A *Formal Methods* Approach Towards Trustworthy Global Computing

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Ist. di Scienza e Tecnologie dell'Informazione "A. Faedo"
Formal Methods && Tools Lab

Bridging Global Computing with Grid
November 28-29, 2006

Tribute

Many concepts and ideas presented here are based on results on formal modeling and analysis of stochastic aspects of system behaviour achieved in the last few years by many colleagues and friends, a.o.:

- C. Baier et al. (Tec. Univ. of Dresden, D);
- M. Bernardo et al. (Univ. of Urbino, IT);
- R. Gorrieri et al. (Univ. of Bologna, IT);
- B. Haverkort et al. (Univ. of Twente, NL);
- H. Hermanns (Univ. of Saarbruecken, D);
- J. Hillston et al. (Univ. of Edinburg, UK);
- J.P. Katoen et al. (Univ. of Aachen, D);
- M. Kwiatkowska et al. (Univ. of Birmingham, UK);
- . . . and many others!

AGILE and SENSORIA

The focus on GC and SOC is the subject of cooperative work in the context of the EU Projects

AGILE and SENSORIA

Many thanks to:

- R. De Nicola (Univ. Firenze)
- J. P. Katoen (Univ. Aachen)
- M. Loreti (Univ. Firenze)
- M. Massink (CNR/ISTI, Pisa)

Outline

1. Background;

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2. Challenges;

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3. (Approaches to) Solutions and Opportunities;

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4. Open Issues;

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Attempt to provide the (software) engineer with "concepts and techniques as thinking tools, which are clean, adequate, and convenient, to support him (or her) in describing, reasoning about, and constructing complex software and hardware systems"

[W. Thomas 2000]

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$$\text{Applying} \left\{ \frac{\text{Logic in}}{\text{Theoretical}} \right\} \text{Computer Science}$$

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For Supporting System Engineering

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- classical issues like completeness.

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Bill Gates, April 18, 2002.
Keynote address at WinHEC 2002

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  based on the solid framework of Mathematical Logic and equipped with efficient decision procedures (e.g. stochastic model-checkers)

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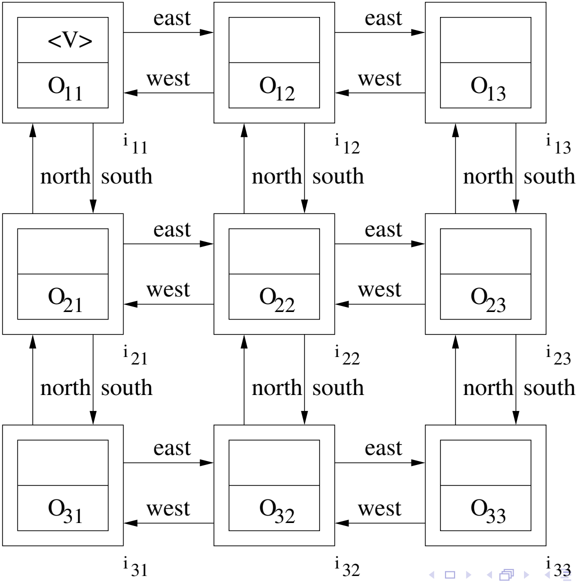
  - Uncertainty on operation execution times and/or possible choices by means of random variables and weights/probabilities (partial/approx. knowledge, performance/dependability analysis)



<V>
O11
O12
O13
O21
O22
O23
O31
O32
O33
east
west
north
south
i11
i12
i13
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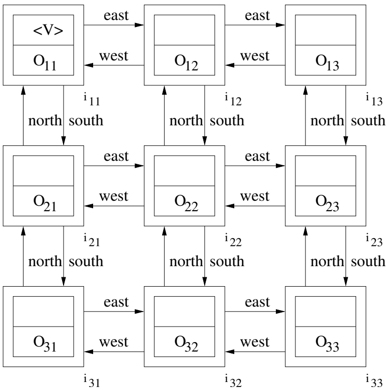
i22
i23
i31
i32
i33



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east
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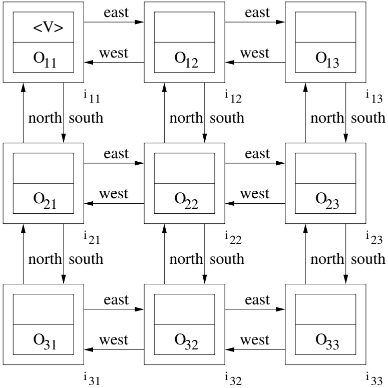
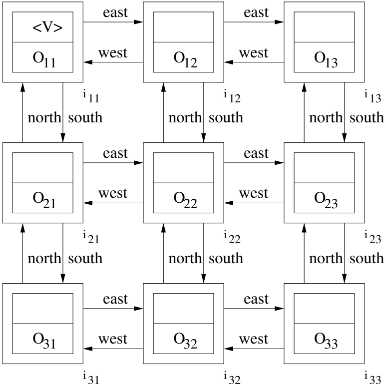
i_{31}
i_{32}
i_{33}



$$V \triangleq ((\mathbf{out}(V)@\mathit{north}, rn).\mathbf{nil}) + ((\mathbf{out}(V)@\mathit{south}, rs).\mathbf{nil}) + ((\mathbf{out}(V)@\mathit{east}, re).\mathbf{nil}) + ((\mathbf{out}(V)@\mathit{west}, rw).\mathbf{nil})$$

Challenges, Solutions & Opportunities: Rigorous modeling



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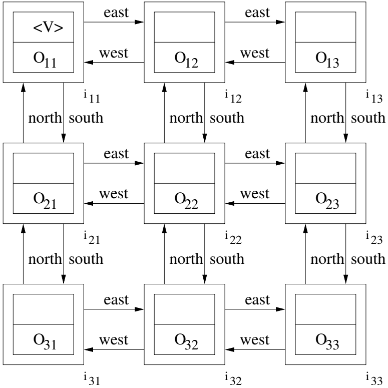
$$O_{jk} \triangleq ((\mathbf{in}(!X)@\mathrm{self}, d_{jk}).O_{jk}) + ((\mathbf{in}(!X)@\mathrm{self}, u_{jk}).(\mathbf{eval}(X)@\mathrm{self}, r_{jk}).O_{jk})$$

Challenges, Solutions & Opportunities: Rigorous modeling



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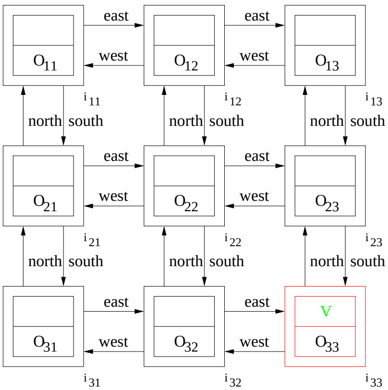
$$i_{11} ::_{\rho_{11}} \langle V \rangle \parallel \left(\big\|_{\substack{1 \leq j \leq 3 \\ 1 \leq k \leq 3}} i_{jk} ::_{\rho_{jk}} O_{jk} \right)$$

Challenges, Solutions & Opportunities: Rigorous reasoning



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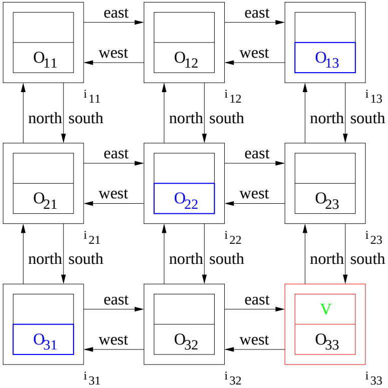

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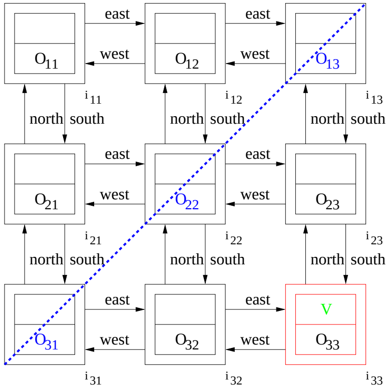

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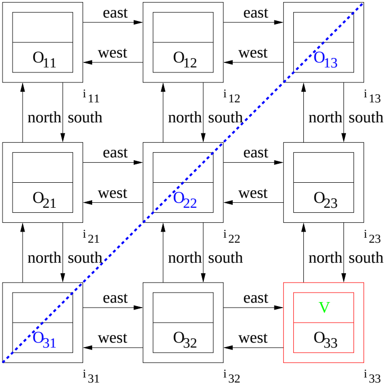
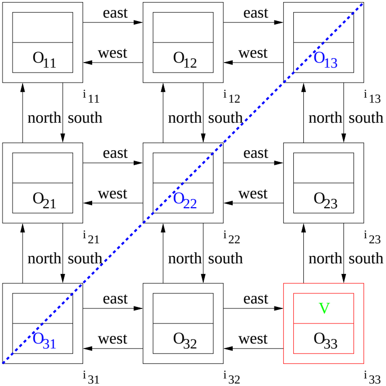


The probability is less then 0.2 that the infection develops (i.e. the virus is running) at site i_{33} by time t, assuming that at time 0 the only site infected is (i.e. the virus is stored at) i_{11}.



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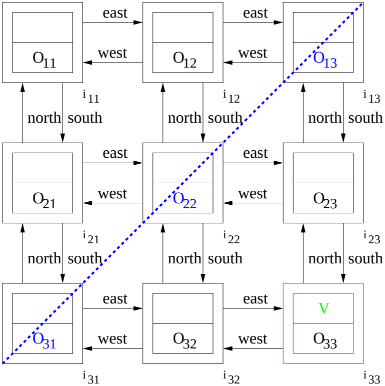

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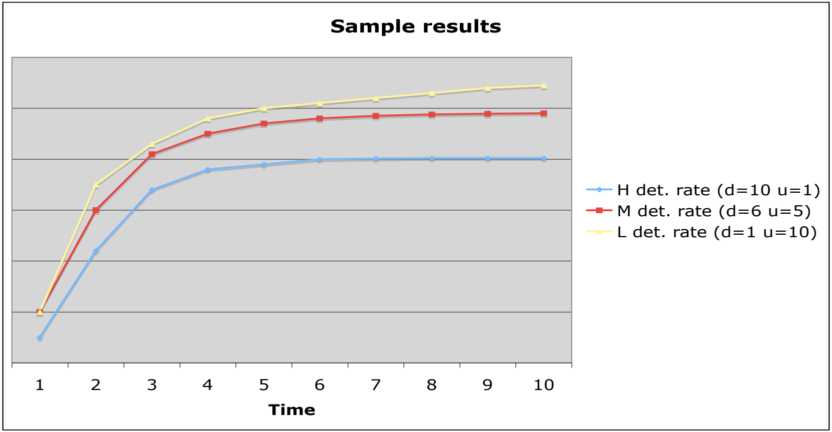
Sample results
1
2
3
4
5
6
7
8
9
10
Time
H det. rate (d=10 u=1)
M det. rate (d=6 u=5)
L det. rate (d=1 u=10)

Logical characterization (and automatic verification) of

Steady State Probability measures

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Challenges, Solutions & Opportunities: Rigorous reasoning

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P could be a malicious (or faulty) process: the formula would characterize the average fraction of time the infection (or faulty component) is active at site i.

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$$\mathcal{P} \quad (\qquad\qquad)$$

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Challenges, Solutions & Opportunities: Rigorous reasoning

Transient probability measures

The probability is at least 0.8 that the system is *not* down at time t

$$\mathcal{P}_{>0.8}(\ \Diamond^{t}\ \neg\, down)$$

Instantaneous availability at time t.

More general path-based measures

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$$\mathcal{P}_{<0.01}(\neg alarm\ \ \mathcal{U}^{<t}\ down)$$

Nested measures

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In equilibrium, the probability is

$$\mathcal{S} \quad (\qquad\qquad\qquad\qquad)$$

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Challenges, Solutions & Opportunities: Rigorous reasoning

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In equilibrium, the probability is at least 0.87, that in at least 75% of the cases the system will have resumed within 500 time units

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Functional and non functional issues of behaviour integrated in the same description language

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[SOFTWARE 2015: A NATIONAL SOFTWARE STRATEGY TO ENSURE U.S. SECURITY AND COMPETITIVENESS.
Report of the 2nd NSS - av. at www.cnsoftware.org]