KeY Proof Obligations

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```
class A{ B b; /*\result==0*/int m() {return b.getC();}}
class B{int c; /*instance invariant c==0;*/ int getC(){return c;}}
```
Not proveable with EnsuresPostcondition

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Lightweight
Design Validation
Properties

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Program Correctness
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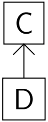

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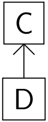

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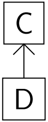

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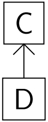

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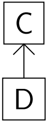

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- Use *exact* quantification in translation — unnatural
- No problem. Specs. are better if they occur again in subclasses...
  PO: $\overline{\forall} o{:}\, D \ (\varphi_D(o) \rightarrow \varphi_C(o))$

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or no modifies information: $$\varphi_D \rightarrow \varphi_C \tag{2'}$$

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Given two operation contracts $opct_1, opct_2$. Do the pre-conditions not overlap?

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$$\forall o \forall r \forall p_1, \ldots, p_n (\neg\psi_1(o, r, p_1, \ldots, p_n) \vee \neg\psi_2(o, r, p_1, \ldots, p_n))$$

with $\psi_i(o, r, p_1, \ldots, p_n)$ precondition of $opct_i(o, r, p_1, \ldots, p_n)$

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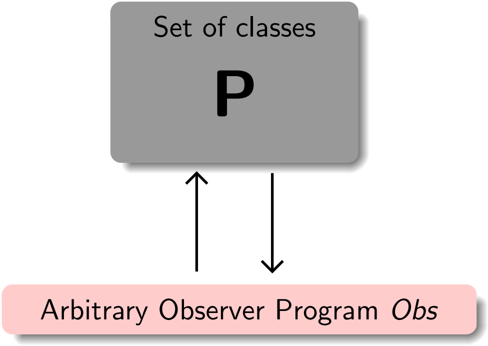

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Judges: Does call of P correspond to specification S of P?

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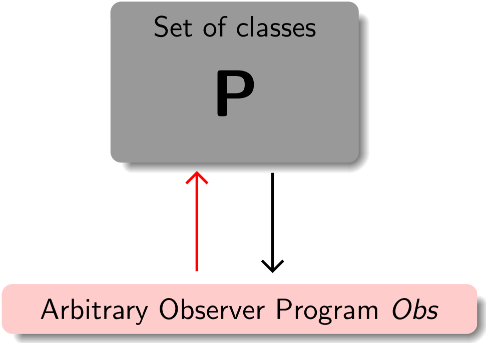

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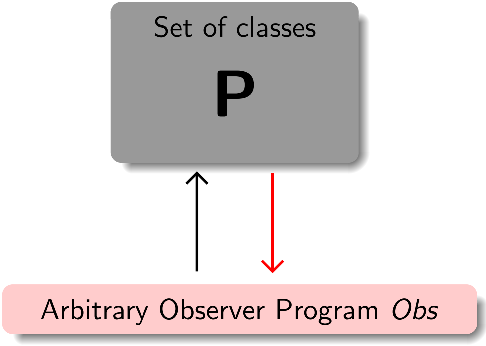

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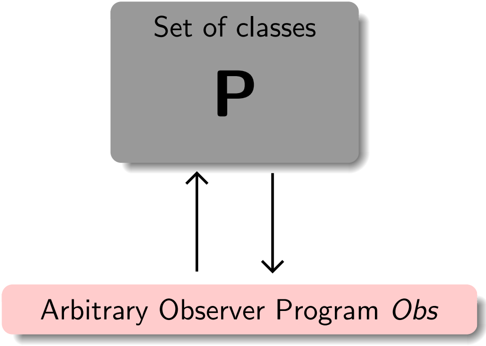

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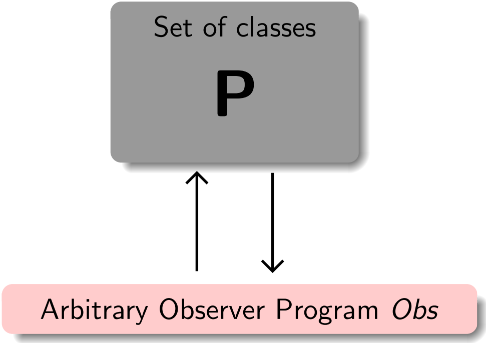

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Two variants: *call correctness* and *persistent correctness*

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Example

Instance invariants: $\forall o{:}\,T\ (o.\texttt{<created>} \rightarrow \varphi(o))$

Before constructor call $\surd$ After constructor call $\surd$

Proof Obligations for Call Correctness

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- Modalities

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The general assumption $\mathcal{A}(op, o, p_1, \ldots, p_n)$ before call to method or constructor *op* on object described by *o*:

$$\bigwedge_{\varphi \in Inv_{cl}} \varphi \wedge \bigvee_{\substack{\varphi_{pre}(\overrightarrow{x}) \\ \text{precondition} \\ \text{of } OpCt_{op}}} \varphi_{pre}(o, p_1, \ldots, p_n) \wedge o.\texttt{<created>} = TRUE$$

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The general assumption $\mathcal{A}(op, o, p_1, \ldots, p_n)$ before call to method or constructor op on object described by o:

$$\bigwedge_{\varphi \in Inv_{cl}} \varphi \wedge \bigvee_{\substack{\varphi_{pre}(\overrightarrow{x}) \\ \text{precondition} \\ \text{of } OpCt_{op}}} \varphi_{pre}(o, p_1, \ldots, p_n) \wedge o.\texttt{<created>} = TRUE$$

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- all invariants of all classes hold,
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Constructors:
new D(p_1,. . . ,p_n);

Programs 2

Gather information on abrupt termination behaviour:

$$\widetilde{\alpha}_{op_D}(\mathsf{self}, (\mathsf{p}_1, \ldots, \mathsf{p}_n), \mathsf{r}, \mathsf{exc}) := \left\{ \begin{array}{l} \mathsf{exc}{=}\textbf{null};\\ \textbf{try}\{\\ \quad \alpha_{op_D}(\mathsf{self}, (\mathsf{p}_1, \ldots, \mathsf{p}_n), \mathsf{r})\\ \}\ \textbf{catch}\ (\mathsf{Throwable\ e})\ \{\\ \quad \mathsf{exc} = \mathsf{e};\\ \} \end{array} \right.$$

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   - only the elements $l_i(o, p_1, \ldots, p_n)$ of the modifies clauses in the operation contracts are (permanently) modified.

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then in the post-state all $\varphi \in I$ are valid.

Program Correctness Proof Obligations

To prove entire call correctness, for all operations *op*:

- EnsuresPost

$$\begin{aligned}&\mathcal{A}(op, \mathsf{self}, (\mathsf{p}_1, \ldots, \mathsf{p}_n)) \land \psi_{opct} \\ &\qquad \to \langle\widetilde{\alpha}_{op}(\mathsf{self}, (\mathsf{p}_1, \ldots, \mathsf{p}_n), \mathsf{r}, \mathsf{exc})\rangle\varphi_{opct}\end{aligned}$$

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$$\mathcal{A}(op, \mathrm{self}, (\mathrm{p}_1, \ldots, \mathrm{p}_n)) \rightarrow [\widetilde{\alpha}_{op_D}(\mathrm{self}, (\mathrm{p}_1, \ldots, \mathrm{p}_n), \mathrm{r})] \bigwedge_{\varphi \in I} \varphi$$

Refinement: Reducing the PO Explosion

For all operations and for all invariants: RecoverInv

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class A{ /*@instance invariant $\overbrace{\text{b.c=0;}}^{\varphi}$ */ private B b;}

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Invariant φ_{enc}: A is the only class that holds references to object in b

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Advanced approach:
Only prove RecoverInv(φ_{enc}) and RecoverInv(φ) for A.

Work still in progress.

Outlook: Persistent Correctness

For open programs call correctness is not enough.

Obs calls operations in P only if

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