A Set-Based Logical Language for Specification of Combinatorial Models

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Combinatorial Model

A **combinatorial model** is defined as tuple consisting of

- a set of parameters,
- their respective possible values, and
- a set of logical restrictions on the value combinations

Combinatorial Test Design (CTD) - methodology for test design of complex software systems, in which a system is modelled using a combinatorial model

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Combinatorial Model

In CTD, a **system** is modelled using a finite set of system parameters

$$\mathcal{A} = \{\mathcal{A}_1, \ldots, \mathcal{A}_n\}$$

together with their corresponding associated values

$$\mathbf{V} = \{\mathbf{V}(\mathcal{A}_1), \ldots, \mathbf{V}(\mathcal{A}_n)\}$$

A **scenario (test)** is an assignment of a value from $\mathbf{V}(\mathcal{A}_i)$ to each $\mathcal{A}_i$

A **combinatorial model** for a system is defined as a set of scenarios.

Combinatorial Test Design (CTD)

- **Aim:** To systematically optimise the number of test cases, while ensuring the coverage of given conditions.
- **Issues:**
  - What should be the process of constructing combinatorial models?
  - Does a manual process for modelling and maintaining the test space fit the industry needs? ☺

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What we would like to have?

- Formalization of the visual notation
- Reducing the cognitive load of the modeller and tester when specifying the logical restrictions
- Reducing the the chances for human errors

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Example

Parameters:

- Item Status (denoted by IS)
- Order Shipping (denoted by OS)
- Delivery Timeframe (denoted by DT)

$$\mathcal{A} = \{\mathrm{IS}, \mathrm{OS}, \mathrm{DT}\}$$

Values:

$$\mathrm{IS} = \{InStock, OutOfStock, NoSuchProduct\}$$
$$\mathrm{OS} = \{Air, Ground\}$$
$$\mathrm{DT} = \{Immediate, 3Days, 1Month\}$$

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R. Tzoref-Brill and S. Maoz. Lattice-based semantics for combinatorial model evolution. In Automated Technology for Verification and Analysis, pages 276–292. Springer, 2015.

Example (continues)

Combinatorial model of the system is a set of scenarios (assignments of values to parameters), such as:

$$s_1 : (\mathbf{IS} = InStock, \mathbf{OS} = Air, \mathbf{DT} = Immediate)$$
$$s_2 : (\mathbf{IS} = InStock, \mathbf{OS} = Ground, \mathbf{DT} = Immediate)$$

How many possible scenarios could we have for this example? ☺

But in praxis not all scenarios are executable.

Challenge:
Separating the valid (executable) scenarios from the invalid ones

More challenges!

The same?

$$R_1 : \mathbf{DT} = \mathit{Immediate} \longrightarrow \mathbf{OS} \neq \mathit{Ground}$$

$$R_2 : \mathbf{DT} = \mathit{Immediate} \longrightarrow \mathbf{OS} = \mathit{Air}$$

But what if we add new value for OS?

$$s_3 = (\mathbf{IS} = \mathit{InStock}, \mathbf{OS} = \mathit{Sea}, \mathbf{DT} = \mathit{Immediate})$$

Challenge:
Inconsistent interpretation of test validity in case a new parameter value is added

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CTD Set-Based Logical Language

$\wedge, \vee, \rightarrow$

Let

$\mathcal{A} = \{\mathcal{A}_1, \ldots, \mathcal{A}_n\}$ be a set of variables,

$M_{\mathcal{A}}$ be a set $\mathbf{V} = \{\mathbf{V}(\mathcal{A}_1), \ldots, \mathbf{V}(\mathcal{A}_n)\}$ of value sets associated with those variables.

Atomic formula:

$$\mathcal{A}_i \in \mathbf{V}(\mathcal{A}_i) \setminus X,$$

might be shorter for small data sets

where $X \subseteq \mathbf{V}(\mathcal{A}_i)$, $1 \leq i \leq n$, or a more explicit form

$$\mathcal{A}_i \in Y \wedge Y \subseteq \mathbf{V}(\mathcal{A}_i).$$

more explicit and provides more intuitive representation

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CTD Set-Based Logical Language (cont.)

A valuation is an assignment of values to variables $\mathcal{A}_i$

so that $v(s_i) \in \mathbf{V}(\mathcal{A}_i)$

We say that (S, v)

is a model of an atomic formula denoted by

$$(S, v) \models \mathcal{A}_i \in \mathbf{V}(\mathcal{A}_i) \setminus X \text{ for some } X$$

if

$$v(\mathcal{A}_i) \in \mathbf{V}(\mathcal{A}_i) \text{ and } v(\mathcal{A}_i) \notin X$$

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Running Example

$$M_{\mathcal{A}} = \{D_1, D_2, D_3\}$$

$$D_1 = \{InStock, OutOfStock, NoSuchProduct\}$$
$$D_2 = \{Air, Ground\}$$
$$D_3 = \{Immediate, 3Days, 1Month\}$$

$\mathbf{DT} = Immediate \rightarrow \mathbf{OS} \neq Ground$ can be written in our language in the following ways

$$\psi_1 = \mathbf{DT} \in D_3 \setminus \{3Days, 1Month\} \rightarrow \mathbf{OS} \in D_2 \setminus \{Ground\}$$

$$\psi_2 = (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \rightarrow \mathbf{OS} \in D_2 \setminus \{Ground\},$$

$$\psi_3 = (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \rightarrow \mathbf{OS} \in \{Air\} \wedge \{Air\} \subseteq D_2.$$

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$$
\begin{array}{lll}
v_1(DT) = 3Days, & v_1(OS) = Sea, & v_1(IS) = Instock \\
v_2(DT) = Immediate, & v_2(OS) = Sea, & v_2(IS) = Instock
\end{array}
$$

$$D_2' = D_2 \cup \{Sea\}$$

$$M'_{\mathcal{A}} = \{D_1, D_2', D_3\}$$

Many possible options for correction:

$$
\begin{aligned}
\psi_1' = \quad & \mathbf{DT} \in D_3 \setminus \{3Days, 1Month\} \\
& \rightarrow \mathbf{OS} \in D_2' \setminus \{Ground\} \\
\psi_2' = \quad & (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \\
& \rightarrow \mathbf{OS} \in D_2' \setminus \{Ground\} \\
\psi_3' = \quad & (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \\
& \rightarrow \mathbf{OS} \in \{Air\} \wedge \{Air\} \subseteq D_2'
\end{aligned}
$$

$$
\begin{aligned}
\psi_1'' = \quad & \mathbf{DT} \in D_3 \setminus \{3Days, 1Month\} \\
& \rightarrow \mathbf{OS} \in D_2' \setminus \{Ground, Sea\} \\
\psi_2'' = \quad & (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \\
& \rightarrow \mathbf{OS} \in D_2' \setminus \{Ground, Sea\} \\
\psi_3'' = \quad & (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \\
& \rightarrow \mathbf{OS} \in \{Air\} \wedge \{Air\} \subseteq D_2' \setminus \{Sea\}
\end{aligned}
$$

$$
\begin{aligned}
\psi_3''' = \quad & (\mathbf{DT} \in \{Immediate\} \wedge \{Immediate\} \subseteq D_3) \\
& \rightarrow \mathbf{OS} \in \{Air, Sea\} \wedge \{Air\} \subseteq D_2'
\end{aligned}
$$

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Proposed Visualisation

$$D_2 = \{Air, Ground\}$$

Parameter: DT	Parameter: OT
Immediate	*Air*
3Days	*Ground*
1Month	

$$D_2' = D_2 \cup \{Sea\}$$

Parameter: DT	Parameter: OS
Immediate	*Air*
3Days	*Ground*
1Month	*Sea*

Validity of the new value is decided for $D_2' = D_2 \cup \{Sea\}$

Parameter: DT	Parameter: OS
Immediate	*Air*
3Days	*Sea*
1Month	*Ground*

Parameter: DT	Parameter: OS
Immediate	*Air*
3Days	*Ground*
1Month	*Sea*

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What next?

- Tool support
- Scalability analysis
- Application in Learning & Teaching

Thank you!

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IS10: Collaboration in Software and System Engineering

Areas of interest include but are not limited to:

- Collaborative modelling and analysis of sustainable software
- Collaborative aspects of global requirements engineering
- Collaborative aspects of formal methods in conceptual modelling, specification, and design
- Collaborative aspects of testing, verification and validation of systems
- New best practices for software and system engineering education to support team-based learning
- Innovative curriculum, assessment or course formats to support team-based learning of software and system engineering
- Diversity in software and systems engineering teams
- Intercultural aspects in software and systems engineering
- Usability aspects in software and systems engineering (including formal methods)
- Successful case studies on application of formal methods in collaborative projects
- Comprehensibility and readability of formal methods in software engineering
- Teaching of formal methods and collaborative aspects thereof
- Cross-disciplinary software and systems engineering (including application of formal methods)
- Industrial challenges, experience reports and case studies