Software specification in CASL - The Common Algebraic Specification Language

Till Mossakowski, Lutz Schröder

October 2006

SFB/TR 8 SPATIAL COGNITION

Overview

- Why formal specification?
- Waterfall Model
- Example: sorting
- CASL – the Common Algebraic Specification Language
- Layers of CASL
- Overview of the course
- Scheinkriterien

Why formal specification?

Erroneous software systems may lead to

- economic losses
  (e.g.: loss of Ariane V and mars probe, pentium bug),

Why formal specification?

Erroneous software systems may lead to

- economic losses
  (e.g.: loss of Ariane V and mars probe, pentium bug),
- security problems (e.g.: Loveletter virus),

Why formal specification?

Erroneous software systems may lead to

- economic losses
  (e.g.: loss of Ariane V and mars probe, pentium bug),
- security problems (e.g.: Loveletter virus),
- damage of persons (e.g.: death due to erroneously computed radiation dose)

Formal specification — Success stories

- complete formal verification of microprocessor arithmetic (pentium 4, AMD)

Formal specification — Success stories

- complete formal verification of microprocessor arithmetic (pentium 4, AMD)
- NASA uses axiomatic specification of physical units

Formal specification — Success stories

- complete formal verification of microprocessor arithmetic (pentium 4, AMD)
- NASA uses axiomatic specification of physical units
- verification of the Java bytecode verifier

Formal specification — Success stories

- complete formal verification of microprocessor arithmetic (pentium 4, AMD)
- NASA uses axiomatic specification of physical units
- verification of the Java bytecode verifier
- found 12 deadlocks in Occam code for international space station

Axiomatic Specfication

- loose requirements, close to informal descriptions

Axiomatic Specfication

- loose requirements, close to informal descriptions
- clarification of underlying mathematical concepts

Axiomatic Specfication

- loose requirements, close to informal descriptions
- clarification of underlying mathematical concepts
- design of algorithms and data structures independently of any implementation language

Axiomatic Specfication

- loose requirements, close to informal descriptions
- clarification of underlying mathematical concepts
- design of algorithms and data structures independently of any implementation language
- CASL is a standard for axiomatic specification

Waterfall Model (slide by M. Roggenbach)

Requirement Elicitation and Analysis

↑ ↓

Nat Lang. Informal Specification

↑ ↓ Validation

Spec. Lang. Formal Requirements Specification

↑ ↓ "Invent & Verify",

Spec. Lang. Formal Design Specification

↑ ↓ Transformation or

Progr. Lang. Implementation

↑ ↓ Systematic Testing

Test

↑ ↓

Maintenance

Example: sorting

Informal specification:

To sort a list means to find a list with the same elements, which is in ascending order.

Example: sorting

Informal specification:

To sort a list means to find a list with the same elements, which is in ascending order.

Formal requirements specification:

- $is\_ordered(sorter(L))$
- $is\_ordered(L) \Leftrightarrow \forall L1, L2 : List;\ x, y : Elem\ .$
  $L = L1 + +[x, y] + +L2 \Rightarrow x \leq y$
- $permutation(L, sorter(L))$
- $permutation(L1, L2) \Leftrightarrow$
  $\forall x : Elem\ .\ count(x, L1) = count(x, L2)$

Sorting (cont'd)

We want to show insert sort to enjoy these properties.

Formal design specification:

- $insert(x, []) = [x]$
- $insert(x, y :: L) =$
  $x :: y :: L)$ $when$ $x \leq y$
  $else$ $y :: insert(x, L)$
- $insert\_sort([]) = []$
- $insert\_sort(x :: L) = insert(x, insert\_sort(L))$

Implementation (in Haskell)

```
insert :: Ord a => (a,[a]) -> [a]
insert(x,[]) = [x]
insert(x,y:l) = if x <= y then x:y:l
                          else y:insert(x,l)

insert_sort :: Ord a => [a] -> [a]
insert_sort([]) = []
insert_sort(x:l) = insert(x,insert_sort(l))
```

CASL – the Common Algebraic Specification Language

- de facto standard for specification of functional requirements

CASL – the Common Algebraic Specification Language

- de facto standard for specification of functional requirements
- developed by the "Common Framework Initiative" (an open international collaboration)

CASL – the Common Algebraic Specification Language

- de facto standard for specification of functional requirements
- developed by the "Common Framework Initiative" (an open international collaboration)
- approved by IFIP WG 1.3
  "Foundations of Systems Specifications"

CASL – the Common Algebraic Specification Language

- de facto standard for specification of functional requirements
- developed by the "Common Framework Initiative" (an open international collaboration)
- approved by IFIP WG 1.3 "Foundations of Systems Specifications"
- CASL User Manual (Lecture Notes in Computer Science 2900) and Reference Manual (Lecture Notes in Computer Science 2960)

Foundations of CASL

- detailed language summary, with informal explantation

Foundations of CASL

- detailed language summary, with informal explantation
- formal definition of abstract and concrete syntax

Foundations of CASL

- detailed language summary, with informal explantation
- formal definition of abstract and concrete syntax
- complete formal semantics

Foundations of CASL

- detailed language summary, with informal explantation
- formal definition of abstract and concrete syntax
- complete formal semantics
- proof systems

Foundations of CASL

- detailed language summary, with informal explantation
- formal definition of abstract and concrete syntax
- complete formal semantics
- proof systems
- libraries of basic datatypes

Foundations of CASL

- detailed language summary, with informal explantation
- formal definition of abstract and concrete syntax
- complete formal semantics
- proof systems
- libraries of basic datatypes

All this is contained in the Reference Manual
— here, we will largely follow the User Manual

CASL has rock-solid foundations

- the complete formal semantics maps the syntax to underlying mathematical concepts

CASL has rock-solid foundations

- the complete formal semantics maps the syntax to underlying mathematical concepts
- CASL specifications denote classes of models

CASL has rock-solid foundations

- the complete formal semantics maps the syntax to underlying mathematical concepts
- CASL specifications denote classes of models
- The semantics is largely indepdendent of the details of the logic (institution)

CASL has rock-solid foundations

- the complete formal semantics maps the syntax to underlying mathematical concepts
- CASL specifications denote classes of models
- The semantics is largely indepdendent of the details of the logic (institution)
- The semantics is the ultimative reference for the meaning of CASL

CASL on the web

- CASL in general: `http://www.cofi.info`
- CASL tools: `http://www.tzi.de/hets`
- CASL libraries: `http://www.cofi.info/Libraries`

Layers of CASL

CASL consists of several major layers, which are quite independent and may be understood (and used) separately:

Basic specifications many-sorted first-order logic, subsorting, partial functions, induction, datatypes.

Layers of CASL

CASL consists of several major layers, which are quite independent and may be understood (and used) separately:

Basic specifications many-sorted first-order logic, subsorting, partial functions, induction, datatypes.

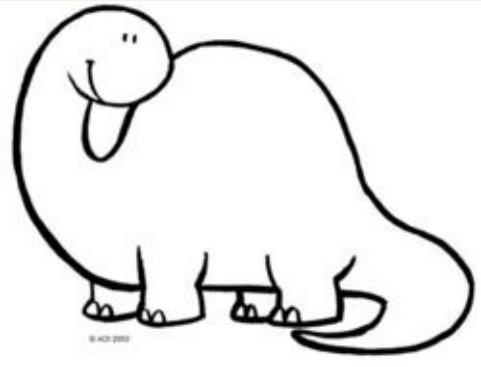
Structured specifications translation, reduction, union, and extension of specifications; generic (parametrized) and named specifications

Why Modular Decomposition?

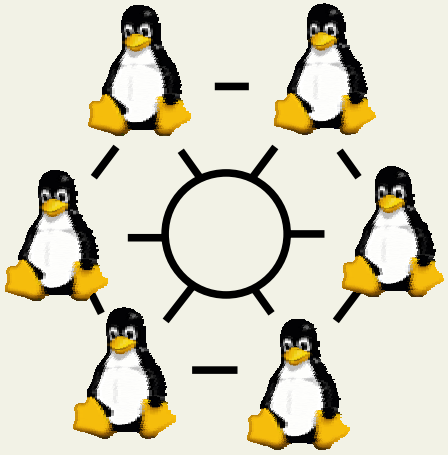
- reduction of complexity
- better understanding of specification and code
  (small pieces, well-defined interfaces)
- better distribution of work

Why Modular Decomposition?

- reduction of complexity
- better understanding of specification and code (small pieces, well-defined interfaces)
- better distribution of work

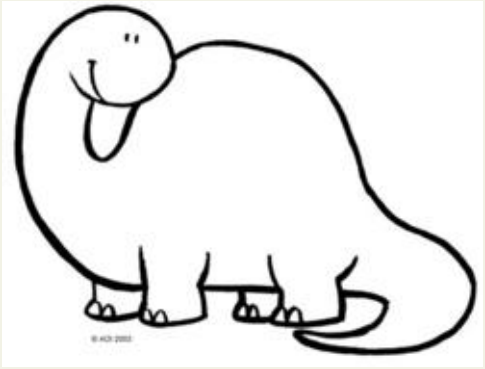


vs.

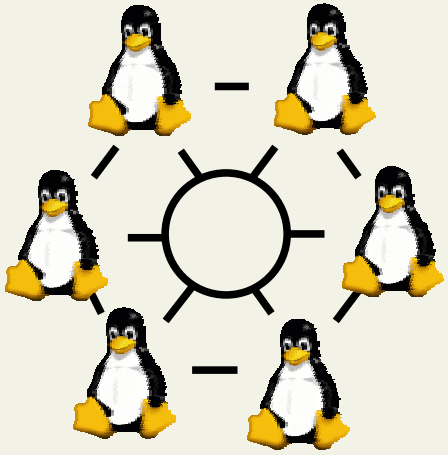


Why Modular Decomposition?

- reduction of complexity
- better understanding of specification and code (small pieces, well-defined interfaces)
- better distribution of work



vs.



- better maintenance and possibilities of re-use

Layers of CASL (cont'd)

Architectural specifications structuring of implementation: define how models of a specification may be constructed out of models of simpler specifications.

Layers of CASL (cont'd)

Architectural specifications structuring of implementation: define how models of a specification may be constructed out of models of simpler specifications.

Libraries allow the distributed (over the Internet) storage and retrieval of (particular versions of) named specifications.

Overview of the course

- recall basics of first-order logic
- loose + free specifications (case study: text formatting)
- CASL tools: Hets and SPASS
- partial functions, subsorting
- generated specifications
- a bit of semantics
- structuring and generic specifications
- architectural specifications
- case studies (invoice system, steam boiler)
- outlook: CASL extensions

Scheinkriterien

- 3 Übungsblätter
- ggf. Fachgespräch
- Modulprüfung möglich

Continue with slides for CASL User Manual (by M. Bidoit and P.D. Mosses)