Software Design, Modelling and Analysis in UML

Lecture 4: OCL Semantics

2016-11-03

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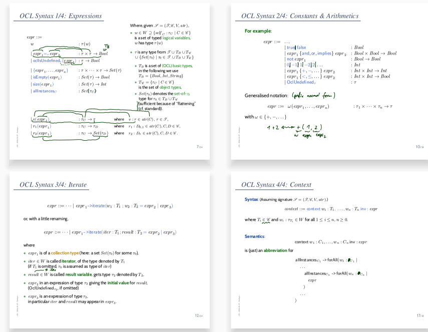
Content

Recall



OCL Semantics: The Task

- **Given**
  - an OCL expression (over signature $\mathscr{S}$), e.g.

    $expr_1 = \textsf{context}\ \ CP\ \ \textsf{inv}:\ \ wen\ \ \textsf{implies}\ \ dd\ .\ wis > 0$

  - and a system state

    $\sigma_1 = \{7_{VM} \mapsto \{dd \mapsto \{1_{DD}\}, cp \mapsto \{3_{DD}, 5_{DD}\}\},\quad 1_{DD} \mapsto \{wis \mapsto 13\},$
    $3_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \textit{true}\},\quad 5_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \textit{false}\}\} \in \Sigma_{\mathscr{S}}^{\mathscr{D}}$

  - and a valuation of the logical variables $\beta_1 : W \to I(\mathscr{T} \cup T_B \cup T_{\mathscr{C}})$.
- **compute** the value $I[\![expr_1]\!](\sigma_1, \beta_1) \in \{\textit{true}, \textit{false}, \bot_{Bool}\}$ of $expr_1$ in σ_1 under β_1.

  three-valued logic

- More general: **Define** the **interpretation** $I[\![expr]\!](\sigma, \beta)$ of $expr$ **in** σ **under** β:

$$I[\![\cdot]\!](\cdot, \cdot) : OCLExpressions(\mathscr{S}) \times \Sigma_{\mathscr{S}}^{\mathscr{D}} \times (W \to I(\mathscr{T} \cup T_B \cup T_{\mathscr{C}})) \to I(Bool)$$

OCL Semantics OMG (2006)

Basically business as usual...

(i) Equip each OCL (!) **type** with a reasonable **domain**, i.e. **define function**

$I_{(i)}$ with $\mathrm{dom}(I_{(i)}) = \mathscr{T} \cup T_B \cup T_{\mathscr{C}}$

(ii) Equip each **set type** $Set(\tau_0)$ with reasonable **domain**, i.e. **define function**

$I_{(ii)}$ with $\mathrm{dom}(I_{(ii)}) = \{Set(\tau_0) \mid \tau_0 \in \mathscr{T} \cup T_B \cup T_{\mathscr{C}}\}$

(iii) Equip each **arithmetical operation** with a reasonable **interpretation** (that is, with a **function** operating on the corresponding **domains**), i.e. **define function**

I with $\mathrm{dom}(I_{(iii)}) = \{+, -, \leq, \dots\}$, e.g., $I(+) \in I(Int) \times I(Int) \to I(Int)$

(iv) Same game for **set operations**: **define function** $I_{(iv)}$ with $\mathrm{dom}(I) = \{\text{isEmpty}, \dots\}$

(v) Equip each **expression** with a reasonable **interpretation**, i.e. define function

$I_{(v)} : Expr \times \Sigma_{\mathscr{S}}^{\mathscr{D}} \times (W \to I_{(i)}(\mathscr{T} \cup T_B \cup T_{\mathscr{C}})) \to I_{(i)}(Bool)$

...except for OCL being a **three-valued logic**, and the "iterate" expression.

$I := I_{(i)} \cup I_{(ii)} \cup I_{(iii)} \cup I_{(iv)} \cup I_{(v)}$

(i) Domains of OCL and (!) Model Basic Types

Recall: OCL basic types

$$T_B = \{Bool, Int, String\}$$

We set:

- $I(Bool) := \{true, false, \bot_{Bool}\}$
- $I(Int) := \mathbb{Z} \dot\cup \{\bot_{Int}\}$
- $I(String) := \ldots \dot\cup \{\bot_{String}\}$

We may omit index τ of $\bot_\tau$ if it is clear from context.

Given signature $\mathscr{T}$ with **model basic types** $\mathscr{T}$ and domain $\mathscr{D}$, set

$$I(T) := \mathscr{D}(T) \dot\cup \{\bot_T\}$$

for each model basic type $T \in \mathscr{T}$.

OCL and Model Types?! An Example.

$\mathscr{T} = (\{Bool_A, Nat\}, \{VM, CP, DD\},$
$\{cp : CP_*, dd : DD_{0,1}, wen : Bool, wis : Nat\},$
$\{VM \mapsto \{cp, dd\}, CP \mapsto \{wen, dd\}, DD \mapsto \{wis\}\})$

Model Types:

$\mathscr{D}(Bool_A) = \{0, 1\}$

$\mathscr{D}(Nat) = \{0, \ldots, 255\}$

$\mathscr{D}(VM) = \mathbb{N} \times \{VM\}$
$= \{\iota_{vm}, 2\iota_{vm}, \ldots\}$

OCL Types:

$I(Bool) = \{true, false, \bot\}$
$I(Int) = \mathbb{Z} \dot\cup \{\bot_{Int}\}$
} fixed for OCL T_B

$I(Bool_A) = \mathscr{D}(Bool_A) \dot\cup \{\bot_{Bool_A}\}$
$= \{0, 1, \bot_{Bool_A}\}$

$I(Nat) = \mathscr{D}(Nat) \cup \{\bot_{Nat}\}$
$= \{0, \ldots, 255\} \dot\cup \{\bot_{Nat}\}$

$I(\tau_{VM}) = \mathscr{D}(VM) \cup \{\bot_{VM}\}$

(i) Domains of Object and (ii) Set Types

- Let τ_C be an (OCL) **object type** for a class $C \in \mathscr{C}$.
- We set

$$I(\tau_C) := \mathscr{D}(C) \dot\cup \{\bot_{\tau_C}\}$$

- Let τ be a type from $\mathscr{T} \cup T_B \cup T_\mathscr{C}$.
- We set

$$I(Set(\tau)) := 2^{I(\tau)} \dot\cup \{\bot_{Set(\tau)}\}$$

Note: in the OCL standard, only **finite** subsets of $I(\tau)$.
Infinity doesn't scare **us**, so we simply allow it.

(iii) Interpretation of Arithmetic Operations

- **Literals** map to fixed values:

$$I(\textbf{true}) := true, \quad I(\text{false}) := false, \quad I(\textbf{0}) := 0, \quad I(1) := 1, \ldots$$
$$I(\textbf{OclUndefined}_\tau) := \bot_\tau$$

- **Boolean operations** (defined point-wise for $x_1, x_2 \in I(\tau)$):

$$I(=_\tau)(x_1, x_2) := \begin{cases} true & \text{, if } x_1 \neq \bot_\tau \neq x_2 \text{ and } x_1 = x_2 \\ false & \text{, if } x_1 \neq \bot_\tau \neq x_2 \text{ and } x_1 \neq x_2 \\ \bot_{Bool} & \text{, otherwise} \end{cases}$$

- **Logical connectives**, e.g. $I(\text{and})(\cdot,\cdot) : \{true, false, \bot\} \times \{true, false, \bot\} \to \{true, false, \bot\}$ is defined by the following truth table:

x_1	*true*	*true*	*true*	*false*	*false*	*false*	$\bot$	$\bot$	$\bot$
x_2	*true*	*false*	$\bot$	*true*	*false*	$\bot$	*true*	*false*	$\bot$
$I(\text{and})(x_1, x_2)$	*true*	*false*	$\bot$	*false*	*false*	*false*	$\bot$	*false*	$\bot$

We assume common logical connectives not, or, ... with the canonical 3-valued interpretation.

(iii) Interpretation of OclIsUndefined

- The **is-undefined** predicate (defined point-wise for $x \in I(\tau)$):

$$I(\text{oclIsUndefined}_\tau)(x) := \begin{cases} true & \text{, if } x = \bot_\tau \\ false & \text{, otherwise} \end{cases}$$

Note: $I(\text{oclIsUndefined}_\tau)$ is **definite**, i.e., it never yields $\bot$.

- **Integer operations** (defined point-wise for $x_1, x_2 \in I(Int)$):

$$I(+)(x_1, x_2) := \begin{cases} x_1 + x_2 & \text{, if } x_1 \neq \bot \neq x_2 \\ \bot & \text{, otherwise} \end{cases}$$

Note: There is a **common principle**.
The **interpretation** of an operation (symbol)

$$\omega : \tau_1 \times \ldots \tau_n \to \tau, \quad n \geq 0$$

is a function

$$I(\omega) : I(\tau_1) \times \cdots \times I(\tau_n) \to I(\tau)$$

on corresponding semantical domain(s) of OCL (!) types.

(iv) Interpretation of Set Operations

Basically the same principle as with arithmetic operations...

Let $\tau \in \mathscr{T} \cup T_B \cup T_\mathscr{C}$.

- **Set comprehension** $(x_1, \ldots, x_n \in I(\tau))$:

$$I(\{\}^\tau_n)(x_1, \ldots, x_n) := \{x_1, \ldots, x_n\}$$

for all $n \in \mathbb{N}_0$

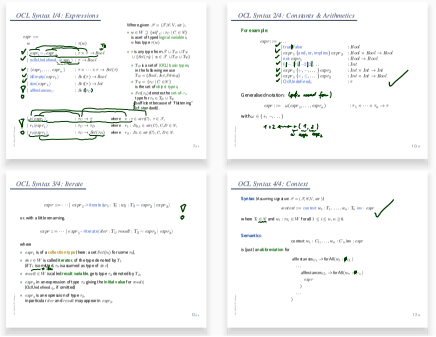
- **Empty-ness check** $(x \in I(Set(\tau)))$:

$$I(\text{isEmpty}^\tau)(x) := \begin{cases} true & \text{, if } x = \emptyset \\ \bot_{Bool} & \text{, if } x = \bot_{Set(\tau)} \\ false & \text{, otherwise} \end{cases}$$

- **Counting** $(x \in I(Set(\tau)))$:

$$I(\text{size}^\tau)(x) := \begin{cases} |x| & \text{, if } x \neq \bot_{Set(\tau)} \text{ and } x \text{ finite} \\ \bot_{Int} & \text{, otherwise} \end{cases}$$

(v) Interpretation of OCL Expressions



Valuations of Logical Variables

- **Recall**: we have typed logical variables $(w \in) W, \tau(w)$ is the type of w.
- By β, we denote a valuation of the logical variables, i.e. for each $w \in W$,

$$\beta(w) \in I(\tau(w)).$$

- $self_{VM} \in W$
- $self_{VM} : \tau_{VM}$ is an OCL expression
- $I[\![self_{VM}]\!](\sigma, \beta) := \beta(self_{VM})$
- $\beta_2 = \{ self_{VM} \mapsto 1_{VM} \}$
  $\hookrightarrow I[\![self_{VM}]\!](\sigma, \beta_2) = \beta_2(self_{VM}) = 1_{VM}$
- $\beta : W \longrightarrow \mathcal{I}(\tau_B \cup \tau_C \cup \tau)$

(v) Interpretation of OCL Expressions

$$expr ::= w \mid \omega(expr_1, \ldots, expr_n) \mid \mathsf{allInstances}_C \mid v(expr_1) \mid r_1(expr_1) \mid r_2(expr_1) \mid expr_1\text{->iterate}(v_1 : \tau_1 ; v_2 : \tau_2 = expr_2 \mid expr_3)$$

- $I[\![w]\!](\sigma, \beta) := \beta(w)$
- $I[\![\omega(expr_1, \ldots, expr_n)]\!](\sigma, \beta) := \mathcal{I}(\omega)\Big(I[\![expr_1]\!](\sigma,\beta), \ldots, I[\![expr_n]\!](\sigma,\beta)\Big)$
- $I[\![\mathsf{allInstances}_C]\!](\sigma, \beta) := \underbrace{dom(\sigma) \cap \mathcal{D}(C)}_{\text{all alive objects in } \sigma \text{ objects of class } C}$

Note: in the OCL standard, $\mathrm{dom}(\sigma)$ is assumed to be **finite**.
Again: doesn't scare us.

Example

$\mathscr{S} = (\{Bool, Nat\}, \{VM, CP, DD\},$
$\{cp : CP_*, dd : DD_{0,1}, wen : Bool, wis : Nat\},$
$\{VM \mapsto \{cp, dd\}, CP \mapsto \{wen, dd\}, DD \mapsto \{wis\}\})$

$\sigma_1 = \{7_{VM} \mapsto \{dd \mapsto \{1_{DD}\}, cp \mapsto \{3_{DD}, 5_{DD}\}\}, \quad 1_{DD} \mapsto \{wis \mapsto 13\},$
$3_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \mathit{true}\}, \quad 5_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \mathit{false}\}\}$

- $I[\![w]\!](\sigma, \beta) := \beta(w)$
- $I[\![\mathsf{allInstances}_C]\!](\sigma, \beta) := \mathrm{dom}(\sigma) \cap \mathscr{D}(C)$
- $I[\![\omega(expr_1, \ldots, expr_n)]\!](\sigma, \beta) := I(\omega)(I[\![expr_1]\!](\sigma, \beta), \ldots I[\![expr_n]\!](\sigma, \beta))$

- $I[\![\mathsf{allInstances}_{CP}]\!](\sigma_1, \beta) = dom(\sigma_1) \cap \mathcal{D}(CP) = \{7_{VM}, 1_{DD}, 3_{CP}, 5_{CP}\} \cap \mathcal{D}(CP)$
  $= \{3_{CP}, 5_{CP}\}$
- $I[\![\mathsf{allInstances}_{CP}\text{->size}]\!](\sigma_1, \beta) = I[\![size(allInstances_{CP})]\!](\sigma, \beta)$
  $= \mathcal{I}(size)\Big(I[\![allInstances_{CP}]\!](\sigma_1, \beta)\Big) = \mathcal{I}(size)\Big(\{3_{CP}, 5_{CP}\}\Big) = 2$
- $\beta_1 := \{\overset{self \mapsto}{3_{CP}}\}, \quad I[\![self]\!](\sigma_1, \beta_1) = \beta_1(self) = 3_{CP}$

(v) Interpretation of OCL Expressions

$$expr ::= w \mid \omega(expr_1, \ldots, expr_n) \mid \mathsf{allInstances}_C \mid v(expr_1) \mid r_1(expr_1) \mid r_2(expr_1) \mid expr_1\text{->iterate}(v_1 : \tau_1 ; v_2 : \tau_2 = expr_2 \mid expr_3)$$

Assume $expr_1 : \tau_C$ for some $C \in \mathscr{C}$. Set $u_1 := I[\![expr_1]\!](\sigma, \beta) \in \mathcal{I}(\tau_C)$

- $I[\![v(expr_1)]\!](\sigma, \beta) := \begin{cases} \sigma(u_1)(v) & \text{, if } u_1 \in dom(\sigma) \\ \bot & \text{, otherwise} \end{cases}$

Example

$\mathscr{S} = (\{Bool, Nat\}, \{VM, CP, DD\},$
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$3_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \mathit{true}\}, \quad 5_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \mathit{false}\}\}$

Assume $expr_1 : \tau_C$ for some $C \in \mathscr{C}$. Set $u_1 := I[\![expr_1]\!](\sigma, \beta) \in \mathcal{I}(\tau_C)$.

- $I[\![v(expr_1)]\!](\sigma, \beta) := \begin{cases} \sigma(u_1)(v) & \text{, if } u_1 \in dom(\sigma) \\ \bot & \text{, otherwise} \end{cases}$

- $\beta_1 := \{\overset{self \mapsto}{3_{CP}}\}, \quad I[\![wen(self)]\!](\sigma_1, \beta_1) = \sigma_1(u_1)(wen) = \sigma_1(3_{CP})(wen) = true$
  $u_1 = I[\![self]\!](\sigma_1, \beta_1) = 3_{CP}$

(v) Interpretation of OCL Expressions

$$expr ::= w \mid \omega(expr_1, \ldots, expr_n) \mid \text{allInstances}_C \mid v(expr_1) \mid r_1(expr_1) \mid r_2(expr_1) \mid expr_1\text{->iterate}(v_1 : \tau_1 ; v_2 : \tau_2 = expr_2 \mid expr_3)$$

Assume $expr_1 : \tau_C$ for some $C \in \mathscr{C}$. Set $u_1 := I[\![expr_1]\!](\sigma, \beta) \in \sigma(\tau_C)$.

- $I[\![v(expr_1)]\!](\sigma,\beta) := \begin{cases} \sigma(u_1)(v) & \text{, if } u_1 \in \text{dom}(\sigma) \\ \bot & \text{, otherwise} \end{cases}$
- $I[\![r_1(expr_1)]\!](\sigma,\beta) := \begin{cases} u & \text{, if } u_1 \in dom(\sigma) \text{ and } \sigma(u_1)(r_1) = \{u\} \\ \bot & \text{, otherwise} \end{cases}$
- $I[\![r_2(expr_1)]\!](\sigma,\beta) := \begin{cases} \sigma(u_1)(r_2) & \text{, if } u_1 \in dom(\sigma) \\ \bot & \text{, otherwise} \end{cases}$

Recall: σ evaluates r_2 of type C_* to a set.

Iterate: Intuitive Semantics

$$expr ::= expr_1\text{->iterate}(iter : T_1; result : T_2 = expr_2 \mid expr_3)$$

$Set(\tau_0)\ hlp := expr_1;$
$\tau_1\ iter;$
$\tau_2\ result := expr_2;$
$while\ (!hlp.empty())\ do$
$\quad iter := hlp.pop();$
$\quad result := expr_3;$
$od;$
$return\ result;$

pick and remove one element

may comprise iter and result

context CP inv : wen

all inst$_{CP}$ -> forAll(self | wen(self))

Iterate: Intuitive Semantics

$$expr ::= expr_1\text{->iterate}(iter : T_1; result : T_2 = expr_2 \mid expr_3)$$

$Set(\tau_0)\ hlp := expr_1;$
$\tau_1\ iter;$
$\tau_2\ result := expr_2;$
$while\ (!hlp.empty())\ do$
$\quad iter := hlp.pop();$
$\quad result := expr_3;$
$od;$
$return\ result;$

Recall: In our (simplified) setting, we always have $expr_1 : Set(\tau_0)$ and $\tau_1 = \tau_0$.
In the type hierarchy of full OCL with inheritance and `oclAny`, τ_0 and τ_1 may be different and still type consistent.

(v) Interpretation of OCL Expressions

$$expr ::= w \mid \omega(expr_1, \ldots, expr_n) \mid \text{allInstances}_C \mid v(expr_1) \mid r_1(expr_1) \mid r_2(expr_1) \mid expr_1\text{->iterate}(v_1 : \tau_1 ; v_2 : \tau_2 = expr_2 \mid expr_3)$$

- $I[\![expr_1\text{->iterate}(v_1 : \tau_1 ; v_2 : \tau_2 = expr_2 \mid expr_3)]\!](\sigma,\beta)$
$$:= \begin{cases} I[\![expr_2]\!](\sigma,\beta) & \text{, if } I[\![expr_1]\!](\sigma,\beta) = \emptyset \\ iterate(hlp, v_1, v_2, expr_3, \sigma, \beta') & \text{, otherwise} \end{cases}$$
where $\beta' = \beta[hlp \mapsto I[\![expr_1]\!](\sigma,\beta),\quad v_2 \mapsto I[\![expr_2]\!](\sigma,\beta)]$ and
- $iterate(hlp, v_1, v_2, expr_3, \sigma, \beta')$
$$:= \begin{cases} I[\![expr_3]\!](\sigma, \beta'[v_1 \mapsto x]) & \text{, if } \beta'(hlp) = \{x\} \\ I[\![expr_3]\!](\sigma, \beta'') & \text{, if } \beta'(hlp) = X \cup \{x\} \text{ and } X \neq \emptyset \end{cases}$$
where $\beta'' = \beta'[v_1 \mapsto x,\quad v_2 \mapsto iterate(hlp, v_1, v_2, expr_3, \sigma, \beta'[hlp \mapsto X])]$

modify β' at v_2.

$\{x$, if v_2 given
$\{\beta'(v_2)$, otherwise

Quiz: Is (our) I a function?

Example

$\mathscr{I} = (\{Bool, Nat\}, \{VM, CP, DD\},$
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$3_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \textit{true}\},\quad 5_{CP} \mapsto \{dd \mapsto \{1_{DD}\}, wen \mapsto \textit{false}\}\}$

context CP inv : wen implies $dd.wis > 0$

allInstances$_{CP}$ -> forAll(self | wen implies dd.wis > 0)

Example

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context CP inv : wen implies $dd.wis > 0$

allInstances$_{CP}$ -> forAll ($self$ | $self.wen$ implies $self.dd.wis > 0$)

allInstances$_{CP}$ -> iterate (self ; t : Bool = true | t and ···)

Example

$\mathscr{S} = (\{Bool, Nat\}, \{VM, CP, DD\},$
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$F :=$ context CP inv : wen implies $dd.wis > 0$

allInstances$_{CP}$ -> iterate $(self; r : Bool = \mathit{true} \mid$ and$(r,$ implies$(wen(self), >(wis(dd(self)), 0))))$

$\mathbb{I}[\![\text{allInstances}_{CP}]\!](\sigma_1, \beta_1) = \{3_{CP}, 5_{CP}\}$

$\mathbb{I}[\![\text{exp}_1]\!](\sigma_1, \{self \mapsto 3_{CP}, r \mapsto \mathit{true}\}) = I(\text{and})\big(\mathbb{I}[\![\text{exp}_2]\!](\sigma_1, \beta_1), \mathbb{I}[\![\text{exp}_3]\!](\sigma_1, \beta_1)\big) = I(\text{and})(\mathit{true}, \mathit{true}) = \mathit{true}$

$\mathbb{I}[\![\text{exp}_2]\!](\sigma_1, \beta_1) = I(\text{implies})\big(\mathbb{I}[\![\text{exp}_4]\!](\sigma_1, \beta_1), I(>)\big(\mathbb{I}[\![\text{exp}_5]\!](\sigma_1, \beta_1), 0\big)\big) = \mathit{true}$ (by)

$\mathbb{I}[\![dd(self)]\!](\sigma_1, \beta_1) = 1_{DD}$

$\mathbb{I}[\![wis(dd(self))]\!](\sigma_1, \beta_1) = 13$

$\doteq I(\text{implies})(\mathit{true}, \mathit{true}) = \mathit{true}$ (IE)

$\mathbb{I}[\![\text{exp}_3]\!](\sigma_1, \{self \mapsto 5_{CP}, r \mapsto \mathit{true}\}) = \mathit{true}$ (ex)

$\mathbb{I}[\![F]\!](\sigma_1, \beta_1) = \mathit{true}$

Tell Them What You've Told Them...

- Given
  - an OCL expression $expr$,
  - and a system state σ,
  - and a valuation β of the logical variables
- we can compute the value

$$I[\![expr]\!](\sigma, \beta) \in \{\mathit{true}, \mathit{false}, \bot_{Bool}\}$$

of $expr$ in σ under β

- using the interpretation function

$I[\![\cdot]\!](\cdot,\cdot) : OCLExpressions(\mathscr{S}) \times \Sigma^{\mathscr{D}}_{\mathscr{S}} \times (W \to I(\mathscr{T} \cup T_B \cup T_{\mathscr{C}}))$
$\to I(Bool).$

User's Guide

- App
  The
  It is

Example:

Task: Given a square with side length $a = 19.1$. What is the length of the longest straight line fully inside the square?

Submission A:	Submission B:
27	The length of the longest straight line fully inside the square with side length $a = 19.1$ is 27.01 (rounded). The longest straight line inside the square is the diagonal. By Pythagoras, its length is $\sqrt{a^2 + a^2}$. Inserting $a = 19.1$ yields 27.01 (rounded).

- Inte
  Abs

- **Exercise submissions:**
  Each task is a **tiny little scientific work**:
  (i) Briefly rephrase the task in your own words.
  (ii) State your claimed solution.
  (iii) Convince your reader that your proposal is a solution (proofs are very convincing).

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- **Exercise submissions:**
  Each task is a **tiny little scientific work**:
  (i) Briefly rephrase the task in your own words.
  (ii) State your claimed solution.
  (iii) Convince your reader that your proposal is a solution (proofs are very convincing).

Formalia: Exercises and Tutorials

- You should work in groups of **approx. 3**, clearly give **names** on submission.
- Please submit via ILIAS (cf. homepage); **paper submissions are tolerated**.
- **Schedule:**

Week N,	Thursday, 8–10 **Lecture A1**	(exercise sheet A **online**)
Week $N+1$,	Tuesday 8–10 **Lecture A2**	
	Thursday 8–10 **Lecture A3**	
Week $N+2$,	Monday, 12:00	(exercises A **early submission**)
	Tuesday, 8:00	(exercises A **late submission**)
	8–10 **Tutorial A**	
	Thursday 8–10 **Lecture B1**	(exercise sheet B **online**)
	...	

- **Rating system:** "most complicated rating system **ever**"
  - **Admission points** (good-will rating, upper bound)
    ("reasonable proposal given student's knowledge **before** tutorial")
  - **Exam-like points** (evil rating, lower bound)
    ("reasonable proposal given student's knowledge **after** tutorial")

  10% bonus for **early** submission.
- **Tutorial:** Plenary, **not recorded**.
  - Together develop **one good solution** based on selection of early submissions (anonymous) – there is no "Musterlösung" for modelling tasks.

- Eg.
  - give a syst. state as pos. example
  - system state
    $\sigma_1 = \{ \dots \}$
    satisfies the req. because ...
- 18 submissions
  – ~10 singleton groups

References

OMG (2006). Object Constraint Language, version 2.0. Technical Report formal/06-05-01.

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