A deontic logical framework for modelling flexibility, adaptability In service computing

Research in progress

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Outline

1. Aim of our research activity
2. Running example
3. Deontic logic
4. Our DHML logic
5. Static and behavioural properties of families
6. Conclusions

Aim of our research activity

- To extend formal/semiformal existing notations and languages for service computing with notions of variability through which increased levels of flexibility and adaptability can be achieved in software-service provision
- To define a rigorous semantics of variability over behavioural models of services that can support a number of design- and run-time analysis techniques
- To develop verification techniques that are still effective over specifications with variability points, including situations when variability is triggered at run time.

We have started from: Product families

In our search for a single logical framework in which to express both static and behavioural aspects of product families:

- we present a straightforward characterization of feature models by means of deontic logics
- we define a deontic extension of a behavioural logic, called DHML, that allows to express in a single framework both static constraints over services belonging to a software service line and constraints over their behaviour
- we give a semantic interpretation of DHML over MTSs, for which a verification framework based on model-checking techniques could be implemented

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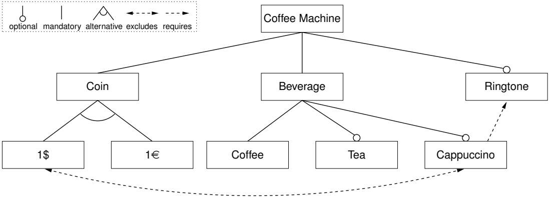
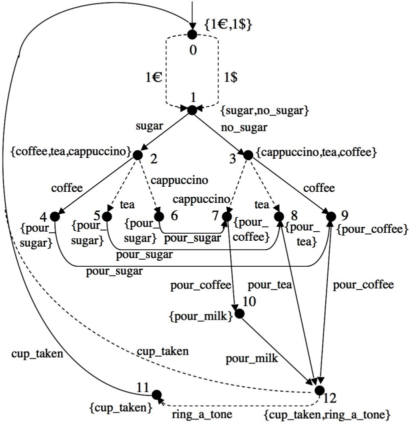
Running example: Coffee machine family

Feature model:



Doubly-Labeled Modal Transition System:



— required transitions

- - - possible transitions

Static & behavioural requirements of product families

Static requirements identify the **features** constituting different products and *behavioural requirements* the **admitted sequences of operations**

Static requirements of product families

- The only accepted coins are the 1 euro coin (1€), exclusively for the European products and the 1 dollar coin (1$), exclusively for the US products (1€ and 1$ are exclusive (**alternative**) features)
- A cappuccino is only offered by European products (**excludes** relation between features)

Behavioural requirements of product families

- After inserting a coin, the user has to choose whether or not (s)he wants sugar, by pressing one of two buttons, after which (s)he may select a beverage
- The machine returns to its idle state when the beverage is taken

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Deontic logic

- Deontic logic provides a natural way to formalize concepts like violation, obligation, permission and prohibition
- Deontic logic seems to be very useful to formalize product families specifications, since they allow one to capture the notions of **optional**, **mandatory** and **alternative** features
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Deontic logic - continued

A deontic logic consists of the standard operators of propositional logic, i.e. negation ($\neg$), conjunction ($\wedge$), disjunction ($\vee$) and implication ($\Longrightarrow$), augmented with deontic operators (O and P in our case)

The most classic deontic operators, namely *it is obligatory that* (O) and *it is permitted that* (P) enjoy the duality property

Informal meaning of the deontic operators

- $O(\alpha)$: action α is *obligatory* (required transition)
- $P(\alpha) = \neg O(\neg\alpha)$: action α is *permitted* (possible transition) if and only if its negation is not obligatory

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DHML: Deontic Hennesy-Milner Logic with until

DHML is a temporal logic based on the "Hennessy-Milner logic with until" [Larsen], augmented with the deontic O and P operators à la PDL logic [Castro & Maibaum] and the path operators E and A from CTL [Clarke et alii]

Syntax of DHML

$$\begin{array}{lcl} \phi & ::= & true \mid p \mid \neg\phi \mid \phi \wedge \phi' \mid [\alpha]\phi \mid E\pi \mid A\pi \mid O(\alpha) \mid P(\alpha) \\ \pi & ::= & \phi \, U \, \phi' \end{array}$$

Informal meaning of remaining operators (p is a proposition)

- $[\alpha]\,\phi$: for all next states reachable with α, ϕ holds
- $E\,\pi$: there exists a path on which π holds
- $A\,\pi$: on each of the possible paths π holds
- $\phi\,U\,\phi'$: in the current or a future state ϕ' holds, while ϕ holds until that state

Usual abbreviations

$false = \neg true$, $\phi \vee \phi' = \neg(\neg\phi \wedge \neg\phi')$, $\phi \implies \phi' = \neg\phi \vee \phi'$, $\langle\alpha\rangle\phi = \neg[\alpha]\neg\phi$,
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DHML: Semantics with MTS as interpretation structure

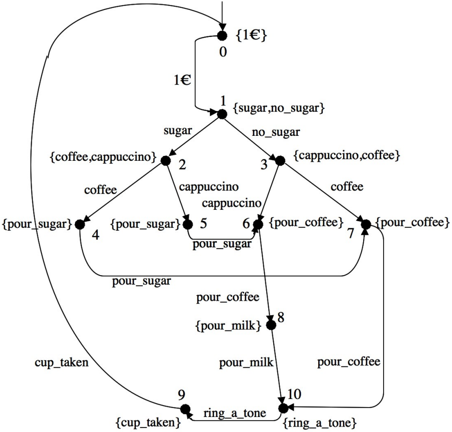
- $\rightarrow \subseteq S \times Act \times S$: transitions between states S are labelled with actions Act
- transitions are either required (—) or possible (- - -)
- $L : S \rightarrow 2^{AP}$: states are labelled with Atomic Propositions AP as well as with the events allowed in the states (i.e. $Act \subseteq AP$)
- $P \subseteq S \times Act$ denotes the actions which are permitted in a state: $P(s, \alpha)$ iff $\alpha \in L(s)$

The satisfaction relation of DHML is defined as follows:

- $s \models true$ always holds
- $s \models p$ iff $p \in L(s)$
- $s \models \neg\phi$ iff not $s \models \phi$
- $s \models \phi \wedge \phi'$ iff $s \models \phi$ and $s \models \phi'$
- $s \models [\alpha]\phi$ iff $s \xrightarrow{\alpha}_{\Diamond} s'$, for some $s' \in S$, implies $s' \models \phi$
- $s \models E\pi$ iff there exists a path σ starting in state s such that $\sigma \models \pi$
- $s \models A\pi$ iff $\sigma \models \pi$ for all paths σ starting in state s
- $s \models P(\alpha)$ iff $P(s, \alpha)$ holds
- $s \models O(\alpha)$ iff $P(s, \alpha)$ holds and $\exists s' : s \xrightarrow{\alpha}_{\Box} s'$
- $\sigma \models [\phi \; U \; \phi']$ iff there exists a state s_j, for some $j \geq 0$, on the path σ such that for all states s_k, with $j \leq k$, $s_k \models \phi'$ while for all states s_i, with $0 \leq i < j$, $s_i \models \phi$

MTS of a European Coffee Machine

A product is represented by a MTS with only required transitions:



Example behavioural properties of families

Behavioural properties of families

1. It is possible to get a coffee with 1€:

$$[1€]\ EF\ < coffee >\ true$$

2. It is always possible to ask for sugar:

$$AF\ < sugar >\ true$$

3. It is not possible to get a beverage without inserting a coin:

$$AG\,(\neg(coffee \vee tea \vee cappuccino)\ U\ (< 1€ >\ true \vee < 1\$ >\ true))$$

Example static and behavioural properties of families

Static and behavioural properties of families

1. actions 1€ and 1\$ are exclusive (**alternative** features):

$$((EF \; \langle 1\$ \rangle \; true) \implies (AG \, \neg P(1€))) \wedge$$
$$((EF \; \langle 1€ \rangle \; true) \implies (AG \, \neg P(1\$)))$$

2. a cappuccino is only offered by European products (**excludes** relation between features):

$$((EF \; \langle cappuccino \rangle \; true) \implies (AG \, \neg P(1\$))) \wedge$$
$$((EF \; \langle 1\$ \rangle \; true) \implies (AG \, \neg P(cappuccino)))$$

3. a ringtone is rung whenever a cappuccino is delivered (**requires** relation between features):

$$(EF \; \langle cappuccino \rangle \; true) \implies (AF \; O(ring\_a\_tone))$$

Conclusions and open problems

Research in Progress—what we have done so far

1. defined a deontic characterization of a feature model (static requirements over a family)
2. defined behavioural deontic logic DHML to express the behavioural variability of a family

Research in Progress—what we are working on

- a model checker able to automatically verify DHML formulae over models described as MTSs, with possible constraints expressed in DHML itself
- exploit the relation between M^2TSs and L^2TSs to reuse the UMC model-checking engine (on-the-fly model checker designed for the efficient verification of UCTL logic over L^2TSs)
- compare the expressiveness of UCTL and DHML, which might lead to enhancements to the model-checking engine to cover DHML deontic operators

Research in Progress—what remains to be done

- how to express dependencies of variation points?
- how to identify properties that, proved on a family, are preserved by all its products?
- how does this scale to real problems and to incremental family construction?
- how to combine DHML with SOCL
- what else???

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