Lexical Meanings Analysed by Means of Typed Applicative Representations

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Abstract

Applicative languages (Church's λ-calculus and Curry's combinatory Logic) and functional types are useful logical tools for studying and representing the meanings of verbal predicates and other linguistic operators (prepositions, preverbs …) of natural languages by means of combinations of abstract and cultural primitives. The situations are semantic expressions associated to sentences; they are written by means of applicative expressions (ae) generated from semantic abstract primitives: (i) cognitive basic types (individual, massive, distributive class, abstract places, activity, situations…); (ii) operators transforming assigned types (as topological operators : take the interior, exterior, boundary, closure of an abstract place); (iii) kinematic, dynamic, cause relators: MOVT and CHANG expressing movement or change the state of an entity; FAIRE, CONTR (to control) and TELEO (to intend a teleonomic situation) introducing a link between a kinematic situation and an entity (agent, intermediary instrument…); CAUSE establishing a link between two different situations (a cause and an effect). These abstract primitives are interpreted inside of the cognitive fields of perception and action. They are sources of numerous grammaticalizations in languages. Verbal predicates involve an actualization over topological intervals of instants; thus, it is necessary to introduce complex operators for transforming a situation into an aspectual situation (state, event, process …). This article presents systematically these abstract primitives with some examples of meanings represented inside the applicative framework. The applicative expressions of situations (semantic schemes) defined to a semantic level can be integrated into lexical predicates of another level, by using combinators of combinatory logic; this integration process in Cognitive and Applicative Grammar (GAC) has already been presented (in precedent FLAIRS).

Applicative representations and functional types

Applicative expressions, designated by ‘ae’, are generated from a set of elementary operators and absolute operands by means of the operation of application of an operator ‘X’ doing an act over an operand ‘Y’; the result, designated by ‘XY’, is an ‘ae’ that can be again an operator or an operand according to the context. The objects are always absolute operands. There are different types of objects and operators. The Church's *functional types* are generated from basic types by the following rules: (i) The basic types are functional types; (ii) If ‘α’ et ‘β’ are functional types, than ‘$\mathbf{F}\alpha\beta$’ is a functional type (Church 1941; Curry 1958). A functional type ‘α’ assigned to an ‘ae’ ‘X’ is noted [X: α]. The types of operators are always with the form ‘$\mathbf{F}\alpha\beta$’. Let an operator ‘X’ and an operand ‘Y’ of ‘X’, the applicative *rule with types* is:

$$[X: \mathbf{F}\alpha\beta] , [Y:\alpha] \Rightarrow [XY :\beta]$$

A product of types is canonically associated to a functional type: any operator ‘$\mathbf{f_n}$’ with a product of types is transformed into an unary operator ‘*Curry*($\mathbf{f_n}$)$_1$’, according to the *Curryfication principle* :

$$[\ \mathbf{f}_n : \mathbf{F}(\alpha_1\ \mathbf{x}\ \alpha_2 \ldots \mathbf{x}\ \alpha_n)\beta\ ] \approx [\ Curry(\mathbf{f}_n)_1 : \mathbf{F}\alpha_1\mathbf{F}\ \alpha_2 \ldots \mathbf{F}\alpha_n\ \beta\ ]$$

Remark : We use two notations; one is prefixed : an operator ‘**f**’ is always positioned before his operand: ‘$\mathbf{f}XY =_{def} ((\mathbf{f}X)Y)$’ ; the second is infixed : a binary relator ‘$\mathbf{f}_2$’ is positioned between two successive operands according to the notational equivalence : $[X\ \mathbf{f}_2\ Y] =_{def} \mathbf{f}_2YX$.

The Church's lambda calculus and Curry's Combinatory Logic (Hindley and Seldin, 1986) are two examples of applicative languages. In Combinatory Applicative Categorial Grammars (CACG) (Desclés and Biskri 1995), Universal Applicative Grammar (GAU) (Shaumyan 1987) and Applicative and Cognitive Grammar (GAC) (Desclés, 1990), all linguistics units (grammatical and lexical units) are operators or absolute operands with assigned functional types; in these formal frameworks, the meanings of verbal predicates and other linguistic operators are also analysed by ‘ae’ generated from *semantic primitives*: basic cognitive types; topological operators and locating relators; static, kinematic, dynamic, causal relators; aspectual operators, enuntiative and commitment operators (Desclés 2009). For instance, the meanings of prepositions are analysed by means of topological operators and by change relating different static situations. Thus, in the sentence *the book is* *on the table*, the preposition *on* express an upper side of the place “the table”. The verbal meanings are analysed by means of different and successive situations located in a temporal framework reference and represented by semantic and cognitive schemes (SSC); the components of these SSC are ‘ae’ with assigned functional cognitive types (Abraham 1995; Abraham and Desclés 1992; Djioua 2000). The “combinators” (abstract operators for combining and transforming operators) of Combinatory Logic (Curry 1958) are useful tools to explain on one side, in a top down approach (or in a synthetic integrative way), how a scheme - an applicative representation of a verbal meaning - can be integrated into a predicate frame with an appropriate number of terms functioning as operands and, in other side, in a bottom up approach (or an analytic way), how a lexical predicate can be semantically decomposed and represented by an applicative scheme (Desclés 1990, 2004, 2010). In this presentation, in first, we list basic cognitive primitives types, associated to different kinds of objects and secondly, we precise systematically different primitive semantic operators and relators used by building static and evolutive (kinematic and dynamic) schemes. The basic types, operators and relators can be closely linked to a cognitive perception of environment and to actions onto this environment. Thus, this model belongs to the field of cognitive representations (Langacker 1987, 1991; Cruse 1986; Desclés 1990, 1995; Lüdi and al. 1995; Croft and Cruse 2004; Pottier 2000) where the categories of natural languages interact with the categorizations organized by perception and action abilities of humans, with a more or less important intention.

Basic cognitive types

We consider different cognitive types of absolute operands (“objects”):

- $\underline{J}$: type of individual (and enumerable) objects as: *John*, *this car*, *a table*, *an human*
- $\underline{M}$: type of massive (and no enumerable) objects as: *butter*, *water*,
- $\underline{I}$: type of content of information as: (read in) *the newspaper*
- $\underline{L}$: type of abstract places with subtypes : $\underline{L}_S$: spatial place as: *in this street / on the table*; $\underline{L}_T$: temporal place as an interval of successive instants: (in) *afternoon*, (in) *this year*; $\underline{L}_A$: activity: (in) *love*, (in) *working*
- $\underline{D}$: type of distributive classes as: *the humans* (a class of humans), *the cars* (a class of cars)
- $\underline{K}$:type of collective class as: *the army*, *an administration*
- $\underline{H}$: type of propositional expressions with two possible values: *true* and *false*
- $\underline{T}$: type of intervals of instants
- $\underline{Sit}$: type of situations with subtypes of situations :
- $\underline{Sit}_{static}$: type of static situations
- $\underline{Sit}_{static\text{-}space}$: type of static situations in the space
- $\underline{Sit}_{evol}$: type of evolutive situations with two subtypes : $\underline{Sit}_{kinem}$: type of cinematic situations and $\underline{Sit}_{dynam}$: type of dynamic situations
- $\underline{Sit}_{caus}$: type of causal situations

The meanings of lexical predicates are represented by situations viewed as applicative expressions that are compositions of the above abstract semantic primitives with some other cultural primitives deeply related to social experiences and technology. For instance, *to-be-alive* is related to the human experience, it is considered as a cultural primitive. A situation is an ‘ae’ representing a fact (actual or imaginary), that is a denotation associated to a propositional expression. There is a deep relation between the type ‘$\underline{Sit}$’ of situations and the type ‘$\underline{H}$’ of true values; indeed, a situation must be *actualized onto a temporal domain* (or spatio-temporal) and this actualisation entails an *evaluation by true values*, hence : [situation : $\underline{Sit}$] if and only if [actualization (situation) : $\underline{H}$]

Remarks : 1°) The type of a relation between n entities is: ‘$\mathbf{F}\alpha_1\mathbf{F}\,\alpha_2\ \ldots\mathbf{F}\alpha_n\underline{H}$’. A binary relator ‘$\mathbf{f_2}$’, used for expressing a situation with two operands, builds up, by the same way, an expression with the type $\underline{H}$, hence the equivalence:

$$[U:\alpha],\ [V:\beta],\ [\mathbf{f_2}\!: \mathbf{F}\alpha\mathbf{F}\beta\underline{Sit}] \Leftrightarrow [U:\alpha],\ [V:\beta],[\mathbf{f_2}\!: \mathbf{F}\alpha\mathbf{F}\beta\underline{H}]$$

2°) The type ‘$\mathbf{F}\underline{J}\underline{H}$’ is the type of a property (or a concept applied to individuals with type $\underline{J}$); it is a subtype of the type $\underline{D}$ of distributive classes.

Operators for changing basic types

Different operators transform the cognitive types assigned of a given entity. Let us take examples:

- The operator $\underline{Loc}$ transforms the type $\underline{J}$ of an individual object A into the type $\underline{L}$: $\underline{Loc}$(A) is now viewed as a place: [$\underline{Loc}$: $\mathbf{F}\underline{J}\underline{L}$], [A : $\underline{J}$] => [$\underline{Loc}$(A) : $\underline{L}$];

- Topological operators act upon a place $\underline{Loc}$(A) to define a part of this place:
[A : $\underline{J}$], [$\underline{Loc}$: $\mathbf{F}\underline{J}\underline{L}$], [$\underline{Top}$: $\mathbf{F}\underline{L}\underline{L}$] => $\underline{Top}$($\underline{Loc}$(A)) : $\underline{L}$];

- The operator $\underline{Ind}$ transforms an entity (with any type α) into an entity with the type ‘$\underline{J}$’ of individual objects:
[$\underline{Ind}$: $\mathbf{F}\alpha\underline{J}$], [A: α] => [$\underline{Ind}$(A) : $\underline{J}$].

Let us give some examples:
- [$\underline{Loc}$: $\mathbf{F}\underline{J}\underline{L}$] , [an house : $\underline{J}$] => [$\underline{Loc}$(an house) : $\underline{L}$]
To sell two houses / to be in an house;
- [*a-part-of* : $\mathbf{F}\underline{M}\underline{J}$], [butter : $\underline{M}$] => [*a part of* butter : $\underline{J}$];
- [one book : $\underline{J}$] => [$\underline{Top}$ ($\underline{Loc}$(one book)) : $\underline{L}$]
one book / on a book.

Topological operators defined on abstract places

There are topological operators acting onto places with the type '$\underline{\text{L}}$': "to take the interior of" ($\underline{\text{Int}}$), "to take the closure of" ($\underline{\text{Clos}}$), "to take the exterior of" ($\underline{\text{Ext}}$), and "to take the boundary (a frontier) of" ($\underline{\text{Fro}}$) ; for instance:

- *in a house* → $\underline{\text{Int}}(\underline{\text{Loc}}(\text{house}))$
- *at the house* → $\underline{\text{Clos}}(\underline{\text{Loc}}(\text{house}))$
- *out of a house* → $\underline{\text{Ext}}(\underline{\text{Loc}}(\text{house}))$
- *on the boundary of the river* → $\underline{\text{Fro}}(\underline{\text{Loc}}(\text{the-river}))$

Let us take a global space $\underline{\text{Loc}}(\text{U})$, defined as a set of possible positions taken by an object in this space; $\underline{\text{Loc}}(\text{X})$ is a part of the global place $\underline{\text{Loc}}(\text{U})$. The two topological operators '$\underline{\text{Int}}$' and '$\underline{\text{Clos}}$' define a Kuratowski's algebra (Kelley 1961 : 43; 56-57) on places with the following properties:

$\underline{\text{Int}}(\underline{\text{Loc}}(\text{X})) = \underline{\text{Loc}}(\text{X})$
$\underline{\text{Int}}(\underline{\text{Loc}}(\text{X})) \subseteq \underline{\text{Loc}}(\text{X})$
$\underline{\text{Int}}(\underline{\text{Loc}}(\text{X}_1) \cap \underline{\text{Loc}}(\text{X}_2)) = \underline{\text{Int}}(\underline{\text{Loc}}(\text{X}_1)) \cap \underline{\text{Int}}(\underline{\text{Loc}}(\text{X}_2)$
$\underline{\text{Int}}(\underline{\text{Int}}(\underline{\text{Loc}}(\text{X})) = \underline{\text{Int}}(\text{Loc}(\text{X}))$
$\underline{\text{Clos}}(\underline{\text{Loc}}(\varnothing)) = \underline{\text{Loc}}(\varnothing) = \varnothing$
$\underline{\text{Clos}}(\underline{\text{Loc}}(\text{X})) \supseteq \underline{\text{Loc}}(\text{X})$
$\underline{\text{Clos}}(\underline{\text{Clos}}(\underline{\text{Loc}}(\text{X})) = \underline{\text{Clos}}(\underline{\text{Loc}}(\text{X}))$

We derive other topological operators from these two basic operators ant the complementary operator with specific properties:

$\underline{\text{Ext}}(\underline{\text{Loc}}(\text{X})) \;=_{def}\; \underline{\text{Loc}}(\text{U}) - \underline{\text{Clos}}(\underline{\text{Loc}}(\text{X}))$
$\underline{\text{Fro}}(\underline{\text{Loc}}(\text{X})) \;=_{def}\; \underline{\text{Clos}}(\underline{\text{Loc}}(\text{X})) - \underline{\text{Int}}(\underline{\text{Loc}}(\text{X}))$
$\underline{\text{Fro}}(\underline{\text{Loc}}(\text{X})) \;=_{def}\; \underline{\text{Clos}}(\underline{\text{Loc}}(\text{X})) \cap \underline{\text{Clos}}(\underline{\text{Ext}}(\underline{\text{Loc}}(\text{X}))$
$\underline{\text{Int}}(\underline{\text{Loc}}(\text{X})$ is the *biggest open place* contained in $\underline{\text{Loc}}(\text{X})$
$\underline{\text{Clos}}(\underline{\text{Loc}}(\text{X}))$ is the *most small place* containing $\underline{\text{Loc}}(\text{X})$

The different topological places of a global place $\underline{\text{Loc}}(\text{U})$ are organized in a network with inclusions between places, overlapping, connection by boundaries... (Egenhofer and Herring 1990; Casati and Varzi 1999; Pustejovsky 2009). These topological operations are used for representing the meanings of prepositions (Desclés and Guentchéva 2010).

Static Archi-relator ($\underline{\text{rep}}$) for locating

Locating archir-relator '$\underline{\text{rep}}$', introduced in linguistics by A. Culioli (1968, 1999) and formalised by (Desclés and Froidevaux, 1982; Desclés 1990) generates *abstract schemes of locating* '$\underline{\text{rep}}$ VU' (or, with a prefixed notation: [U $\underline{\text{rep}}$ V]) between a *located entity* 'U' and a *locating entity* 'V':

$[\text{U} : \alpha], [\text{V}: \underline{\beta}], [\underline{\text{rep}}: \mathbf{F}\alpha\mathbf{F}\beta\ \underline{\text{H}}] \Rightarrow [\underline{\text{rep}}\ \text{VU} : \underline{\text{H}}]$

Several semantic values are specifications of this general archir-relator '$\underline{\text{rep}}$' : *identification* (=) between entities; *membership* (∈) of an individual entity to a class; *mereonomic ingredience* (ε) between a part and a whole; *inclusion* (⊂) between classes; relators of locating (is-located) relative to an abstract place, for instance topological places; relator (has-access-to) meaning that somebody may access to an object, a place, an activity…:

$[\,=\ \mathbf{F}\underline{\text{J}}\mathbf{F}\underline{\text{JH}}\,]$: [Socrates = the master of Plato]
$[\varepsilon : \mathbf{F}\underline{\text{M}}\mathbf{F}\underline{\text{MH}}]$: [butter ε butter] ; [water ε a river]
$[\in : \mathbf{F}\underline{\text{J}}\mathbf{F}\underline{\text{DH}}]$: [Socrates ∈ {x; is-a-philosopher (x)}]
$[\subset : \mathbf{F}\underline{\text{D}}\mathbf{F}\underline{\text{DH}}]$: [{x; is-a-man(x)} ⊂ {x; is-an-animal (x)}]
$[\underline{\text{is-located}} : \mathbf{F}\underline{\text{J}}\mathbf{F}\underline{\text{LH}}]$: [John $\underline{\text{is-located}}$ ($\underline{\text{Int}}(\underline{\text{Loc}}(\text{Florida}))$)]
$[\underline{\text{has-access-to}}: \mathbf{F}\underline{\text{J}}\mathbf{F}\underline{\text{JH}}]$: [John $\underline{\text{has-access-to}}$ books]

Static situations expressing different spatial positions of an object (*the ball*) relative to a place (*the swimming pool*) are for instance:

- [(the-ball) $\underline{\text{is-located}}$ ($\underline{\text{Int}}(\underline{\text{Loc}}(\text{the- swimming pool}))$)]
- [(the-ball) $\underline{\text{is-located}}$ ($\underline{\text{Ext}}(\underline{\text{Loc}}(\text{the- swimming pool}))$)]
- [(the-ball) $\underline{\text{is-located}}$ ($\underline{\text{Fro}}(\underline{\text{Loc}}(\text{the-swimming pool}))$)]

Evolutive (kinematic and dynamic) operators

A *kinematic situation* express a transformation (a movement or a change) from one static situation SIT^1 oriented towards a terminal situation (or to a situation in progress) SIT^2. 'MOVT' and 'CHANG' are two kinematic relators with functional types:

$\text{MOUVT} : \ \mathbf{F}\ \underline{\text{Sit}_{\text{static-space}}}\ \ \mathbf{F}\ \underline{\text{Sit}_{\text{static-space}}}\ \underline{\text{Sit}_{\text{kinem}}}$
$\text{CHANG} : \ \mathbf{F}\underline{\text{sit}_{\text{static}}}\ \mathbf{F}\ \underline{\text{Sit}_{\text{static}}}\ \underline{\text{Sit}_{\text{kinem}}}$

The relator MOUVT is restricted to movements in space; the relator CHANG is used for changing or transforming the properties affecting an object. In a spatial movement, a new situation SIT^2 is built from a given SIT^1 by the operator MOVT° (with the type $\mathbf{F}\underline{\text{sit}_{\text{static}}}\ \underline{\text{sit}_{\text{static}}}$) and the kinematic situation (viewed as a binary relation):

$[\ \text{SIT}^2 = \text{MOVT}°\ (\text{SIT}^1)\ ]$
$[\ \text{Sit}_{\text{kinem}} = \text{MOVT}\ (\text{SIT}^1)\ (\text{SIT}^2)\ ]$

The change of properties of an entity generates a similar unary operator CHANG° and binary relation.

Remark : We designate by 'SIT [x,y,..]' a situation where 'x', 'y', … are involved as being parameters. For instance, the meaning of the lexical verb *to enter* in the sentence *The ball enters the room*, is represented by the following kinamatic scheme (a movement from the outside of into inside of a same place):

$\text{MOVT}\ \ (\text{SIT}^1\ [\text{x, y}])\ (\text{SIT}^2\ [\text{x, y}])$

whith : SIT^1 [x, y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Ext}}$($\underline{\text{Loc}}$(y))) x
SIT^2 [x, y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Int}}$($\underline{\text{Loc}}$(y))) x
[x := the-ball] ; [y := the-room]

A *dynamic situation* express that an entity (often an individual entity) produces a kinematic situation by controlling or not this production. The primitives FAIRE, CONTR and TELEO are dynamic relators. FAIRE builds a relation between the entity producing and a produced cinematic transformation. CONTR (to control) express that an *agent* has a control over a kinematic situation (or a dynamic situation), that is this agent has the ability to start and also to stop a movement or a change expressed by a kinematic or a dynamic situation. An agent can control a transformation (a movement or a change) by an intermediary (for instance, an instrument) that produces effectively this transformation. TELEO holds between an agent (an entity having the ability to start and to stop a cinematic or dynamic situation) and an intended situation. The primitive CAUSE establish a relation between two situations where the first is the cause (an event or a class of events), of the second (the effect, result, side effect …). The types of these dynamic relators are:

- FAIRE : $\mathbf{F}\underline{J}\ \mathbf{F}\ \underline{\text{Sit}_{kinem}}\ \underline{\text{Sit}_{dynam}}$
- CONTR : $\mathbf{F}\underline{J}\ \mathbf{F}\ \underline{\text{Sit}_{evol}}\ \underline{\text{Sit}_{dynam}}$
- TELEO : $\mathbf{F}\ \underline{J}\ \mathbf{F}\ \underline{\text{Sit}}\ \underline{H}$
- CAUSE : $\mathbf{F}\ \underline{\text{Sit}}\ \underline{\text{Sit}}$

We can express different dynamical semantico-cognitive schemes (SSC); for instance:

- FAIRE (CHANG (SIT^1_{stat} [y])(SIT^2_{stat} [y])) x
- CONTR (CHANG (SIT^1_{stat} [x])(SIT^2_{stat} [x])) x
- CONTR (FAIRE (CHANG (SIT^1_{stat} [x,y])(SIT^2_{stat} [x,y])) v) x
- [(CONTR (FAIRE (CHANG (SIT^1_{stat} [x,y])(SIT^2_{stat} [x,y]))v)x)
  & (TELEO (SIT^2_{stat} [x,y]) x)]
- CAUSE (SIT^1 [x,y]) (SIT^2 [u,v])

These schemes are useful to explain the grammatical roles ("agent", "patient", "instrument", "experiencer" "location", …) by means of abstracts relations defined inside a SSC. For instance, a *middle scheme* indicates that an agent controls his action affecting himself; a *semantic transitive scheme* indicates that an agent controls a change affecting a patient and not directly the patient. Let us give examples of SSC. The meaning of the lexical verb *to enter* in the sentence *John enters the room* is represented by the dynamic scheme (*without a control* onto the movement):

CONTR (MOUVT (SIT^1_{stat} [u,y]) (SIT^2_{stat} [u,y])

with : SIT^1_{stat} [u,y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Ext}}$(Loc(y))) u
SIT^2_{stat} [u,y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Int}}$(Loc(y))) u
[u := John]; [y := the-room]

The lexical verb *to enter* in the sentence *John enters his car in the garage* is now represented by the dynamic scheme (*with a control* onto the movement):

CONTR (MOUVT (SIT^1_{stat} [x,y]) (SIT^2_{stat} [x,y]) u

with : SIT^1_{stat} [x,y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Ext}}$(Loc(y)))
SIT^2_{stat} [u,y] $=_{def}$ $\underline{\text{is-located}}$ ($\underline{\text{Int}}$(Loc(y))) x
[u := John]; [y := the-garage] ; [x := his-car]

The meaning of *to involve* in the sentence *Being a soldier involves getting killed* is represented by a causal scheme:

CAUSE ($\text{SIT}^1_{\underline{stat}}$ [x]) ($\text{SIT}^2_{\underline{cinem}}$ [x])

with: $\text{SIT}^1_{\underline{stat}}$ [x]) $=_{def}$ being-a-soldier (x)
$\text{SIT}^1_{\underline{kinem}}$ [x]) $=_{def}$ getting (to-be killed (x))(x)
[x = anybody]

Aspectual operators : EVEN $_F$, STATE $_O$, PROC $_J$

A situation is expressed by an 'ae'; it represents a fact (actual or imaginary), it is a denotation associated to a proposition. Since each verb contains an underlying temporal dimension, it is necessary to introduce aspectual operators for giving this dimension. Each aspectual operator transforms into an *aspectualised situation* a proposition - a predicative relation or a "lexis", designated by 'Λ', in the sense of Culioli (1999), -; this aspectualised situation is actualised over a topological interval of instants (with open or closed bounds). The aspectual scheme associated to this operator ASP_I is given by:

$$[\Lambda : \underline{H}\ ] , [\ \text{ASP}_I : \mathbf{F}\ \underline{\text{Sit}}\ \mathbf{F}\underline{T}\ \underline{\text{Sit}}\ ]\ \ [\ I : \underline{T}]\ \Rightarrow$$
$$[\ \text{ASP}_I\ (\Lambda) : \underline{\text{Sit}}\ ]\ \&\ [\text{ASP}_I(\Lambda) : \underline{H}]$$

The expression '$\text{ASP}_I(\Lambda)$' is *an aspectualised situation*; it express that the predicative relation 'Λ' is viewed as a *state* or an *event* or a *process* actualised over a topological interval 'I' (where '$\underline{T}$' is the type of intervals of instants) and it is true at different instants of this interval 'I' according to the choice of aspect (Desclés 1989; Desclés and Ro 2011).

An *state* is actualised as a static situation *actualised* over an open interval O : 'Λ' is true at any instant of O; for each open interval O' included into O, 'Λ' is also true.

An *event* is actualised as an evolutive situation : 'Λ' *has been actualised* on the close interval F; it is true at the closed bound at right of F; for any closed interval F' included in F, 'Λ' is in general no true.

A *process* is an actualisation of an evolutive situation such that it is actualized over an interval J with a closed bound at left and an open bound at right ; it is true at any instant of the interval J but it is not true at the right open bound of

J, because the process *is not complete*. If an interval J', with an open bound at right, is such that the closed bounds at left of J' and J are the same, then 'Λ' is also true for any instant of J'. In *a complete process*, the right bound of the interval J became closed, then the complete process generates an event.

An event is an aspectual specification of a situation expressed by a predicative relation; it does not admit a subclassification into "Processes", "States" and "Transitions" as Pustejovsky (1995: 68, 246) assumes (see also Pustejovsky and al., 200); for us, event is not a generic notion but a transition between two states and it can be generated from a complete process.

Analysis of the meaning of *to kill*

It is known that the meaning of *to kill* has been analysed by McCawley (1993) (from the deep predicates CAUSE, BECOME, TO BE ALIVE and the negation NEG (Dowty, 1979; Cann, 1993). By a different way in using other primitives and an applicative language, we analyse the meaning of the tensed verb *killed* in the sentence *John killed a deer* from the following scheme:

$\text{EVENT}_F\,(\text{CONTR}\,(\text{CHANG}\,(\text{SIT}^1_{stat}\,[x])(\text{SIT}^2_{stat}\,[y])\; x\,))$

with : $\text{SIT}^1_{stat}\,[y] \;=_{def} \text{STATE}_{O1}\,(\in \{\, z : \text{is-alive}(z)\}y)$
$\text{SIT}^2_{stat}\,[y] \;=_{def} \text{STATE}_{O2}\,(\neg\,(\in \{\, z : \text{is-alive}(z)\}y\,))$
$[\delta(O_1) = \gamma(F)]\ \&\ [\delta(F) = \gamma(O_2)]$
$[\, x := \text{John}]\ ;\ [\, y := \text{the-deer}]$

The primitive CAUSE is not used (as in Seohyun and Pustejovsky 2010 or McCawley 1993) since, for us, the situation underlying to *kill* integrates an agent and a patient *in a same situation* and not in two different events. The analysis of the meaning of lexical predicate *to assassinate* introduces the primitive of teleonomy (TELEO) since the murderer has planed an aim (the victim must be killed).

The grammatical meaning of the "perfect" of the tensed verb *has killed* in the sentence *John has killed a deer, (now, he is happy* is analysed as follows:

$\text{STATE}_{O3}\,(\text{has-killed } y,\, x)\ \&$
$\exists\,(\text{EVENT}_F\,(\text{CONTR}(\text{CHANG}(\text{SIT}^1_{stat}\,[y])(\text{SIT}^2_{stat}\,[y])\; x\,)))$

with : $\text{SIT}^1_{stat}\,[y] \;=_{def}\; \text{STATE}_{O1}\,(\in \{z : \text{is-alive}(z)\}\; y)$
$\text{SIT}^2_{stat}\,[y] \;=_{def}\; \text{STATE}_{O2}\,(\neg\,(\in \{z : \text{is-alive}(z)\}\; y))$
$[\delta(O_1) = \gamma(F)]\ \&\ [\delta(F) = \gamma(O_2)]$
$[\delta(F) = \gamma(O_3)]\ \&\ [\, O_3 \subseteq O_2]$
$[x := \text{John}]\ ;\ [y := \text{the-deer}]$

This *resulting state* is actualised over an interval O_3 contained in O_2 and such that O_3 is contiguous to the previous event already actualised over F. The relation $[\delta(F) = \gamma(O_3)]$ express the continuity (in the well know Dedekind"s sense of a continuous cut) : the closed boundary δ(F) at right of F is identical with the open boundary $\gamma(O_3)$ at left of O_3 (Desclés 2005; Desclés and Ro 2011).

Analysis of the meaning of *to give*

A lot of linguistic publications in Cognitive Semantics (for instance, R. Langacker 1987, 1991; Pottier 2000) present an analysis of the meaning of the lexical predicate *to give*, by using the primitive of "possession". We replace this primitive by the more abstract and general primitive has-access-to to take in account different uses of this lexical predicate. Indeed, when somebody *gives his arm* or *gives information*, he does not lose his arm or the exchanged information. The more general representation of *to give* in *John gave information to his friend* is:

$\text{EVENT}_F\,(\text{CONTR}\,(\text{CHANG}\,(\text{SIT}^1_{stat}\,[x,y,z])(\text{SIT}^2_{stat}\,[x,y,z])\; x\,))$

with : $\text{SIT}^1_{stat}\,[x,y,z] \;=_{def} \text{STATE}_{O1}\,([\,[x \text{ have-access-to } y]$
$\&\ [\neg\,[z \text{ has-access-to } y]\,])$
$\text{SIT}^2_{stat}\,[x,y,z] \;=_{def} \text{STATE}_{O2}\,(\,[\,[z \text{ has-access-to } y]$
$\&\ [x \text{ has-access-to } y]\,]\,)$
$[\delta(O_1) = \gamma(F)]\ \&\ [\delta(F) = \gamma(O_2)]$
$[x := \text{John: } J]\ ;\ [y = \text{information: } I];\ [\, z := \text{his-friend: } J]$

As for the same lexical predicate *to give* in *John gives a book to his friend*, the representation is different with

$\text{STATE}_{O2}\,([z \text{ has-access-to } y]\ \&\ (\neg\,[x \text{ has-access-to } y])$

since the types of a-book and information are different: [a-book: J], [information: I]. With this primitive has-access-to, it becomes possible to analyse and to represent the polysemy of verbs as *to give* and their equivalents in other languages (French, Russian, Korean…).

Conclusion

We have presented the different abstract primitives used for representing meanings by semantic and cognitive schemes (SSC) defined at a semantic level. The SSC was already presented in different publications (for instance: Abraham 1995; Djioua 2000; Desclés 1990, 2004) in using applicative formalisms, with a lot of analysis of the meaning of lexical predicates. The applicative situations built by combination of abstract and cultural primitives can be integrated into predicate frames of another level. A predicate frame is a combination of a lexical predicate with an appropriate number of arguments. For this formal integrative process, the combinators of Curry's Combinatory Logic are used as it was already been presented in other publications (for instance in precedent FLAIRS) about Cognitive and Applicative Grammars (CAG). In this computational and linguistic model, different levels of autonomous representation are defined and articulated between them by means of abstract operators (combinators), giving the possibility to explain how it is possible to pass from one level to another level (Desclés 2004, 2005, 2010; Desclés and Ro 2011). The topological notions are abstracted into topological operators of typed applicative expressions and used for a processing of aspectualised situations located in a temporal framework anchored onto enunciator (speaker). The above semantic analysis is a contribution to a linguistic ontology of time (Arena 2012, Desclés 2010). It will be interesting to compare the above approach of temporal relations and aspectual operators in natural languages with other linguistic ontologies (Pustejovsky 2009) and TimeML annotations guides (Pustejovsky and al. 2005; Sehoyun and al. 2010).

References

Abraham, M. 1995. *Analyse sémantico-cognitive des verbes de mouvement et d'activité*, Ph-D, EHESS : Paris.

Abraham, M., and Desclés, J-P. 1992. "Interaction between Lexicon and Image : Linguistic specifications of Animation", *Proc. of COLING-92*.

Arena, A., 2012. *Ontologie de la temporalité pour application au web sémantique*, Ph-D, Université de Paris-Sorbonne.

Cann, R., 1993. *Formal semantics. An introduction*, Cambridge Univerqsity Press.

Casati R. and Varzi A.C., 1999. *Parts and Places: the Structures of Spatial Representations*, The MIT Press.

Church, A. 1941. *The Calculi of Lambda Conversion*, Princeton University Press.

Culioli, A., 1968. La formalisation en linguistique, *Cahiers pour l'Analyse*, 9, Paris : Seuil, 106-117 .

Culioli, A., 1999. *Pour une linguistique de l'énonciation. Formalisation et opérations de repérage*, tome 2, Paris: Ophrys, 17-29.

Croft, W. and Cruse , D.A.. 2004. *Cognitive Linguistics*, Cambridge University Press.

Cruse, D.A., 1986. *Lexical Semantics*, Cambridge University Press.

Curry, H.B., and Feys, R. 1958. *Combinatory logic.* Vol. I. Studies in logic and the foundations of mathematics, Amsterdam: North-Holland Publishing.

Desclés, J.-P., 1989. State, Event and Process and Topology, *General Linguistics*, 29, 3, University Park and London: Pennsylvania State University Press, 159-200.

Desclés, J.-P., 1990. *Langages applicatifs, langues naturelles et cognition*, Paris : Hermès.

Desclés, J.-P., 1995, Langues, langage et cognition, *in* Lüdi et al.,1995, 1-32.

Desclés, J.-P., 2004. Combinatory Logic, Language, and Cognitive Representations, in Weingartner**,** P. (ed.) *Alternative Logics. Do Sciences Need Them ?*, Springer, 115-148.

Desclés, J.-P., 2005. Reasoning and Aspectual-temporal calculus, in Vanderveken, D. (ed.) *Logic, Thought and Logic*, Springer, 217-244.

Desclés, J.-P., 2010. Reasoning in Natural Language in Using Combinatory Logic and Topology. An Example with Aspect and Temporal Relations, FLAIRS 2010.

Desclés, J.-P. and Froidevaux C., 1982. Axiomatisation de la notion de repérage abstrait, *Mathématiques et sciences humaines*, 78, 73-119.

Desclés, J.-P. and Biskri I., 1995. Logique combinatoire et linguistique : grammaire catégorielle combinatoire applicative, *Mathématiques et sciences humaines*, 132, 39-68.

Desclés J.-P. and Guentchéva Z., 2010. Quasi Topological Representations (QTR) of Spatial Places and Spatio-temporal Movements in Natural Languages, in G. Marotta et al. (eds), *Space in Language, Proceedings of the Pisa International Conference*, Edizioni ETS, 213-233.

Descles, J.-P. and Ro, H.-J., 2011. Opérateurs aspecto-temporels et logique combinatoire, *Mathématiques et Sciences humaines*, 194, 39-70.

Djioua, B., 2000. *Modélisation informatique d'une base de données lexicales (DISSC) : réseaux polysémiques et schemes sémantico-cognitifs*, Ph-D, Université de Paris-Sorbonne.

Dowty D.R. 1979. *Word Meaning and Montague GrammarThe semantics of Verbs and Times in Genrative Semantics and in Montague 'SPTQ*, Dordrecht and Boston: Reidel Publishing Company.

Egenhofer M.J. and Herring J., 1990. A mathematical framework for the definition of topological relationships, *in* Brassel K. and Kishimoto, H. (eds), *Proceedings of the Fourth International Symposium on Spatial data banding*, Zurich, Switzerland, 457-472.

Hindley, J.R. and Seldin, J.P., 1986. *Introduction to Combinators and Lambda-Calculus*, Cambridge University Press.

Kelley, J.L., 1961. *General Topology*, New York : Van Nostrand.

Langacker, R., 1987, 1991. *Foundations of Cognitive Grammar*, vol. 1 and vol. 2, Stanford, Calf.: Standford University Press.

Lüdi G. and Zuber C.A. (eds), 1995. *Linguistique et modèles cognitifs, Contributions à l'Ecole d'été de la Société Suisse de Linguistique*, *Sion, 6-10 septembre 1993*, 3 Acta Romanica Basiliensia, ARBA, Université de Bâle.

Shaumyan, S. 1987. *A Semiotric Theory of Language*, Bloomington and Indianapolis: Indiana University Press.

McCawley, J., 1993. *Everything that linguists have always wanted to know about logic (but were ashamed to ask),* (2nd ed.), Chicago : University of Chicago Press.

Pottier, B., 2000. *Représentations mentales et catégorisations linguistiques*, Louvain, Paris: Editions Peeters.

Pustejovsky, J., 1995. *The generative lexicon*. Cambridge, Mass.:MIT Press.

Pustejovsky, J., Ingria R., Sauri R., Castano J., Littman J., Gaizaukas R., Setze A., Katz G., Mani I., 2005. , The Specification Language Time ML, in *The Language of Time. A Reader*, New York : Oxford University Press.

Pustejovsky, J., 2009. Linguistic ontologies for time and space, FLAIRS 22.

Seohyun I. and Pustejovsky, J. 2010. Annotating Lexically Entailed Subevents for Textual Inference Tasks, FLAIRS 23.