Underspecified changes: a dynamic, probabilistic frame theory for verbs

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Data and central issue. Though most non-stative verbs express a change, in many contexts no unique kind of change needs to be singled out, as shown in (1)-(3).

(1) a. The temperature (of the liquid) rises.
 b. China rises. (example taken from [Coo10])

(2) They loaded the truck with hay.

(3) a. Surii tɛɛŋ klɔɔn k^hɯn tɛɛ jaŋ mâj sèd.
 Surii compose poem ascend but still not finish.
 'Surii composed a/the poem, but has not finished it yet.' (Thai; [KM00])

Underspecification can arise at two different levels. First, the attribute in regard to which the change is measured and second the way the change is measured: is the change maximal, i.e. is there a definite end point on the scale (culmination)? 'Rise' shows both kinds of underspecification. In (1-a) the attribute is fixed, TEMPERATURE, but no unique value is determined which has to hold in the end state. In addition, without a constraining context no particular attribute is determined in (1-b). Possible instances are POLITICAL POWER or ECONOMIC POWER. In (2) the change can be measured either in regard to the loading capacity of the truck or the volume of the hay. Though no end point is explicitly determined, the value in the end state is compatible both with a maximal (culminated) or a non-maximal reading. Hence, there is underspecification at both levels though there is a dependency: maximality implies a change in regard to the volume of the truck. For the Thai example in (3), a unique attribute is determined and a culmination reading is preferred. This latter inference is, however, defeasible as shown by the non-contradictory continuation.

The underspecification can be resolved by various types of information sources: (i) context (e.g. talking about China's role as a global player in the economic sector); (ii) 'by'-phrase ('rise by n degree'); (iii) determiner (mass term 'hay' vs. '*the* hay') and (iv) morphological marker (the perfective marker 'k^hɯn' in Thai). Two kinds of information must be distinguished: 'soft' and 'hard'. Soft information does not completely resolve underspecification, but one particular kind of change is singled out as the most probable one. By contrast, hard information singles out a unique change and discards all others. Both types are illustrated in (3). The perfective marker 'k^hɯn' provides soft information: a culmination reading is singled out as the preferred one. Other readings are not completely excluded as shown by the continuation in (3). This continuation, however, excludes the completion at reference time and therefore provides hard information. In addition, this example shows the non-monotonic character of the resolution process.

In our talk we will present a unifying analysis of the above data by focussing on the following two questions: (i) how can underspecification w.r.t. various kinds of changes be represented? and (ii) How can the resolution process be formally modelled? This requires not only a modelling of soft and hard information as well as their contribution to the resolution process but in addition also an account of the non-monotonic character of this process.

Outline of the analysis. Our analysis is based on four assumptions about what types of information are specified for the lexical entry of a verb: (i) *sortal* information σ is added: e.g. it is a rising or a loading; (ii) an event e of this sort is added to the current information state. Hence, verbs are *not* static, i.e. tests, but change the current information state; (iii) information about admissible changes is not explicitly given in the lexical representation of a verb, yielding underspecification. Rather, this information is built into the dynamics. The change of information triggered by introducing e is non-deterministic. For each admissible kind of change there is an output state; and (iv) the strengths with which a particular change is endorsed is modelled by defining a probability distribution on the set of output states.

We use frames (i.e., recursive attribute-value structures) to represent information states. For the dynamics, we use *Incremental Dynamics*, [vE01], a context c is represented as a stack of objects. New information is added by context concatenation, $c \triangleleft c'$ (context c extended by $|c'|$ elements). A frame is defined relative to a context c. Nodes in a frame correspond to elements of c so that the universe of a frame is a substack of c. Frames are built from attributes $attr(x, y)$, that are typed. Attribute formulas can be combined to paths formulas π using functional composition $\bullet$. $\pi = \lambda c \exists jk.\tau(c[j], c[k])$ for $\tau = attr_1 \bullet \ldots \bullet attr_n$ is called a *path property*.

There are two constraints on admissible changes. First, on the value range of attributes. Value ranges can be classified according to their algebraic properties, say a flat or a linear order. E.g., for 'rise', we follow [HL10] and assume that in its motion verb use the value range of the attribute w.r.t. which the change occurs is required to be an unbounded linear path with a minimal element. Let this constraint be θ. Second, changes proper are defined by imposing a constraint on how the values of attributes that get changed are distributed during the change. To this end one considers a linearly ordered sequence of subevents $e_1 \ldots e_n$ of e s.t. (i) $meet(e_i, e_{i+1})$ for $1 \leq i \leq n$, (ii) $\bigsqcup\{e_1, \ldots, e_n\} = e$ and (iii) each e_i is assigned a subframe of e. E.g., a culminated reading for 'load' or 'klɔɔn' in Thai, the culmination is required to be false for all e_i except for the last one e_n, for which it has to be true. This is implemented using Fernando's string theory of events, [Fer04].

The different strengths are modeled by a probability distribution defined on the set of output contexts α consisting of a context and a path property defined below. The first projection of each element w of α is assigned a probability pr with $pr(w) \in [0, 1]$. The elements of α differ w.r.t. the way e brings about a change which is expressed by the second projection, whose probabilities are defined in terms of w in the usual way. E.g., for (1-b), there is an element c' in which China's political power rises and another element in which it is its economic power. Without a constraining context, both output contexts can be taken to receive the same probability. Let this initial distribution be $pr(\cdot)$. Additional information about a frame can change these initial probabilities assigned to the value of an attribute. Formally, this change is calculated by *conditioning* on the new information. This yields the new probability distribution $pr(\cdot \mid \pi)$, for π the new information. Soft information 'redistributes' probability information without discarding any possibilities. Hard information singles out one possibility and discards the others. Hence, the semantic function of the perfective marker 'k^{h}ɯn' in Thai consists in raising the probability for a culminated change and lowers that for a non-culmination reading though it is still considered possible. By contrast, the continuation in (3), being hard information, excludes the culmination reading at reference time. This non-monotonic character of the resolution process is captured by the fact that changing the probability distribution is an iterable process. E.g., one can have $pr(\pi_1) < pr(\pi_1|\pi_2)$ and $pr(\pi_1|\pi_2) > pr(\pi_1|\pi_2 \wedge \pi_3)$ with the temporal ordering: $\pi_1 - \pi_2 - \pi_3$ so that the probability of path π_1 is first raised and then lowered. The translation of 'rise' in (4-a) has a path PATH $\bullet$ VALUE whose value has to be token-identical to the path whose value gets changed. The relation between (4-a) and the probability component is established by a polymorphic combinator G which lifts a state transformer or a relation between n individuals and a state transformer to a relation between a context and a property of contexts. In (4-b) the instance for an intransitive verb is given. Applying (4-b) to (4-a) yields a relation between (output) contexts and properties of those contexts. In the translation of 'China', (4-c), both paths are of sort θ defined above so that their values can be changed by a rising event. Applying (4-c) to (4-a) therefore excludes attributes like TEMPERATURE or PRICE which are not defined for the China-frame. Applying the appropriate instance of G to the translation of 'China rises' yields (4-d) which still leaves underspecification w.r.t. the two attributes. Given a context saying that China is an economic global player, expressed by a path property π, triggers an update, yielding ECO_POWER $\bullet$ VALUE as the most preferred attribute to be changed by the rising.

(4) a. rise := $\lambda jcc' \exists kl[c \lhd c' \wedge c'[k] = e_{rise} \wedge \text{THEME}(c'[k], c'[j]) \wedge \text{PATH} \bullet \text{VALUE}(c'[j], c'[l])]$.

b. $G_c := \lambda \phi c' \pi \exists j[\phi jcc' \wedge \pi c']$.

c. China := $\lambda P \lambda c \lambda c' \exists j \exists k[c \lhd c' \wedge c'[j] = china \wedge [(\text{POL\_POWER} \cup \text{ECO\_POWER}) \bullet \text{VALUE}](c'[j], c'[k]) \wedge Pjcc']$.

d. $\lambda c' \pi \exists jklm[c \lhd c' \wedge c'[j] = china \wedge [(\text{POL\_POWER} \cup \text{ECO\_POWER}) \bullet \text{VALUE}](c'[j], c'[k]) \wedge c'[l] = e_{rise} \wedge \text{THEME}(c'[l], c'[j]) \wedge \text{PATH} \bullet \text{VALUE}(c'[l], c'[m])]$.

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