Teaching Principles of Dependable Distributed Software

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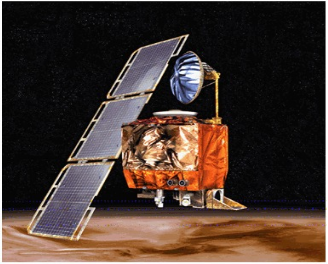
Software – what our everyday life is depending on

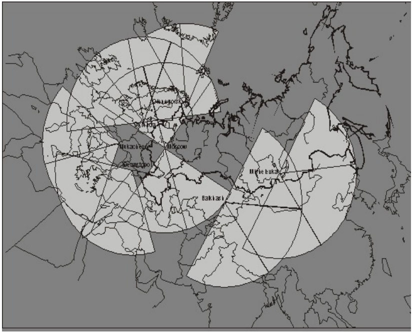
- communication: phone, e-mail, social media
- navigation
- home banking
- healthcare administration, medical devices
- car – in-vechile software: diagnostic, safety, driver assistance
- aircraft – autopilot control system ("Who's really flying the plane?")
- nuclear power plant control system safety software

Infamous software bugs

- The Mars Climate Orbiter doesn't orbit (1998, metric system, $327.6 million)



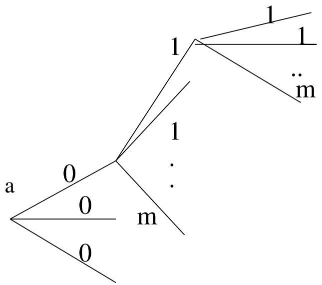
- Call waiting ... and waiting ... and waiting (On Jan. 15, 1990, around 60,000 AT&T custumers, congestion lead to cascade reset of 114 switches)
- Therac-25 Medical Accelerator disaster (1985, race condition, two modes)
- Soviet early-warning system (Sep. 23, 1983, Petrov)



- Nuclear Power Plant shutdown (June 5, 2008, USA, software update in a distributed system)

- Ford in-vechile software failiure - hw. reset at Körösfő (2014)
- Samsung mobile network connection error (2014, flight mode off and on)

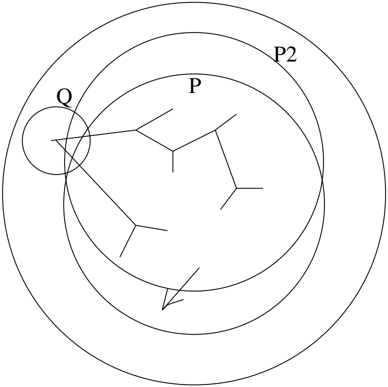
Correctness of Distributed programs



- interleaving, branching time semantics of distributed and parallel programs
- testing of properties, reachable states
- specification of the problem to solve
- static verification, analysis, calculation of reachable states

Always true is not always invariant

- P invariant – P holds initialy and P is preserved (also in unreachable states)
- P2 always true – P2 holds in all reachable states



Only invariants do compose!

Motivation for using formal methods:
- safety critical applications
- safe application of software components
- **primary goal**: sound concepts about distributed and parallel programs

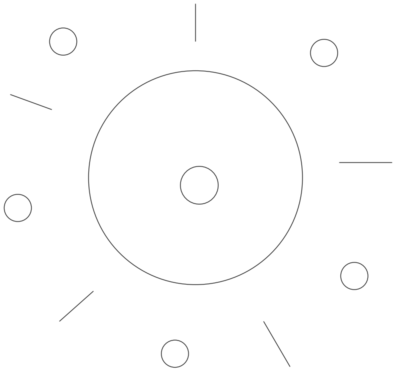
A formal model for precise semantics

We need a formal model, which is appropriate for specification of *problems* and developing the *solutions* of problems in case of *parallel and distributed systems*.

The introduced model

- is an extension of a relational model of nondeterministic sequential programs,
- provides tools for stepwise refinement of problems, in a functional approach,
- uses the concept of iterative abstract program of UNITY,
- the concept of solution is based on the comparison of the problem as a relation and the behaviour relation of the program.

Example problem: the dining philosophers



States: thinking:t, forks in hands:f, eating:e, at home:h, Some requirements (problem specification): $\forall i :$

unless: $f(i).t \rhd f(i).f \vee f(i).h$

unless: $f(i).f \rhd f(i).e$

ensures: $f(i).e \mapsto f(i).t$

inevitable leads-to: $f(i).t \hookrightarrow f(i).h$

invariant: $(f(i).e \rightarrow (\neg f(i+1).e \wedge f(i-1).e)) \in \mathrm{inv}$

fixed point: $\mathrm{FP} \Rightarrow f(i).h$

termination: $\forall i : f(i).t \in \mathrm{TERM}$

Example for abstract program

$$S = (SKIP,$$
$$\{\,\square_{i \in [1..n-1]}\, a(i), a(i+1) := a(i+1), a(i),\ \text{if } a(i) > a(i+1)\})$$

Abstract execution model: No control flow, free processors select atomic assignments asynchronously
Program: scheduling, processes, location, communication infrastructure, language
Example: C++/PVM PC-cluster (Parallel Virtual Machine) / Erlang
Solution: Specification requirements are satisfied by program properties (synthsis and formal verification)

Characteristics of the formal model

- The notion of the state space makes it possible to define the semantical meaning of a problem independently of any program (functional approach).
- The generalized concept of a problem is applicable for cases in which termination is not required but the behaviour of the specified system is restricted by safety and progress properties.
- The solution of a problem may be a sequential program, a parallel one, or even *a program built up from both sequential and parallel components*.
- synthesis of a solution for asynchronous operations (reduce), parallel elemenwise processing (map), solutions based on process networks, pipeline (function composition)

Institute

- Eötvöós Loránd University of Sciences, cca. 30 000 stutents, leading research university of Hungary, 8 facultues
- Faculty of Informatics, cca. 3000 students in CS, in teacher of infromatics, in geoinformatics. Computer Scince program since 1972,
- applications: 40% of the annual budget, leader of EIT ICT Labs node, double degree joinr European masters, strong industrial (joint R&D Labs) and international partnership (e.g. CEEPUS network with Novi Sad, Maribor, Cluj, Ljubljana, Plovdiv)
- Computer Science: 550 + 120 new bachelor students (three specializations) selected from 1200+ applicants, 120+ new master students per year (three specializations), 20+ new PhD students per year, 60+ international students,

Curricula

- 48-60 ECTS mathematics in BSc curricula (depending on specialization item strong specialization in Software Technology (formal model for sequential programming (15 ECTS), 3 semesters of Programming languages (15 ECTS): C++, Ada, functional programming, Software engineering, Object oriented programming, etc.),
- Software Technology Lab: R&D projects are part of master program (16+20 ECTS), 6 projects with cca. 70 master students in teams,
- design of parallel and distributed software both at bacshelor and at master level: theory, practice, programming assignments, computer lab tests, oral exams.

Parallelism and Functional Programming

- Sparkle-T - proof tool for temporal properties (e.g. invariants) of Clean programs - with Máté Tejfel and Tamás Kozsik
- DClean - a coordination language for type safe distributed cooperation of Clean programs - with Viktória Zsók, Zoltán Hernyák
- Static analysis - to support code comprehension at industrial level in Erlang - with Melinda Tóth, István Bozó and others
- Paraphrase - property preserving transformations of Erlang programs to enable parallel multicore execution - with Tamás Kozsik, Melinda Tóth, István Bozó, Judit Kőszegi, Dániel Horpácsi, Viktória Fördős and others
- DSL - functional programming for CPS - Rea language (based on Erlang and on Sacla)