak di NUS!**

# Properti pada quantifiers

- $\forall x \forall y$  is the same as  $\forall y \forall x$
- $\exists x \exists y$  is the same as  $\exists y \exists x$
- $\exists x \forall y$  is **not** the same as  $\forall y \exists x$
- $\exists x \forall y \text{ Loves}(x,y)$ 
  - “There is a person who loves everyone in the world”
- $\forall y \exists x \text{ Loves}(x,y)$ 
  - “Everyone in the world is loved by at least one person”
- **Quantifier duality:**
- $\forall x \text{ Likes}(x, \text{IceCream})$                        $\neg \exists x \neg \text{Likes}(x, \text{IceCream})$
- $\exists x \text{ Likes}(x, \text{Broccoli})$                        $\neg \forall x \neg \text{Likes}(x, \text{Broccoli})$

# Equality

- $term_1 = term_2$  bernilai benar dalam interpretasi jika dan hanya jika  $term_1$  dan  $term_2$  merefer ke obyek yang sama
- Misal: pendefinisian *Sibling* pada term pada *Parent*:  
$$\forall x,y \text{ Sibling}(x,y) \Leftrightarrow [\neg(x = y) \wedge \exists m,f \neg (m = f) \wedge \text{Parent}(m,x) \wedge \text{Parent}(f,x) \wedge \text{Parent}(m,y) \wedge \text{Parent}(f,y)]$$

# Penggunaan FOL

- Brothers are siblings

$$\forall x,y \text{ Brother}(x,y) \Leftrightarrow \text{Sibling}(x,y)$$

- One's mother is one's female parent

$$\forall m,c \text{ Mother}(c) = m \Leftrightarrow (\text{Female}(m) \wedge \text{Parent}(m,c))$$

- “Sibling” is symmetric

$$\forall x,y \text{ Sibling}(x,y) \Leftrightarrow \text{Sibling}(y,x)$$

# Latihan → First-order logic

- Some students took French in spring 2001
- Every student who takes French passes it
- Only one student took Greek in spring 2001
- The best score in Greek is always higher than the best score in French
- Every person who buys a policy is smart
- No person buys an expensive policy
- There is an agent who sells policies only to people who are not insured



Sumber :

1.Slide perkuliahan Stuart Russell's (Berkeley) <http://aima.cs.berkeley.edu/>

