Situation Theory and its Applications

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Origins and Present of Situation Theory (SitT)

- 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: $\mathcal{A}_{\mathrm{IND}} = \{a, b, c, \dots\}$
- Space-time locations: $\mathcal{A}_{\mathrm{LOC}} = \{l, l_0, l_1, \dots\}$
  associated with some space and time relations, e.g.:

$$l_i \prec l_j \qquad \text{(time precedence)}$$
$$l_i \circ l_j \qquad \text{(time overlapping)}$$
$$l_i \diamond l_j \qquad \text{(space overlapping)}$$
$$l_i \subseteq_t l_j \qquad \text{(time inclusion)}$$
$$l_i \subseteq_s l_j \qquad \text{(space inclusion)}$$
$$l_i \subseteq l_j \qquad \text{(space-time inclusion)}$$

- Primitive relations: $\mathcal{A}_{\mathrm{REL}} = \{r_0, r_1, \dots\}$

Primitive (basic) types

$$B_{\text{TYPE}} = \{ \text{IND}, \text{REL}, \text{ARGR}, \text{LOC}, \text{POL}, \tag{2a}$$

$$\text{INFON}, \text{SIT}, \text{PROP}, \text{PARAM}, \text{TYPE}, \models \} \tag{2b}$$

- 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 σ are of the type "supports", i.e., "s supports σ":

$$(s \models \sigma) \qquad \text{(a proposition)}$$
$$s \models \sigma \qquad \text{(a verified proposition)}$$

- Primitive and complex types $\mathcal{T}_{\mathrm{TYPE}}$

$$B_{\mathrm{TYPE}} \subseteq \mathcal{T}_{\mathrm{TYPE}} \tag{4}$$

Basic argument roles with appropriateness constraints

- basic argument roles: $\mathcal{BA}_{\text{ARGR}}$, e.g., $\mathcal{BA}_{\text{ARGR}} = \{\rho_1, \dots, \rho_m\}$;
  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 *ArgR*. I.e.:
- for every $\gamma \in \mathcal{A}_{\text{REL}} \cup B_{\text{TYPE}}$

$$ArgR(\gamma) = \{\langle arg_1, T_1\rangle, \dots, \langle arg_n, T_n\rangle\} \tag{5}$$

$$\equiv \{T_1 : arg_1, \dots, T_n : arg_n\} \quad (n \geq 0) \tag{6}$$

  where $arg_1, \dots, arg_n \in \mathcal{A}_{\text{ARGR}}$,
  $T_1, \dots, T_n \in \mathcal{P}(\mathcal{T}_{\text{TYPE}})$ are sets of types (basic or complex).
- The objects $arg_1, \dots, arg_n$ are called the argument roles or argument slots of γ.
- $T_1, \dots, T_n$ are specific for γ and are called the appropriateness constraints of the argument roles of γ.

Relations and Types with Argument Roles

- Each relation is associated with a set *ArgR* of argument roles

$$ArgR(smile) = \{T_a : smiler\} \quad (7a)$$

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

$$ArgR(read_1) = \{T_a : reader, T_o : read\text{-}ed\}\} \quad (7c)$$

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

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

$$ArgR(\models) = \{\mathrm{SIT} : arg_{\mathrm{SIT}},\ \mathrm{INFON} : arg_{\mathrm{INFON}}\}. \quad (8)$$

Primitive parameters

- Typed primitive parameters (sometimes called indeterminates):

$$\mathcal{P}_{\mathrm{IND}} = \{\dot{a}, \dot{b}, \dot{c}, \ldots\}, \tag{9a}$$

$$\mathcal{P}_{\mathrm{LOC}} = \{\dot{l}_0, \dot{l}_1, \ldots\}, \tag{9b}$$

$$\mathcal{P}_{\mathrm{REL}} = \{\dot{r}_0, \dot{r}_1, \ldots\}, \tag{9c}$$

$$\mathcal{P}_{\mathrm{POL}} = \{\dot{i}_0, \dot{i}_1, \ldots\}, \tag{9d}$$

$$\mathcal{P}_{\mathrm{SIT}} = \{\dot{s}_0, \dot{s}_1, \ldots\}. \tag{9e}$$

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

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

$$ArgR(\gamma) = \{\langle arg_1, T_1 \rangle, \ldots, \langle arg_n, T_n \rangle\} \quad (n \geq 0), \tag{10}$$

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

- θ is an argument filling for γ, i.e.:

$$\theta = \{\langle arg_1, \xi_1 \rangle, \ldots, \langle arg_n, \xi_n \rangle\}, \tag{11}$$

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

$$T_1 : \xi_1, \ldots, T_n : \xi_n \tag{12}$$

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

Definition (Infons)

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

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

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

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

$$\langle \wedge, \sigma_1, \sigma_2 \rangle \in \mathcal{I}_{INF} \tag{13a}$$
$$\langle \vee, \sigma_1, \sigma_2 \rangle \in \mathcal{I}_{INF} \tag{13b}$$

- basic infons in linear notations:

$$\begin{aligned} \ll \gamma, T_1 &: \mathrm{arg}_1 : \xi_1, \ldots, \\ T_n &: \mathrm{arg}_n : \xi_n, \\ \textsc{loc} &: Loc : \tau, \textsc{pol} : Pol : i \gg \end{aligned} \tag{14}$$

$$\ll \gamma, arg_1 : \xi_1, \ldots, arg_n : \xi_n, Loc : \tau; Pol : i \gg \tag{15}$$

$$\ll \gamma, \xi_1, \ldots, \xi_n, \tau; i \gg \tag{16}$$

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)

$$\begin{aligned}\ll read,\ \ & T_{a_1} : reader : a,\\ & T_m : read\text{-}ed : b,\\ & T_{a_2} : readee : c,\\ & \mathrm{LOC} : Loc : l;\ \mathrm{POL} : Pol : 1 \gg\end{aligned} \tag{17}$$

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

$$\begin{aligned}\ll read,\ \ & T_{a_1} : reader : a, && \text{(specific)}\\ & T_m : read\text{-}ed : b, && \text{(specific)}\\ & T_{a_2} : readee : \dot{c},\ \dot{l};\ : 1 \gg && \text{(parametric)}\end{aligned}$$

Example (infons in linear notations)

Other parametric infons, e.g.

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

$$\begin{aligned} \ll read,\ & T_{a_1} : reader : a, && \text{(specific)} \\ & T_m : read\text{-}ed : \dot{b}, && \text{(parametric)} \\ & T_{a_2} : readee : \dot{c},\ \dot{l};\ 1 \gg && \text{(parametric)} \end{aligned}$$

- the info that *a* either reads or does not — unknown polarity $\dot{p}$

$$\begin{aligned} \ll read,\ & T_{a_1} : reader : a, && \text{(specific)} \\ & T_m : read\text{-}ed : \dot{b},\ T_{a_2} : readee : \dot{c},\ \dot{l}; && \text{(parametric)} \\ & \dot{p} \gg && \text{(parametric)} \end{aligned}$$

Definition (Propositions)

Proposition is any tuple $\langle \mathrm{PROP}, \mathbb{T}, \theta \rangle$, where

- $\mathbb{T} \in \mathcal{T}_{\mathrm{TYPE}}$ is a type with a set of argument roles

$$ArgR(\mathbb{T}) = \{\langle arg_1, T_1 \rangle, \ldots, \langle arg_n, T_n \rangle\}, \quad n \geq 0 \tag{21}$$

- θ is an argument filling for $\mathbb{T}$, i.e.:

$$\theta = \{\langle arg_1, \xi_1 \rangle, \ldots, \langle arg_n, \xi_n \rangle\}, \tag{22}$$

  for some objects $\xi_1, \ldots, \xi_n$ that satisfy the appropriateness type constraints of the type $\mathbb{T}$, i.e.:

$$T_1 : \xi_1, \ldots, T_n : \xi_n \tag{23}$$

Notation

$$\langle \mathbb{T}, \theta \rangle \equiv (\mathbb{T} : \theta) \tag{24a}$$
$$\equiv (\theta : \mathbb{T}) \tag{24b}$$
$$\equiv \langle \text{PROP}, \mathbb{T}, \theta \rangle \tag{24c}$$

- The variant notations (24a) and (24b) are used depending on context.
- The notation (24a) resemble the application operation.

Definition (Situated propositions)

- The type $\models$ (“supports”):

$$ArgR(\models) = \{\mathrm{SIT} : arg_{\mathrm{SIT}},\ \mathrm{INFON} : arg_{\mathrm{INFON}}\} \tag{25}$$

- *Situated proposition*:

$$\langle \mathrm{PROP}, \models, s, \sigma \rangle, \ \text{ where } s \in \mathcal{P}_{\mathrm{SIT}} \text{ and } \sigma \in \mathcal{I}_{\mathrm{INFON}} \tag{26}$$

Notation

$$\langle \models, s, \sigma \rangle \equiv (s \models \sigma) \tag{27a}$$

$$\equiv \langle \mathrm{PROP}, \models, s, \sigma \rangle \tag{27b}$$

Example (The situation s supports a positive information)

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

Example (The situation s supports a negative information)

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

Example (The situation s does not support a positive information)

$$(s \not\models \ll \mathit{book}, \textsc{ind} : \mathit{arg} : b, \tag{30a}$$

$$\textsc{loc} : \mathit{Loc} : l; \textsc{pol} : \mathit{Pol} : 1 \gg) \tag{30b}$$

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

$$(s \not\models \ll \mathit{book}, \textsc{ind} : \mathit{arg} : b, \tag{31a}$$

$$\textsc{loc} : \mathit{Loc} : l; \textsc{pol} : \mathit{Pol} : 0 \gg) \tag{31b}$$

Example (actual vs. fallible situations)

$$(s_1 \models \ll book,\ b,\ l;\ 1 \gg) \tag{32a}$$

$$(s_2 \models \ll book,\ b,\ l;\ 0 \gg) \tag{32b}$$

- 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)

$$(s_1 \models \ll book, b, l; 1 \gg) \tag{32a}$$

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  - 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)

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

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

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

Example (conjunctive information)

- a conjunctive infon in a proposition

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

- a conjunctive proposition

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

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

Example (conjunctive information)

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$$\wedge\ \ l \circ l_1) \tag{34c}$$

- a conjunctive proposition

$$(s \models \ \ll smiles,\ \text{IND} : arg : a,\ l; 1 \gg) \tag{35a}$$
$$\wedge (s \models \ \ll animate,\ \text{IND} : arg : a,\ l_1; 1 \gg) \tag{35b}$$
$$\wedge (l \circ l_1) \tag{35c}$$

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$$\wedge (l \circ l_1) \quad (35c)$$

- 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.

$$\text{The book } b \text{ is read} \tag{36}$$

$$\begin{aligned}
(s \models \quad & \ll \mathit{read},\ \mathit{reader} : \dot{x},\ \mathit{readed} : b,\ \mathit{readee} : \dot{y}, && (37a)\\
& \qquad \mathit{Loc} : l; 1 \gg \\
\wedge \quad & \ll \mathit{book},\ \mathit{arg} : b,\ \mathit{Loc} : l_1; 1 \gg) && (37b)\\
\wedge \quad & (l \subset l_1) && (37c)
\end{aligned}$$

(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 σ be a given infon, and $\{\xi_1, \ldots, \xi_n\}$ a set of parameters that occur in σ.
- Let, for each $i \in \{1, \ldots, n\}$, T_i be the union of the constraints over the argument roles filled up by ξ_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.:

$$ArgR(\lambda\{\xi_1, \ldots, \xi_n\}\sigma) = \{\langle[\xi_1], T_1\rangle, \ldots, \langle[\xi_n], T_n\rangle\} \tag{38}$$

Example (A complex infon)

$$\ll book,\ b,\ l_1;\ 0 \gg \tag{39a}$$

$$\wedge\ \ll writes,\ a,\ b,\ l_2;\ 1 \gg \tag{39b}$$

$$\wedge\ \ll book,\ b,\ l_3;\ 1 \gg \tag{39c}$$

$$\wedge\ l_1 \prec l_2\ \wedge\ l_2 \prec l_3 \tag{39d}$$

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

$$\lambda\{\dot{x},\dot{y},\dot{l}_1,\dot{l}_2,\dot{l}_3\}\big[\ll book,\ \dot{y},\ \dot{l}_1;\ 0 \gg \tag{40a}$$

$$\wedge\ \ll writes,\ \dot{x},\ \dot{y},\ \dot{l}_2;\ 1 \gg \tag{40b}$$

$$\wedge\ \ll book,\ \dot{y},\ \dot{l}_3;\ 1 \gg \tag{40c}$$

$$\wedge\ \dot{l}_1 \prec \dot{l}_2\ \wedge\ \dot{l}_2 \prec \dot{l}_3\big] \tag{40d}$$

Example (A complex infon)

$$\begin{aligned} & \ll book,\ b,\ l_1;\ 0 \gg && (39a)\\ \wedge\ & \ll writes,\ a,\ b,\ l_2;\ 1 \gg && (39b)\\ \wedge\ & \ll book,\ b,\ l_3;\ 1 \gg && (39c)\\ \wedge\ & l_1 \prec l_2\ \wedge\ l_2 \prec l_3 && (39d) \end{aligned}$$

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

$$\begin{aligned} \lambda\{\dot{x},\dot{y},\dot{l}_1,\dot{l}_2,\dot{l}_3\}\big[& \ll book,\ \dot{y},\ \dot{l}_1;\ 0 \gg && (40a)\\ & \wedge \ll writes,\ \dot{x},\ \dot{y},\ \dot{l}_2;\ 1 \gg && (40b)\\ & \wedge \ll book,\ \dot{y},\ \dot{l}_3;\ 1 \gg && (40c)\\ & \wedge\ \dot{l}_1 \prec \dot{l}_2\ \wedge\ \dot{l}_2 \prec \dot{l}_3\big] && (40d) \end{aligned}$$

Definition (Complex types and appropriateness constraints)

- Let Θ be a given proposition, and $\{\xi_1, \ldots, \xi_n\}$ be a set of parameters that occur in Θ.
- Let, for each $i \in \{1, \ldots, n\}$, T_i be the union of the constraints over the argument roles filled up by ξ_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.:

$$ArgR(\lambda\{\xi_1, \ldots, \xi_n\}\Theta) = \{\langle[\xi_1], T_1\rangle, \ldots, \langle[\xi_n], T_n\rangle\} \tag{41}$$

Notation

Alternative classic notations for the complex types (corresponding to the set-theoretical comprehension):

$$\lambda\{\xi_1, \ldots, \xi_n\}\Theta \equiv \Big[T_1 : [\xi_1], \ldots, T_n : [\xi_n] \mid \Theta\Big] \tag{42a}$$

$$\lambda\{\xi_1, \ldots, \xi_n\}\Theta \equiv \Big[[\xi_1], \ldots, [\xi_n] \mid \Theta\Big] \tag{42b}$$

Example (A proposition)

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

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

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

Example (A proposition)

$$
\begin{aligned}
&(s_1 \not\models \ll book,\ b,\ l_1;\ 0 \gg) && (43a)\\
\wedge &(s_2 \models \ll writes,\ a,\ b,\ l_2;\ 1 \gg) && (43b)\\
\wedge &(s_3 \models \ll book,\ b,\ l_3;\ 1 \gg) && (43c)\\
\wedge &(l_1 \prec l_2 \prec l_3) && (43d)
\end{aligned}
$$

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

$$
\begin{aligned}
\lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\}\big[&(s_1 \not\models \ll book,\ \dot{y},\ \dot{l}_1;\ 0 \gg) && (44a)\\
\wedge &(s_2 \models \ll writes,\ \dot{x},\ \dot{y},\ \dot{l}_2;\ 1 \gg) && (44b)\\
\wedge &(s_3 \models \ll book,\ \dot{y},\ \dot{l}_3;\ 1 \gg) && (44c)\\
\wedge &(\dot{l}_1 \prec \dot{l}_2 \prec \dot{l}_3)\big] && (44d)
\end{aligned}
$$

Definition (Complex propositions)

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

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

- Let $T_{i,1} : a_i, \ldots, T_{i,k_i} : a_i$, for $i = 1, \ldots, n$.
- Then we can form the proposition

$$(\lambda\{\xi_1, \ldots, \xi_n\}\Theta, \theta) \qquad (46)$$

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)

$$\Big(\lambda\{\dot{x}, \dot{y}, \dot{l}_1, \dot{l}_2, \dot{l}_3\}\Big[(s_1 \not\models \ll book,\ \dot{y},\ \dot{l}_1;\ 0 \gg) \tag{49a}$$

$$\land (s_2 \models \ll writes,\ \dot{x},\ \dot{y},\ \dot{l}_2;\ 1 \gg) \tag{49b}$$

$$\land (s_3 \models \ll book,\ \dot{y},\ \dot{l}_3;\ 1 \gg) \tag{49c}$$

$$\land (\dot{l}_1 \prec \dot{l}_2 \prec \dot{l}_3)\Big] \tag{49d}$$

$$: a, b, l_1, l_2, l_3 \Big) \tag{49e}$$

Definition (Complex restricted parameters)

Given that

- ξ 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 ξ
- x is a parameter of type τ, i.e., $\tau : x$, and τ is compatible with the types (constraints) T,
- then $x^{\lambda\xi\,\Theta(\xi)}$ is a complex parameter of type τ, 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 is of type τ, i.e., $\tau : a$,
  $T_i : a$, for each type $T_i \in T$,
  and $\lambda\xi\,\Theta(\xi) : a$, i.e., the proposition $\Theta(a)$ 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
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    - models of processes?
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Definition (States of Affairs, Events, Situations)

- A set of infons that have the same location components is called a state of affairs (soa).
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Example (A Situated Proposition)

$$(s \models \ll read, reader : x, readed : b, Loc : l_1; 1 \gg \wedge \quad (50a)$$
$$\ll book, arg : b, Loc : l_2; 1 \gg \wedge \quad (50b)$$
$$l_1 \circ l_2) \quad (50c)$$

- The proposition (50a)-(50c) is true iff
  - x reads b in the location l_1, in the situation s:
    $$s \models \ll read, reader : x, readed : b, Loc : l_1; 1 \gg \quad (51)$$
  - b is having the property *book* in l_2, in the situation s:
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Quantificational scheme in Situation Semantics

Semantic quantifiers as relations between types of situated objects:

$$\Big(s \models \ll every,\ [x/(s_i \models \ll student, x, l_i; 1 \gg)],\ [y/(s_j \models \ll walk, y, l_j; 1 \gg)],\ l; 1 \gg \Big) \tag{54a}$$

$$\Big(s \models \ll some,\ [x/(s_i \models \ll student, x, l_i; 1 \gg)],\ [y/(s_j \models \ll walk, y, l_j; 1 \gg)],\ l; 1 \gg \Big) \tag{54b}$$

$$\Big(s \models \ll two,\ [x/(s_i \models \ll student, x, l_i; 1 \gg)],\ [y/(s_j \models \ll walk, y, l_j; 1 \gg)],\ l; 1 \gg \Big) \tag{54c}$$

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

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

$pu(u, l, x, y, \alpha)$ 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:

$$u \models \ll tells\_to, x, y, \alpha, l; 1 \gg \tag{56}$$

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 α
  - α is the expression uttered in u by the speaker agent x

- The type of an utterance situation is

$$ru(l, x, y, \alpha) \equiv [u \mid pu(u, l, x, y, \alpha)] \tag{57}$$

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Types for the concepts of situated linguistic agents

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

$$pu(u, l, x, y, \alpha) \equiv (u \models \ll tells\_to, x, y, \alpha, l; 1 \gg) \tag{58}$$

- the type of a speaker agent in u is:

$$rsp(u, l, y, \alpha) \equiv [x \mid pu(u, l, x, y, \alpha)] \tag{59}$$

- the type of a listener agent in u is:

$$rlst(u, l, x, \alpha) \equiv [y \mid pu(u, l, x, y, \alpha)] \tag{60}$$

- the type of the utterance space-time location is

$$rdl(u, x, y, \alpha) \equiv [l \mid pu(u, l, x, y, \alpha)] \tag{61}$$

- in u, x is the speaker agent and y is the listener agent iff u supports the uttering act:

$$u \models \ll tells\_to, x, y, \alpha, l; 1 \gg \tag{62}$$

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Speaker's References: referent agents

- the type of the speaker's referent agent of the expression α

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

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

$$q(u, l, x, y, z, \alpha) \equiv \tag{64a}$$
$$(u^{ru(l,x,y,\alpha)} \models \tag{64b}$$
$$\ll refers\text{-}to, x^{rsp(u,l,y,\alpha)}, z, \alpha, l^{rdl(u,x,y,\alpha)}; 1 \gg) \tag{64c}$$

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 α

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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 $x^{rsp(u,l,y,\alpha)}$

where r may be

- general, sincere reference

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

- belief reference

$$r = [z \mid (u \models \ll \mathit{refers\_to\_by}, x^{rsp(u,l,y,\alpha)}, z, \mathrm{MARIA}, l^{rdl}; 1 \gg) \wedge (u \models \ll \mathit{believes}, x^{rsp(u,l,y,\alpha)}, (s_{res} \models \ll \mathit{named}, \mathrm{MARIA}, z; 1 \gg), l^{rdl}; 1 \gg)]$$

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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

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

introduces:

- pure linguistic meaning of α
- interpretation of the utterance of α 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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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

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