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This detail from Michelangelo's 'The Fall of Man' focuses on the figures of Adam and Eve. Adam is depicted on the left, reclining on his side with a long, flowing pinkish-red robe. His body is muscular and youthful, with a green cloth draped over his lower body. Eve is on the right, sitting up and looking towards Adam with a concerned expression. She is also muscular and youthful, with a green cloth draped over her lower body. The background is a soft, hazy landscape with a small green pool of water in the foreground. The overall style is characteristic of the High Renaissance, with a focus on anatomical detail and emotional expression.

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Hasso Plattner Institute for IT Systems Engineering
University of Potsdam
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Ontologies and Logic

An **ontology** is an **explicit**, **formal specification** of a shared conceptualization.

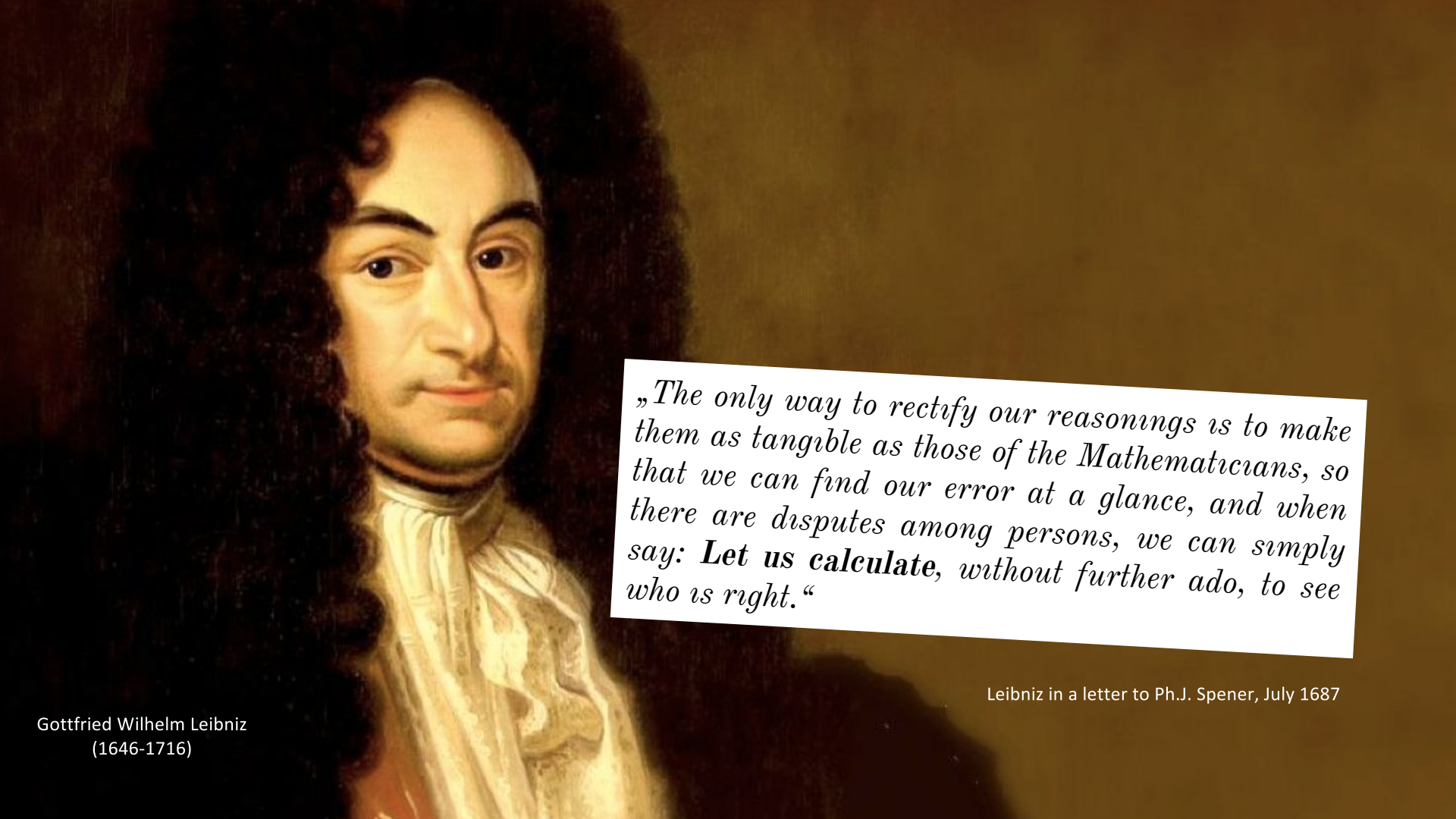
*acc. to Thomas R. Gruber: A Translation Approach to Portable Ontology Specifications.
Knowledge Acquisition, 5(2):199-220, 1993.*

formal (machine readable) semantics

mathematical logic

The Foundations of Logic

- Definition (for our lecture):
Logic is the study of how to make formal correct deductions and inferences.
- Why “formal logic”? $\Rightarrow$ to enable automation



*„The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: **Let us calculate**, without further ado, to see who is right.“*

Gottfried Wilhelm Leibniz
(1646-1716)

Leibniz in a letter to Ph.J. Spener, July 1687

The Foundations of Logic

- **Syntax:** *symbols without meaning*
defines rules, how to construct well-formed and valid sequences of symbols (strings)
- **Semantic:** *meaning of syntax*
defines rules how the meaning of complex sequences of symbols can be derived from atomic sequences of symbols.

Syntax

```
If (i<0) then display ("negative account!")
```

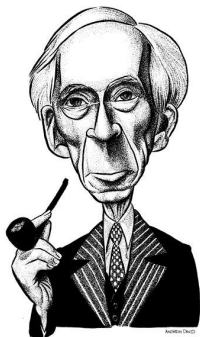
assignment of meaning

print the message "negative account!", if the account balance is negative

The Importance of Semantics

- Why should I care about semantics?

Well, from a philosophical POV, we need to specify the relationship between statements in the logic and the existential phenomena they describe.

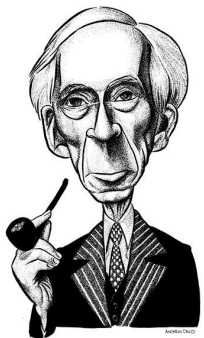


Bertrand Russell
(1872-1970)

The Importance of Semantics

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- That's OK, but I don't get paid for philosophy.

From a practical POV, in order to specify, build and test (ontology-based) tools/systems we need to precisely define relationships (like entailment) between logical statements – this defines the intended behaviour of tools/systems.

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION f(n:  
natural):natural;  
BEGIN  
    IF n=0 THEN f:=1  
    ELSE f:=n*f(n-1);  
END;
```

computation of the factorial

intentional semantics

- „the meaning intended by the user“
- restricts the set of all possible models (meanings) to the meaning intended by the (human) user

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION f(n:  
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    IF n=0 THEN f:=1  
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```

computation of the factorial

$f:n \rightarrow n!$

formal semantics

*aims to express the meaning of symbol sequences (programs) in a **formal language**, in a way that assertions over the symbol sequences (programs) can be proven by the application of deduction rules.*

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION f(n:  
natural):natural;  
BEGIN  
    IF n=0 THEN f:=1  
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END;
```

computation of the factorial

$f:n \rightarrow n!$

behaviour of the program at execution

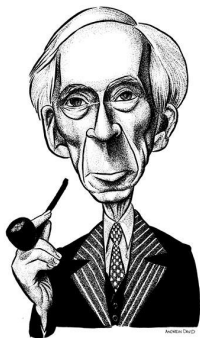
procedural semantics

the meaning of a language expression (program) is the procedure that takes place internally, whenever the expression does occur.

Semantics and Mathematical Logic

- How do I define the semantics of a mathematical logic?

*In mathematical logic we define the semantics in terms of **models** (a model theory). A model is supposed to be an analogue of (part of) the world being modeled.*



Bertrand Russell
(1872-1970)

Model-Theoretic Semantics



Alfred Tarski
(1901-1983)

- **Model-theoretic semantics** performs the semantic interpretation of artificial and natural languages by *„identifying meaning with an exact and formally defined interpretation with a model“*
- = **formal Interpretation with a model**
- e.g. model-theoretic semantics of **propositional logic**
 - assignment of truth values *„true“* and *„false“* to atomic assertions and
 - description of logical connectives with *truth tables*

Model-Theoretic Semantics

- Any logic $L := (S, \models)$ consists of
 - (1) a **set of statements** S and
 - (2) an **entailment relation** $\models$

- Let $\Phi \subseteq S$ and $\varphi \in S$: $\Phi \models \varphi$

*„ φ is a logical consequence of Φ “ or
„from the assertions of Φ follows the assertion φ “*

- If for 2 assertions $\varphi, \psi \in S$
both $\{\varphi\} \models \psi$ and $\{\psi\} \models \varphi$,
then both assertions φ and ψ are logically equivalent:

$$\varphi \equiv \psi$$



04: Short Recapitulation of Propositional Logic

OpenHPI - Course Knowledge Engineering with Semantic Web Technologies

Lecture 3: Ontologies and Logic