Situation Theory and its Applications

Roussanka Loukanova

Stockholm University

Logics for Linguistics

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1 Brief Intro to Situation Theory
   - Origins and Present
   - Atomic and basic objects

2 More Complex Objects
   - Infons
   - Propositions
   - Complex Relations
   - Complex Types and Parameters
   - Restricted Parameters

3 Linguistic Contexts and Agents

4 Applications

5 Some References
Barwise [1] is the most influential and debated works on SitT
Barwise and Perry [2]
  - a general model theory of information and its fundamentals
  - by modelling relational and partial information
  - dependence of information on situations
  - parameters as basic and complex informational components
Devlin [4, 5] is a detailed, intuitive introduction to SitT
Seligman and Moss [8] is a mathematical model theory of SitT
Loukanova [6, 7], is an intro to the mathematics of set-theoretical (non-well founded) foundations of SitT
  - information in context, w.r.t. agents
  - primitive and complex parameters
    - model (represent) objects with partially available information
    - model objects in nature that are undeveloped or in developmental stage
Sets of basic situation theoretical objects

- Primitive individuals: \( A_{\text{IND}} = \{a, b, c, \ldots\} \)
- Space-time locations: \( A_{\text{LOC}} = \{l, l_0, l_1, \ldots\} \)
  associated with some space and time relations, e.g.:

\[
\begin{align*}
  l_i & \prec l_j & \text{(time precedence)} \\
  l_i & \circ l_j & \text{(time overlapping)} \\
  l_i & \diamond l_j & \text{(space overlapping)} \\
  l_i & \subseteq_t l_j & \text{(time inclusion)} \\
  l_i & \subseteq_s l_j & \text{(space inclusion)} \\
  l_i & \subseteq l_j & \text{(space-time inclusion)} 
\end{align*}
\]

- Primitive relations: \( A_{\text{REL}} = \{r_0, r_1, \ldots\} \)
Primitive (basic) types

\[ B_{\text{TYPE}} = \{ \text{IND, REL, ARGR, LOC, POL, INFON, SIT, PROP, PARAM, TYPE}, \models \} \]  

- IND: primitive and complex individuals;
- REL: primitive and complex relations;
- ARGR: primitive and complex argument roles;
- LOC: space-time locations;
- POL: polarities 0 and 1;
- INFON: basic or complex information units;
- SIT: situations;
- PROP: basic or complex propositions;
- PARAM: primitive and complex parameters;
- TYPE: basic and complex types;
• $\models$ is a special type called “supports” (“holds”), e.g., used in the type of propositions that a situation $s$ and an infon $\sigma$ are of the type “supports”, i.e., “$s$ supports $\sigma$”:

\[
(s \models \sigma) \quad \text{(a proposition)} \\
\models s \models \sigma \quad \text{(a verified proposition)}
\]

• Primitive and complex types $\mathcal{T}_{\text{TYPE}}$

\[
\mathcal{B}_{\text{TYPE}} \subseteq \mathcal{T}_{\text{TYPE}} \quad \text{(4)}
\]
Basic argument roles with appropriateness constraints

- **basic argument roles**: \( \mathcal{BA}_{\text{ARGR}} \), e.g., \( \mathcal{BA}_{\text{ARGR}} = \{ \rho_1, \ldots, \rho_m \} \);
- **basic and complex argument roles**: \( \mathcal{BA}_{\text{ARGR}} \subseteq \mathcal{A}_{\text{ARGR}} \)

A set of argument roles is assigned to the primitive relations and types by a function \( \text{ArgR} \). I.e.:

- **for every** \( \gamma \in \mathcal{A}_{\text{REL}} \cup \mathcal{B}_{\text{TYPE}} \)
  
  \[
  \text{ArgR}(\gamma) = \{ \langle \text{arg}_1, T_1 \rangle, \ldots, \langle \text{arg}_n, T_n \rangle \} \quad (5)
  \]
  
  \[
  \equiv \{ T_1 : \text{arg}_1, \ldots, T_n : \text{arg}_n \} \quad (n \geq 0) \quad (6)
  \]

where \( \text{arg}_1, \ldots, \text{arg}_n \in \mathcal{A}_{\text{ARGR}}, \)

\( T_1, \ldots, T_n \in \mathcal{P}(\mathcal{T}_{\text{TYPE}}) \) are sets of types (basic or complex).

- The objects \( \text{arg}_1, \ldots, \text{arg}_n \) are called the **argument roles** or argument slots of \( \gamma \).
- \( T_1, \ldots, T_n \) are specific for \( \gamma \) and are called the appropriateness constraints of the argument roles of \( \gamma \).
Each relation is associated with a set $ArgR$ of argument roles

$ArgR(smile) = \{ T_a : smiler \}$ \hspace{1cm} (7a)

$ArgR(read) = \{ T_{a_1} : reader, \ T_m : read-ed, \ T_{a_2} : readee \}$ \hspace{1cm} (7b)

$ArgR(read_1) = \{ T_a : reader, \ T_o : read-ed \}$ \hspace{1cm} (7c)

$ArgR(give) = \{ T_a : giver, \ T_r : receiver, \ T_g : given \}$ \hspace{1cm} (7d)

Each type is associated with a set $ArgR$ of argument roles, e.g., for the “supports” type $\models$ of situations and infons:

$ArgR(\models) = \{ SIT : arg_{SIT}, \ INFON : arg_{INFON} \}$. \hspace{1cm} (8)
Typed primitive parameters (sometimes called indeterminates):

\[ P_{\text{IND}} = \{ \dot{a}, \dot{b}, \dot{c}, \ldots \}, \]  \hspace{1cm} (9a)

\[ P_{\text{LOC}} = \{ \dot{l}_0, \dot{l}_1, \ldots \}, \]  \hspace{1cm} (9b)

\[ P_{\text{REL}} = \{ \dot{r}_0, \dot{r}_1, \ldots \}, \]  \hspace{1cm} (9c)

\[ P_{\text{POL}} = \{ \dot{i}_0, \dot{i}_1, \ldots \}, \]  \hspace{1cm} (9d)

\[ P_{\text{SIT}} = \{ \dot{s}_0, \dot{s}_1, \ldots \}. \]  \hspace{1cm} (9e)
We will define complex objects recursively

- Infons
- states
- events
- situations
- propositions
- situated propositions
- complex relations
- complex types
- restricted parameters
Definition (Basic Infons)

A basic infon is every tuple $\langle \gamma, \theta, \tau, i \rangle$, where

- $\gamma \in \mathcal{R}_{\text{REL}}$ is a relation (primitive or complex)

$$\text{ArgR}(\gamma) = \{\langle \text{arg}_1, T_1 \rangle, \ldots, \langle \text{arg}_n, T_n \rangle\} \quad (n \geq 0), \quad (10)$$

where $T_1, \ldots, T_n \in \mathcal{P}(\mathcal{T}_{\text{TYPE}})$

- $\theta$ is an argument filling for $\gamma$, i.e.:

$$\theta = \{\langle \text{arg}_1, \xi_1 \rangle, \ldots, \langle \text{arg}_n, \xi_n \rangle\}, \quad (11)$$

for $\xi_1, \ldots, \xi_n$ that satisfy the type constraints over $\gamma$:

$$T_1 : \xi_1, \ldots, T_n : \xi_n \quad (12)$$

- LOC : $\tau$ (basic or complex),   POL : $i$, $i \in \{0, 1\}$,
Definition (Infons)

The class $\mathcal{I}_{INF}$ of infons has basic and complex infons:

$$\mathcal{B}\mathcal{I}_{INF} \subset \mathcal{I}_{INF}$$

- **Complex infons** (for representation of conjunctive and disjunctive information), e.g.:

  For any infons $\sigma_1, \sigma_2 \in \mathcal{I}_{INF}$,

  $$\langle \land, \sigma_1, \sigma_2 \rangle \in \mathcal{I}_{INF}$$ (13a)
  $$\langle \lor, \sigma_1, \sigma_2 \rangle \in \mathcal{I}_{INF}$$ (13b)
basic infons in linear notations:

\[
\langle \gamma, T_1 : \text{arg}_1 : \xi_1, \ldots, T_n : \text{arg}_n : \xi_n, \text{LOC} : \text{Loc} : \tau, \text{POL} : \text{Pol} : i \rangle \tag{14}
\]

\[
\langle \gamma, \text{arg}_1 : \xi_1, \ldots, \text{arg}_n : \xi_n, \text{Loc} : \tau; \text{Pol} : i \rangle \tag{15}
\]

\[
\langle \gamma, \xi_1, \ldots, \xi_n, \tau; i \rangle \tag{16}
\]
Example (infons in linear notations)

An infon can be specific or parametric, e.g.

- **a reads b to c at the space-time location l** (specific objects)

  \[
  \ll read, T_{a_1} : reader : a, \\
  T_m : read-ed : b, \\
  T_{a_2} : readee : c, \\
  LOC : Loc : l; POL : Pol : 1 \gg
  \] (17)

- **a reads b to the unknown \( \dot{c} \) at the unknown location \( \dot{l} \)**

  \[
  \ll read, T_{a_1} : reader : a, \\
  T_m : read-ed : b, \\
  T_{a_2} : readee : \dot{c}, \dot{l}; : 1 \gg
  \] (specific)

  (parametric)
Example (infons in linear notations)

Other parametric infons, e.g.

- **a reads**
  (the unknown \(\hat{b}\) to the unknown \(\hat{c}\) at the unknown location \(\hat{l}\))

\[
\ll \text{read}, T_{a_1} : \text{reader} : a, \quad (\text{specific}) \\
T_m : \text{read-ed} : \hat{b}, \quad (\text{parametric}) \\
T_{a_2} : \text{readee} : \hat{c}, \hat{l}; 1 \gg \quad (\text{parametric})
\]

- **the info that a either reads or does not** — unknown polarity \(\hat{p}\)

\[
\ll \text{read}, T_{a_1} : \text{reader} : a, \quad (\text{specific}) \\
T_m : \text{read-ed} : \hat{b}, \quad T_{a_2} : \text{readee} : \hat{c}, \hat{l}; \hat{p} \gg \quad (\text{parametric})
\]
Definition (Propositions)

**Proposition** is any tuple \( \langle \text{PROP}, T, \theta \rangle \), where

- \( T \in \mathcal{T}_{\text{TYPE}} \) is a type with a set of argument roles

\[
\text{ArgR}(T) = \{ \langle \text{arg}_1, T_1 \rangle, \ldots, \langle \text{arg}_n, T_n \rangle \}, \quad n \geq 0 \quad (21)
\]

- \( \theta \) is an argument filling for \( T \), i.e.:

\[
\theta = \{ \langle \text{arg}_1, \xi_1 \rangle, \ldots, \langle \text{arg}_n, \xi_n \rangle \}, \quad (22)
\]

for some objects \( \xi_1, \ldots, \xi_n \) that satisfy the appropriateness type constraints of the type \( T \), i.e.:

\[
T_1 : \xi_1, \ldots, T_n : \xi_n \quad (23)
\]
The variant notations (24a) and (24b) are used depending on context.

The notation (24a) resemble the application operation.
Definition (Situated propositions)

- The type $\vdash$ ("supports"): 
  \[
  \text{ArgR}(\vdash) = \{ \text{SIT} : \text{arg}_{\text{SIT}}, \ \text{INFON} : \text{arg}_{\text{INFON}} \} \tag{25}
  \]

- Situated proposition:
  \[
  \langle \text{PROP}, \vdash, s, \sigma \rangle, \quad \text{where } s \in \mathcal{P}_{\text{SIT}} \text{ and } \sigma \in \mathcal{I}_{\text{INFON}} \tag{26}
  \]

Notation

\[
\langle \vdash, s, \sigma \rangle \equiv (s \vdash \sigma) \tag{27a}
\]
\[
\equiv \langle \text{PROP}, \vdash, s, \sigma \rangle \tag{27b}
\]
Example (The situation $s$ supports a positive information)

\[
(s \models \ll book, \text{IND} : \text{arg} : b, \text{LOC} : \text{Loc} : l; \text{POL} : \text{Pol} : 1) \] (28a)

\[
(28b)
\]

Example (The situation $s$ supports a negative information)

\[
(s \models \ll book, \text{IND} : \text{arg} : b, \text{LOC} : \text{Loc} : l; \text{POL} : \text{Pol} : 0) \] (29a)

\[
(29b)
\]
Example (The situation $s$ does not support a positive information)

$$(s \not\models \ll book, \text{IND} : \text{arg} : b, \quad (30a)$$

$$\text{LOC} : \text{Loc} : l ; \text{POL} : \text{Pol} : 1 \gg) \quad (30b)$$

Example (The situation $s$ does not support a negative information)

$$(s \not\models \ll book, \text{IND} : \text{arg} : b, \quad (31a)$$

$$\text{LOC} : \text{Loc} : l ; \text{POL} : \text{Pol} : 0 \gg) \quad (31b)$$
Example (actual vs. fallible situations)

\[(s_1 \models \ll book, b, l; 1 \gg)\]  \hspace{1cm} (32a)
\[(s_2 \models \ll book, b, l; 0 \gg)\]  \hspace{1cm} (32b)

- In case that both propositions (32a), (32b) are true, at least one of the situations \(s_1, s_2\) is not actual, because of the shared location \(l\).
- It may be that
  - \(s_1\) is actual situation, corresponding to a part of the reality
  - \(s_2\) is erroneous, i.e., “carries” wrong information
    E.g., \(s_2\) can be a state of an informational entity.
Example (actual vs. fallible situations)

\[(s_1 \models \ll \text{book}, b, l; 1 \gg)\]  
\[(s_2 \models \ll \text{book}, b, l; 0 \gg)\] (32a) (32b)

- In case that both propositions (32a), (32b) are true, at least one of the situations \(s_1, s_2\) is not actual, because of the shared location \(l\).

- It may be that
  - \(s_1\) is actual situation, corresponding to a part of the reality
  - \(s_2\) is erroneous, i.e., “carries” wrong information
  E.g., \(s_2\) can be a state of an informational entity.
Example (actual vs. fallible situations)

\[(s_1 \models \langle book, b, l; 1 \rangle) \quad (32a)\]
\[(s_2 \models \langle book, b, l; 0 \rangle) \quad (32b)\]

- In case that both propositions (32a), (32b) are true, at least one of the situations \(s_1, s_2\) is not actual, because of the shared location \(l\).

- It may be that
  - \(s_1\) is actual situation, corresponding to a part of the reality
  - \(s_2\) is erroneous, i.e., “carries” wrong information
    E.g., \(s_2\) can be a state of an informational entity.
Example (A situation $s$ can “carry” partial information)

$$(s \not\models \ll book, b, l; 1 \gg) \quad (33a)$$

$$(s \not\models \ll book, b, l; 0 \gg) \quad (33b)$$

Both propositions (33a) and (33b) can be true.
Example (conjunctive information)

- a conjunctive infon in a proposition

\[
(s \models \langle\langle \text{smiles}, \text{IND : arg : a, LOC : Loc : l; 1} \rangle \quad (34a) \\
\land \langle\langle \text{animate}, \text{IND : arg : a, l}_1; 1 \rangle \rangle \quad (34b) \\
\land (l \circ l_1) \quad (34c)
\]

- a conjunctive proposition

\[
(s \models (s \models \langle\langle \text{smiles}, \text{IND : arg : a, l; 1} \rangle) \land (s \models \langle\langle \text{animate}, \text{IND : arg : a, l}_1; 1 \rangle) \land (l \circ l_1) \quad (35a) \\
\land (35b) \\
\land (35c)
\]

- There is another way to present the information (34b) and (35b). More on this later.
Example (conjunctive information)

- a conjunctive infon in a proposition

\[
\begin{align*}
(s &
\models
\llangle \text{smiles}, \text{IND} : \text{arg} : a, \text{LOC} : \text{Loc} : l; 1 \rrangle) \quad (34a) \\
\wedge
\llangle \text{animate}, \text{IND} : \text{arg} : a, l_1; 1 \rrangle \quad (34b) \\
\wedge
(l \circ l_1) \quad (34c)
\end{align*}
\]

- a conjunctive proposition

\[
\begin{align*}
(s &
\models
\llangle \text{smiles}, \text{IND} : \text{arg} : a, l; 1 \rrangle) \quad (35a) \\
\wedge
(s &
\models
\llangle \text{animate}, \text{IND} : \text{arg} : a, l_1; 1 \rrangle) \quad (35b) \\
\wedge
(l \circ l_1) \quad (35c)
\end{align*}
\]

- There is another way to present the information (34b) and (35b). More on this later.
Example (conjunctive information)

- a conjunctive infon in a proposition

\[(s \models \ll \text{smiles}, \ \text{IND} : \text{arg} : a, \ \text{LOC} : \text{Loc} : l; 1 \gg) \quad (34a)\]
\[\land \ll \text{animate}, \ \text{IND} : \text{arg} : a, \ l_1; 1 \gg \quad (34b)\]
\[\land (l \circ l_1) \quad (34c)\]

- a conjunctive proposition

\[(s \models \ll \text{smiles}, \ \text{IND} : \text{arg} : a, \ l; 1 \gg) \quad (35a)\]
\[\land (s \models \ll \text{animate}, \ \text{IND} : \text{arg} : a, \ l_1; 1 \gg) \quad (35b)\]
\[\land (l \circ l_1) \quad (35c)\]

- There is another way to present the information (34b) and (35b). More on this later.
Example

The propositional content of the sentence (36) might be expressed by the proposition (37a)–(37c), with some (great) approximation.

\[ (s \models \llangle \text{read}, \ \text{reader} : \dot{x}, \ \text{readed} : b, \ \text{readee} : \dot{y}, \ \text{Loc} : l; 1 \rrangle) \]
\[ \land \llangle \text{book}, \ \text{arg} : b, \ \text{Loc} : l_1; 1 \rrangle \)
\[ \land (l \subset l_1) \]

(37b) and (37c) are presented as parts of the propositional content of (36). There are other ways to include this information (later).
**Definition (Complex relations and appropriateness constraints)**

- Let $\sigma$ be a given infon, and 
  $\{\xi_1, \ldots, \xi_n\}$ a set of parameters that occur in $\sigma$.
- Let, for each $i \in \{1, \ldots, n\}$,  
  $T_i$ be the union of the constraints over the argument roles filled up by $\xi_i$.
- Then $\lambda\{\xi_1, \ldots, \xi_n\}\sigma$ is a complex relation,  
  with abstract argument roles denoted by $[\xi_1], \ldots, [\xi_n]$  
  and having $T_1, \ldots, T_n$ as appropriateness type constraints, respectively, i.e.:

$$
\text{ArgR}(\lambda\{\xi_1, \ldots, \xi_n\}\sigma) \\
= \{\langle [\xi_1], T_1 \rangle, \ldots, \langle [\xi_n], T_n \rangle \} 
$$

(38)
Example (A complex infon)

\[ \langle \text{book}, b, l_1; 0 \rangle \]  
\[ \land \langle \text{writes}, a, b, l_2; 1 \rangle \]  
\[ \land \langle \text{book}, b, l_3; 1 \rangle \]  
\[ \land l_1 < l_2 \land l_2 < l_3 \]  

(39a)  
(39b)  
(39c)  
(39d)

Example (A complex relation between \( \dot{x}, \dot{y}, \) and locations \( \dot{l}_1, \dot{l}_2, \dot{l}_3 \))

\[ \lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\} \left[ \langle \text{book}, \dot{y}, \dot{l}_1; 0 \rangle \right. \]  
\[ \land \langle \text{writes}, \dot{x}, \dot{y}, \dot{l}_2; 1 \rangle \]  
\[ \land \langle \text{book}, \dot{y}, \dot{l}_3; 1 \rangle \]  
\[ \land \dot{l}_1 < \dot{l}_2 \land \dot{l}_2 < \dot{l}_3 \]  

(40a)  
(40b)  
(40c)  
(40d)
Example (A complex infon)

\[
\begin{align*}
\langle \text{book, } b, \ l_1; \ 0 \rangle & \quad (39a) \\
\land \ \langle \text{writes, } a, \ b, \ l_2; \ 1 \rangle & \quad (39b) \\
\land \ \langle \text{book, } b, \ l_3; \ 1 \rangle & \quad (39c) \\
\land \ l_1 \prec l_2 \land l_2 \prec l_3 & \quad (39d)
\end{align*}
\]

Example (A complex relation between \( \dot{x}, \dot{y} \), and locations \( \dot{l}_1, \dot{l}_2, \dot{l}_3 \))

\[
\lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\} \left[ \begin{align*}
\langle \text{book, } \dot{y}, \dot{l}_1; \ 0 \rangle & \quad (40a) \\
\land \ \langle \text{writes, } \dot{x}, \dot{y}, \dot{l}_2; \ 1 \rangle & \quad (40b) \\
\land \ \langle \text{book, } \dot{y}, \dot{l}_3; \ 1 \rangle & \quad (40c) \\
\land \ \dot{l}_1 \prec \dot{l}_2 \land \dot{l}_2 \prec \dot{l}_3 & \quad (40d)
\end{align*} \right]
\]
Definition (Complex types and appropriateness constraints)

- Let \( \Theta \) be a given proposition, and \( \{\xi_1, \ldots, \xi_n\} \) be a set of parameters that occur in \( \Theta \).
- Let, for each \( i \in \{1, \ldots, n\} \), \( T_i \) be the union of the constraints over the argument roles filled up by \( \xi_i \).
- Then \( \lambda\{\xi_1, \ldots, \xi_n\}\Theta \) is a complex type, with abstract argument roles denoted by \([\xi_1], \ldots, [\xi_n]\) and having \( T_1, \ldots, T_n \) as appropriateness type constraints, respectively, i.e.:

\[
\text{ArgR}(\lambda\{\xi_1, \ldots, \xi_n\}\Theta) = \{\langle [\xi_1], T_1 \rangle, \ldots, \langle [\xi_n], T_n \rangle \}
\] (41)
Alternative classic notations for the complex types (corresponding to the set-theoretical comprehension):

\[
\lambda\{\xi_1, \ldots, \xi_n\}\Theta \equiv \left[ T_1 : [\xi_1], \ldots, T_n : [\xi_n] \mid \Theta \right]
\]  
(42a)

\[
\lambda\{\xi_1, \ldots, \xi_n\}\Theta \equiv \left[ [\xi_1], \ldots, [\xi_n] \mid \Theta \right]
\]  
(42b)
Example (A proposition)

\[(s_1 \not= \ll book, b, l_1; 0 \gg)\] (43a)
\[\land (s_2 = \ll writes, a, b, l_2; 1 \gg)\] (43b)
\[\land (s_3 = \ll book, b, l_3; 1 \gg)\] (43c)
\[\land (l_1 \prec l_2 \prec l_3)\] (43d)

Example (Complex type of objects \(\dot{x}, \dot{y}\), and locations \(\dot{l}_1, \dot{l}_2, \dot{l}_3\))

\[\lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\}[(s_1 \not= \ll book, \dot{y}, \dot{l}_1; 0 \gg)\] (44a)
\[\land (s_2 = \ll writes, \dot{x}, \dot{y}, \dot{l}_2; 1 \gg)\] (44b)
\[\land (s_3 = \ll book, \dot{y}, \dot{l}_3; 1 \gg)\] (44c)
\[\land (\dot{l}_1 \prec \dot{l}_2 \prec \dot{l}_3)\] (44d)
Example (A proposition)

\[(s_1 \not\models \ll book, b, l_1; 0 \gg)\]  \hspace{1cm} (43a)
\[\land (s_2 \models \ll writes, a, b, l_2; 1 \gg)\]  \hspace{1cm} (43b)
\[\land (s_3 \models \ll book, b, l_3; 1 \gg)\]  \hspace{1cm} (43c)
\[\land (l_1 \prec l_2 \prec l_3)\]  \hspace{1cm} (43d)

Example (Complex type of objects \(\dot{x}, \dot{y}\), and locations \(\dot{l}_1, \dot{l}_2, \dot{l}_3\))

\[\lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\}[(s_1 \not\models \ll book, \dot{y}, \dot{l}_1; 0 \gg)\]  \hspace{1cm} (44a)
\[\land (s_2 \models \ll writes, \dot{x}, \dot{y}, \dot{l}_2; 1 \gg)\]  \hspace{1cm} (44b)
\[\land (s_3 \models \ll book, \dot{y}, \dot{l}_3; 1 \gg)\]  \hspace{1cm} (44c)
\[\land (\dot{l}_1 \prec \dot{l}_2 \prec \dot{l}_3)\]  \hspace{1cm} (44d)
Definition (Complex propositions)

- Let \( \text{TYPE} : \lambda\{\xi_1, \ldots, \xi_n\} \Theta, \) and

\[
\operatorname{ArgR}(\lambda\{\xi_1, \ldots, \xi_n\} \Theta) = \{\langle [\xi_1], T_1 \rangle, \ldots, \langle [\xi_n], T_n \rangle\} \tag{45}
\]

- Let \( T_{i,1} : a_i, \ldots, T_{i,k_i} : a_i, \) for \( i = 1, \ldots, n. \)

- Then we can form the proposition

\[
\left( \lambda\{\xi_1, \ldots, \xi_n\} \Theta, \theta \right) \tag{46}
\]

where \( \theta = \{\langle [\xi_1], a_1 \rangle, \ldots, \langle [\xi_n], a_n \rangle\}. \)
Notation

\[
(\lambda\{\xi_1, \ldots, \xi_n\} \Theta, \theta) \quad (47a)
\]
\[
\equiv (\lambda\{\xi_1, \ldots, \xi_n\} \Theta, \{T_1 : [\xi_1] : a_1, \ldots T_n : [\xi_n] : a_n\}) \quad (47b)
\]
\[
\equiv (\{T_1 : [\xi_1] : a_1, \ldots T_n : [\xi_n] : a_n\} : \lambda\{\xi_1, \ldots, \xi_n\} \Theta) \quad (47c)
\]

Linear Notations

By assuming an order over the argument roles

\[
(\lambda\{\xi_1, \ldots, \xi_n\} \Theta, \theta) \quad (48a)
\]
\[
\equiv (a_1, \ldots, a_n : \lambda\{\xi_1, \ldots, \xi_n\} \Theta) \quad (48b)
\]
\[
\equiv (\lambda\{\xi_1, \ldots, \xi_n\} \Theta \{a_1, \ldots, a_n\}) \quad \text{(reminds application)} \quad (48c)
\]
\[
\equiv (\lambda\{\xi_1, \ldots, \xi_n\} \Theta : a_1, \ldots, a_n) \quad \text{(reminds application)} \quad (48d)
\]
Example (Complex proposition)

\[
\left( \lambda \{x, y, l_1, l_2, l_3\} \right) \left[ (s_1 \not\models \ll book, y, l_1; 0 \gg) \right.
\wedge (s_2 \models \ll writes, x, y, l_2; 1 \gg)
\wedge (s_3 \models \ll book, y, l_3; 1 \gg)
\wedge (l_1 \prec l_2 \prec l_3) \right] (49d)
\]

\[ : a, b, l_1, l_2, l_3 \] (49e)
Definition (Complex restricted parameters)

Given that

- $\xi$ is a parameter and $\Theta(\xi)$ is a proposition
- $T$ is the set of the types that are constraints over the argument roles in $\Theta(\xi)$ that are filled up by $\xi$
- $x$ is a parameter of type $\tau$, i.e., $\tau : x$, and $\tau$ is compatible with the types (constraints) $T$,
- then $x^{\lambda \xi \Theta(\xi)}$ is a complex parameter of type $\tau$, which is called a parameter restricted by the type $\lambda \xi \Theta(\xi)$.
- An object $a$ can be anchored to the parameter $x^{\lambda \xi \Theta(\xi)}$
  \[\iff a \text{ is of type } \tau, \text{ i.e., } \tau : a,\]
  \[T_i : a, \text{ for each type } T_i \in T,\]
  \[\text{and } \lambda \xi \Theta(\xi) : a, \text{ i.e., the proposition } \Theta(a) \text{ is true.}\]
Definition (States of Affairs, Events, Situations)

- A set of infons that have the same location components is called a **state of affairs (soa)**.
- A set of infons with multiple locations is called an **event (course of events — coa)**.
- A **situation** is a collection (non-well founded set) of infons.

- Note: further refinement of these definitions, e.g., w.r.t.:
  - Sets of infons may include inconsistency, e.g., by modelling contradictory or circular information. There are definitions of (in)consistent situations.
  - How to distinguish between states and events based on kinds of relations that are components of infons (there are verb classifications reflecting such differentiations) models of processes? space-time locations? models of space-time?
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  - models of processes?
  - space-time locations; models of space-time?
Example (A Situated Proposition)

\[(s \models \ll \text{read}, \text{reader} : x, \text{readed} : b, \text{Loc} : l_1; 1 \gg \land \) \]
\[\ll \text{book}, \arg : b, \text{Loc} : l_2; 1 \gg \land \] 
\[l_1 \circ l_2) \] (50a) 
(50b) 
(50c)

- The proposition (50a)-(50c) is true iff
  - x reads b in the location \(l_1\), in the situation \(s\):
    \[s \models \ll \text{read}, \text{reader} : x, \text{readed} : b, \text{Loc} : l_1; 1 \gg \] (51)
  - b is having the property \text{book} in \(l_2\), in the situation \(s\):
    \[s \models \ll \text{book}, \arg : b, \text{Loc} : l_2; 1 \gg \] (52)
  - and
    \[l_1 \circ l_2 \] (53)
Example (A Situated Proposition)

\[(s \models \ll read, reader : x, readed : b, Loc : l_1; 1 \gg) \land \ll book, arg : b, Loc : l_2; 1 \gg \land l_1 \circ l_2)\]

- The proposition (50a)-(50c) is true iff
  - \(x\) reads \(b\) in the location \(l_1\), in the situation \(s\):
    \[s \models \ll read, reader : x, readed : b, Loc : l_1; 1 \gg\]  (51)
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    \[l_1 \circ l_2\]  (53)
Example (A Situated Proposition)

\[(s \vdash \ll read, reader : x, readed : b, Loc : l_1; 1 \gg) \land \ll book, arg : b, Loc : l_2; 1 \gg) \land \ll l_1 \circ l_2) \]

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\[(l_1 \circ l_2)\]  

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- and
  \[l_1 \circ l_2\]  
  (53)
Example (A Situated Proposition)

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- The proposition (50a)-(50c) is true iff
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  - and
    \[l_1 \circ l_2\]
Semantic quantifiers as relations between types of situated objects:

\[
\begin{align*}
(s &\models \ll every, \quad [x/(s_i \models \ll student, x, l_i; 1 \gg)],[y/(s_j \models \ll walk, y, l_j; 1 \gg)],\quad l; 1 \gg) \\
(s &\models \ll some, \quad [x/(s_i \models \ll student, x, l_i; 1 \gg)],[y/(s_j \models \ll walk, y, l_j; 1 \gg)],\quad l; 1 \gg) \\
(s &\models \ll two, \quad [x/(s_i \models \ll student, x, l_i; 1 \gg)],[y/(s_j \models \ll walk, y, l_j; 1 \gg)],\quad l; 1 \gg)
\end{align*}
\]
The proposition $pu(u, l, x, y, \alpha)$, where

$$pu(u, l, x, y, \alpha) \equiv (u \models \ll tells\_to, x, y, \alpha, l; 1 \gg)$$ (55)

$pu(u, l, x, y, \alpha)$ states that the situation $u$ is an utterance situation.

The proposition $pu(u, l, x, y, \alpha)$ is true iff $u$ supports the uttering act:

$$u \models \ll tells\_to, x, y, \alpha, l; 1 \gg$$ (56)

i.e., iff

- $x$ is the speaker agent in $u$
- $y$ is the listener agent in $u$
- $l$ is the space-time location of the act of $x$ uttering $\alpha$
- $\alpha$ is the expression uttered in $u$ by the speaker agent $x$

The type of an utterance situation is

$$ru(l, x, y, \alpha) \equiv [u \mid pu(u, l, x, y, \alpha)]$$ (57)
Minimal Linguistic Context of Utterances

- The proposition $pu(u, l, x, y, \alpha)$, where

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The type of an utterance situation is

$$ru(l, x, y, \alpha) \equiv [u \mid pu(u, l, x, y, \alpha)] \quad (57)$$
Types for the concepts of situated linguistic agents

- The proposition $pu(u, l, x, y, \alpha)$ that $x$ tells $\alpha$ to $y$ in $u$:
  $$pu(u, l, x, y, \alpha) \equiv (u \models \ll tells\_to, x, y, \alpha, l; 1 \gg)$$ (58)

- the type of a speaker agent in $u$ is:
  $$rsp(u, l, y, \alpha) \equiv [x | pu(u, l, x, y, \alpha)]$$ (59)

- the type of a listener agent in $u$ is:
  $$rlst(u, l, x, \alpha) \equiv [y | pu(u, l, x, y, \alpha)]$$ (60)

- the type of the utterance space-time location is
  $$rdl(u, x, y, \alpha) \equiv [l | pu(u, l, x, y, \alpha)]$$ (61)

- in $u$, $x$ is the speaker agent and $y$ is the listener agent iff $u$ supports the uttering act:
  $$u \models \ll tells\_to, x, y, \alpha, l; 1 \gg$$ (62)
Types for the concepts of situated linguistic agents

- The proposition $pu(u, l, x, y, \alpha)$ that $x$ tells $\alpha$ to $y$ in $u$:
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  (60)

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Types for the concepts of situated linguistic agents

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  \[
  pu(u, l, x, y, \alpha) \equiv (u \models \ll tells_{-to}, x, y, \alpha, l; 1 \gg) \quad (58)
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  \[
  u \models \ll tells_{-to}, x, y, \alpha, l; 1 \gg \quad (62)
  \]
Speaker’s References: referent agents

- the type of the speaker’s referent agent of the expression $\alpha$

$$r_{\alpha}(u, l, x, y) = [z \mid q(u, l, x, y, z, \alpha)]$$  \hspace{1cm} (63)

where $q(u, l, x, y, z, \alpha)$ is a proposition such as (64a)

$$q(u, l, x, y, z, \alpha) \equiv$$  \hspace{1cm} (64a)

$$\left( u^{ru(l,x,y,\alpha)} \models \right.$$

$$\ll \text{refers-to}, x^{rsp(u,l,y,\alpha)}, z, \alpha, l^{rdl(u,x,y,\alpha)}; 1 \gg \right)$$  \hspace{1cm} (64c)

The proposition $q(u, l, x, y, z, \alpha)$ in (64a) states that

- in the utterance $u^{ru(l,x,y,\alpha)}$, the speaker $x^{rsp(u,l,y,\alpha)}$ refers to the referent agent $z$ of the expression $\alpha$. 
Speaker’s References: referent agents

- the type of the speaker’s referent agent of the expression $\alpha$

$$\text{r}_\alpha(u, l, x, y) = [z \mid q(u, l, x, y, z, \alpha)] \quad (63)$$

where $q(u, l, x, y, z, \alpha)$ is a proposition such as (64a)

$$q(u, l, x, y, z, \alpha) \equiv \quad (64a)$$

$$\begin{align*}
(u^{ru(l, x, y, \alpha)} \models & \quad \langle \text{refers-to}, x^{rsp(u, l, y, \alpha)}, z, \alpha, l^{rdl(u, x, y, \alpha)}; 1 \rangle) \quad (64c)
\end{align*}$$

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where $q(u, l, x, y, z, \alpha)$ is a proposition such as (64a)

$$q(u, l, x, y, z, \alpha) \equiv \quad (64a)$$

$$u^{ru(l, x, y, \alpha)} \models (64b)$$

$$\ll \text{refers-to, } x^{rsp(u, l, y, \alpha)}, z, \alpha, l^{rdl(u, x, y, \alpha)}; 1 \gg \quad (64c)$$

The proposition $q(u, l, x, y, z, \alpha)$ in (64a) states that

- in the utterance $u^{ru(l, x, y, \alpha)}$, the speaker $x^{rsp(u, l, y, \alpha)}$ refers to the referent agent $z$ of the expression $\alpha$
Speaker's denotations of referent agents

Denotation of a proper name, e.g., MARIA, as a referent agent

- a referent agent \( z' \) determined by a reference restriction \( r \),
- in an utterance situation (context) \( u \),
- by a speaker agent \( x^{r_{sp}(u,l,y,\alpha)} \)

where \( r \) may be

- general, sincere reference

\[
r = [z \mid (u \models \ll ref_to_by, x^{r_{sp}(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land 
(u \models \ll named, MARIA, , z; 1 \gg)]
\]

- belief reference

\[
r = [z \mid (u \models \ll ref_to_by, x^{r_{sp}(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land 
(u \models \ll believes, x^{r_{sp}(u,l,y,\alpha)}, 
(s_{res} \models \ll named, MARIA, z; 1 \gg), 
l^{rdl}; 1 \gg)]
\]
Speaker’s denotations of referent agents

Denotation of a proper name, e.g., MARIA, as a referent agent

- a referent agent $z^r$ determined by a reference restriction $r$,
- in an utterance situation (context) $u$,
- by a speaker agent $x^{\text{rsp}(u,l,y,\alpha)}$

where $r$ may be

- general, sincere reference
  
  \[ r = [z | (u \models \llrefersby\rrsp(u,l,y,\alpha), z, \text{MARIA}, \llrdl; 1 \gg) \land (u \models \llnamed, \text{MARIA}, \rrd; 1 \gg)] \]

- belief reference
  
  \[ r = [z | (u \models \llrefersby\rrsp(u,l,y,\alpha), z, \text{MARIA}, \llrdl; 1 \gg) \land (u \models \llbelieves, \rrsp(u,l,y,\alpha), (s_{\text{res}} \models \llnamed, \text{MARIA}, z; 1 \gg), \llrdl; 1 \gg)] \]
Speaker’s denotations of referent agents

Denotation of a proper name, e.g., MARIA, as a referent agent

- a referent agent $z'$ determined by a reference restriction $r$,
- in an utterance situation (context) $u$,
- by a speaker agent $x^{rsp(u,l,y,\alpha)}$

where $r$ may be

- general, sincere reference
  \[ r = [z \mid (u \models \ll refers\_to\_by, x^{rsp(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land (u \models \ll named, MARIA, z; 1 \gg)] \]

- belief reference
  \[ r = [z \mid (u \models \ll refers\_to\_by, x^{rsp(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land (u \models \ll believes, x^{rsp(u,l,y,\alpha)}, (s_{res} \models \ll named, MARIA, z; 1 \gg), l^{rdl}; 1 \gg)] \]
Speaker’s denotations of referent agents

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  r = [z \mid (u \models \ll refer_to_by, x^{rsp(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land \\
  (u \models \ll named, MARIA, , z; 1 \gg)]
  \]

- belief reference
  \[
  r = [z \mid (u \models \ll refer_to_by, x^{rsp(u,l,y,\alpha)}, z, MARIA, l^{rdl}; 1 \gg) \land \\
  (u \models \ll believes, x^{rsp(u,l,y,\alpha)}, \\
  (s_{res} \models \ll named, MARIA, z; 1 \gg), \\
  l^{rdl}; 1 \gg)]
  \]
Speaker’s denotations of referent agents

Denotation of a proper name, e.g., MARIA, as a referent agent

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- in an utterance situation (context) $u$,
- by a speaker agent $x_{\text{rsp}}(u,l,y,\alpha)$

where $r$ may be

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$$r = [z \mid (u \models \ll \text{refers\_to\_by}, x_{\text{rsp}}(u,l,y,\alpha), z, \text{MARIA}, l^{rdl}; 1 \gg) \land (u \models \ll \text{named}, \text{MARIA}, , z; 1 \gg)]$$

- belief reference

$$r = [z \mid (u \models \ll \text{refers\_to\_by}, x_{\text{rsp}}(u,l,y,\alpha), z, \text{MARIA}, l^{rdl}; 1 \gg) \land (u \models \ll \text{believes}, x_{\text{rsp}}(u,l,y,\alpha),$$

$$(s_{\text{res}} \models \ll \text{named}, \text{MARIA}, z; 1 \gg), l^{rdl}; 1 \gg)]$$
Linguistic meaning vs. interpretations with respect to different agents

- A restricted (constrained) utterance situation $u[u|pu(u,l,x,z,\alpha)]$, by the proposition

$$pu(u, l, x, y, \alpha) = (u \models \ll tells\_to, x, y, \alpha, l; 1 \gg)$$  \hspace{1cm} (65)

introduces:

- pure linguistic meaning of $\alpha$
- interpretation of the utterance of $\alpha$ with respect to various agents:
  - the speaker (done in this paper)
  - various listeners (in extended work)
  - actual vs. intended and (mis)understood agents (in extended work)
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  - actual vs. intended and (mis)understood agents
    (in extended work)
Existing and potential applications

- Type-theoretic syntax-semantics interfaces involving information representation
  - programming languages
  - algorithm specifications: higher-order type theory of algorithms
  - data basis
  - information representation systems, e.g., in
    - health and medical systems
    - medical sciences
    - legal systems

- Syntax-semantics interface in grammar systems for human language

- Applications to:
  - Human language processing
  - AI
  - Neuroscience
  - Life sciences
Some References I

Jon Barwise.  
Scenes and other situations.  

Jon Barwise and John Perry.  
*Situations and Attitudes*.  
Republished as [3].

Jon Barwise and John Perry.  
*Situations and Attitudes*.  
Some References II


Roussanka Loukanova.
Situated Agents in Linguistic Contexts.

Roussanka Loukanova.
Situation Theory, Situated Information, and Situated Agents.
Jerry Seligman and Lawrence S. Moss.
Situation Theory.