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Reflections on 10 Years of Software Process Simulation Modeling: A Systematic Review

- *International Conference on Software Process 2008*



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Outline



- Background
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- Method
- Results
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- Conclusion
- Limitations and future work



- SPSM and ProSim: a brief history

- Software process modeling and simulation (SPSM) was introduced into the software engineering by Abdel-Hamid and Madnick's pioneering work.
- ProSim workshop series has taken place since 1998, and focuses on the state-of-the-art theories and applications of SPSM research.
- Kellner, Madachy, and Raffo's (KMR) seminal paper "*Software process simulation modeling: Why? What? How?*" published in ProSim'98.
- ProSim workshop was conjunct with SPW in 2006, and continued as a special track of ICSP since 2007.



- Motivation

- KMR's paper discussed a variety of aspects of software process simulation, such as purposes, paradigms, and scopes of SPSM.
- The arguments of KMR's paper were mainly derived from the publications in ProSim'98 and prior literature in a less formal approach.
- It is appropriate to review and update the state-of-the-art of SPSM research after 10 years progress in support of our future research.
- This paper reports the preliminary results of a systematic literature review of the publications associated with ProSim since 1998.
- As part of a larger study, this paper also partially serves as the latest continuation and enhancement to the topics discussed in KMR's paper.

- Systematic Literature Review
 - Evidence-based software engineering (EBSE) aims to apply an evidence-based approach to software engineering research and practice.
 - A systematic literature review (SLR) is the main method of synthesis for supporting EBSE.
 - SLR is a means for identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest.
 - SLR is a form of *secondary study*, the identified individual studies contributing to a review called *primary studies*.
 - Three phases: *planning the review*, *conducting the review*, and *reporting the review*.

- Research guideline:
 - This study follows Kitchenham’s methodological guidelines for systematic literature reviews.
- Participants:
 - 3 individuals: one principal reviewer, one secondary reviewer, plus one researcher as expert panel.
- Two review stages:
 - ① Studies published in ProSim series proceedings and journals.
 - ② Studies published outside ProSim.
 - This paper reports the review process and the preliminary results from Stage 1.

Method – research questions



- ① Q1: What are the purposes or motivations of SPSM in the last decade's practice? Q1.1 How are the purposes identified by KMR supported by SPSM practice? Q1.2 Are any updates required?
- ② Q2: What simulation paradigms have been applied in the last decade, and how popular are they? Are there any new paradigms emerging?
- ③ Q3: What simulation tools are available for SPSM and have been in use in the last decade? And how popular are they?
- ④ Q4: On model level, what are problem domains and model scopes focused on by software process simulation models?
- ⑤ Q5: On parameter level, what are the output variables of interest when developing software process simulation models of software process?
- ⑥ Q6: Which simulation paradigm is most appropriate for a specific SPSM purpose and scope?

- Search sources:

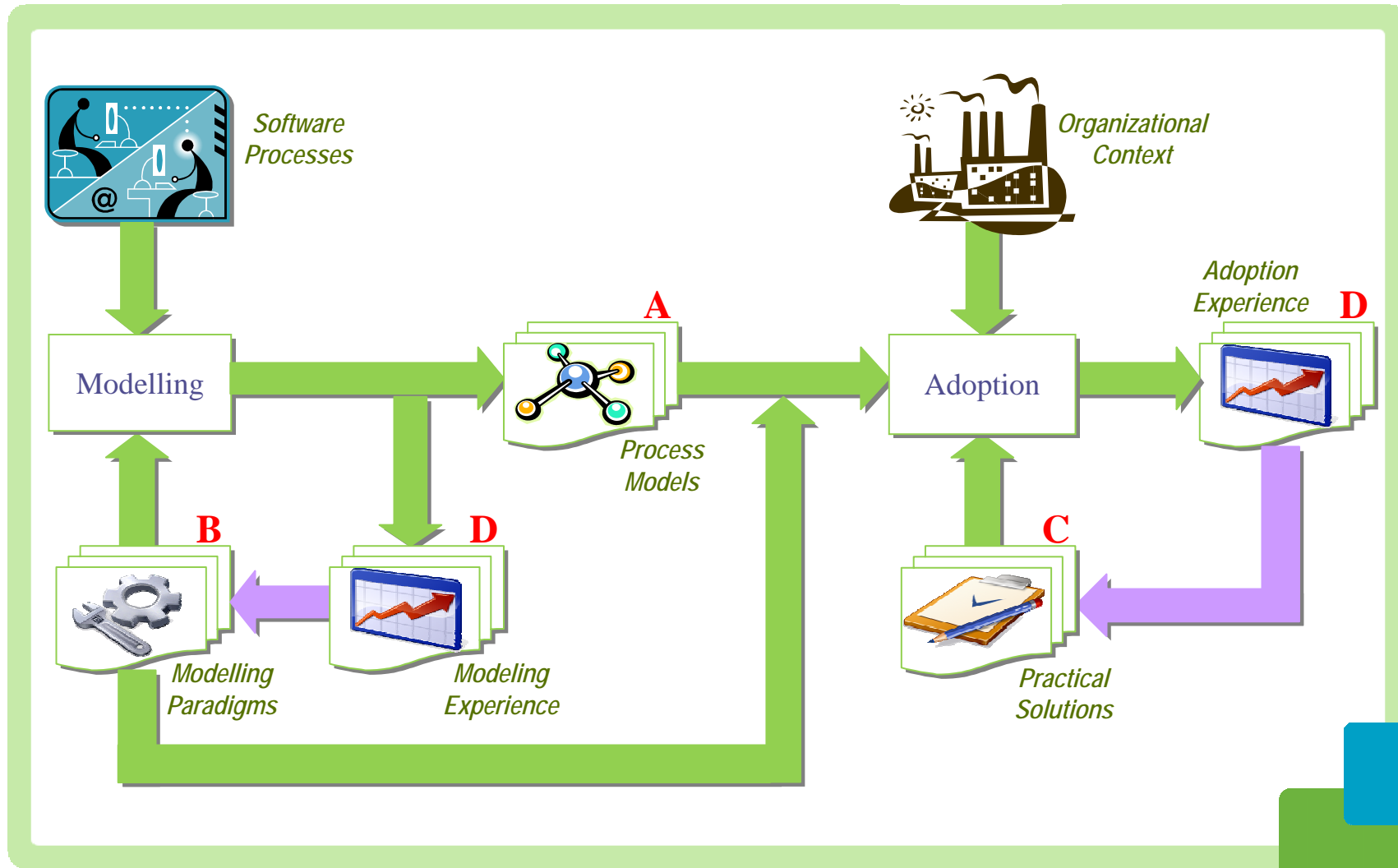
Source	Acronym	Period	Search method
The proceedings of ProSim workshop	ProSim	1998 - 2006	Manual
The proceedings of ICSP conference	ICSP	2007	Manual
Journal of Systems and Software	JSS	1999 - 2001	Manual
Software Process Improvement and Practice	SPIP	2000 - 2007	Manual

- Selection criteria:

- “*Software process*” + “*simulation modeling*”: the software process model or modeling in the publications can be used for simulation-based studies.
- Initial selection by reviewing *title, abstract, keywords, paper’s structure, conclusion, and important references* of the publications.
- Final selection by excluding *editorials, position papers, keynotes, abstracts, posters, slides, and duplicated papers*.

- Study categories identified in the pilot review:
 - A* Software process simulation models or simulators;
 - B* Process simulation modeling paradigms, methodologies, and environments;
 - C* Applications, guidelines, and frameworks of adopting process simulation in software engineering practice;
 - D* Experience reports of SPSM research and practice.
- The categorization is not mutually exclusive, i.e. it is possible that a specific study falls into more than one category.

Method – study classification



Method – quality assessment



- 20 questions for assessing study quality

Question	Score	Question	Score
Common questions (for all categories)		Questions for Category B and C	
Did the study clearly state the aims/research questions?	y/p/n	Are the scopes of the method/paradigm/solution clearly defined?	y/p/n
Did the study review the related work for the problem?	y/p/n	Are the modeling approach/method/environment clearly defined?	y/p/n
Did the study discuss related issues, and compare with the alternatives?	y/p/n	Are the problems that the study addresses defined with appropriate SE examples?	y/p/n
Did the study recommend the further continuous research?	y/p/n	Did the study specify the limitations of the argued paradigm/method/solution?	y/p/n
Questions for Category A		Did the empirical evidence included support the arguments of the study?	y/p/n
Are the model's assumptions explained explicitly?	y/p/n	Questions for Category D	
Is the model construction fully described?	y/p/n	Can the experience be used for validating and calibrating simulation model/modeling?	y/p/n
Did the study explain why choosing the applied simulation paradigm(s)?	y/p/n	Are the best practices or lessons learnt extracted from experience?	y/p/n
Are the conditions when the model adoption explained?	y/p/n		
Did the study avoid any selection bias exist during experiment design?	y/p/n		
Has the model been trialed on an industry scale problem?	y/p/n		
Did the study carry out a sensitivity or residual analysis?	y/p/n		
Are any model evaluation methods applied on the model?	y/p/n		
Does the study interpret the findings?	y/p/n		

- 14 attributes for extracting data
 - **Common** attributes: modeling purpose(s) and paradigm(s);
 - Attributes for Category **A**: problem domain, simulation tool, output variable(s), model complexity (module number) and scope;
 - Attributes for Category **B**: study's theme;
 - Attributes for Category **C**: focused questions and proposed solution;
 - Attributes for Category **D**: experience source, outcome of applying SPSM, and supported arguments.

Results – primary studies



- Primary studies: 96 studies out of 209 papers

	1998	1999	2000	2002	2003	2004	2005	2006	2007	Total
Proceedings	15	13	21	0	32	27	24	8	8	148
<i>Missing</i>	<i>2</i>	<i>1</i>	<i>6</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>9</i>
JSS	11	0	12	0	0	0	0	0	0	23
SPIP	0	10	0	7	5	7	7	2	0	38
Selected	13	9	14	7	16	10	13	6	8	96

- Study distribution: over years and countries

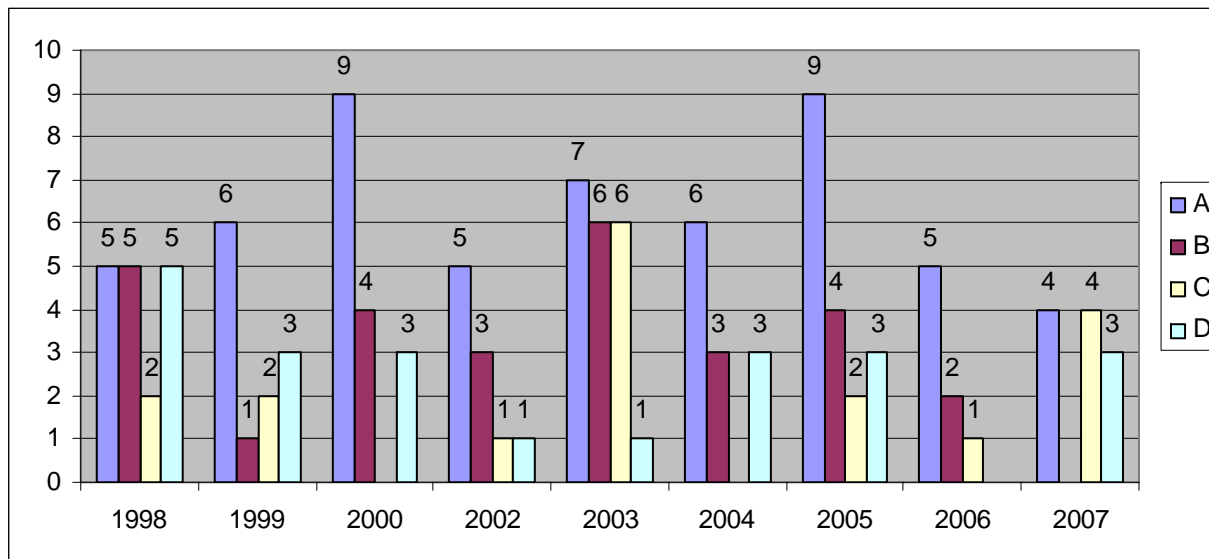
	1998	1999	2000	2002	2003	2004	2005	2006	2007	Total
Number of Country	3	3	7	5	5	5	6	4	6	13

- USA (49%) is the leading country of SPSM research in terms of ProSim publications, followed by Germany (18%) and UK (17%).

Results - classification

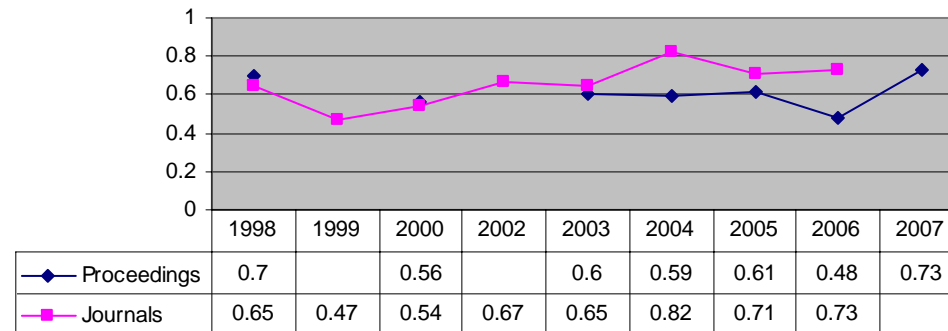


- Study classification over years



- Studies were identified as Category A (58%), B (29%), C (19%) and D (23%).
- 25 studies fall into more than one category.

- Study quality over years



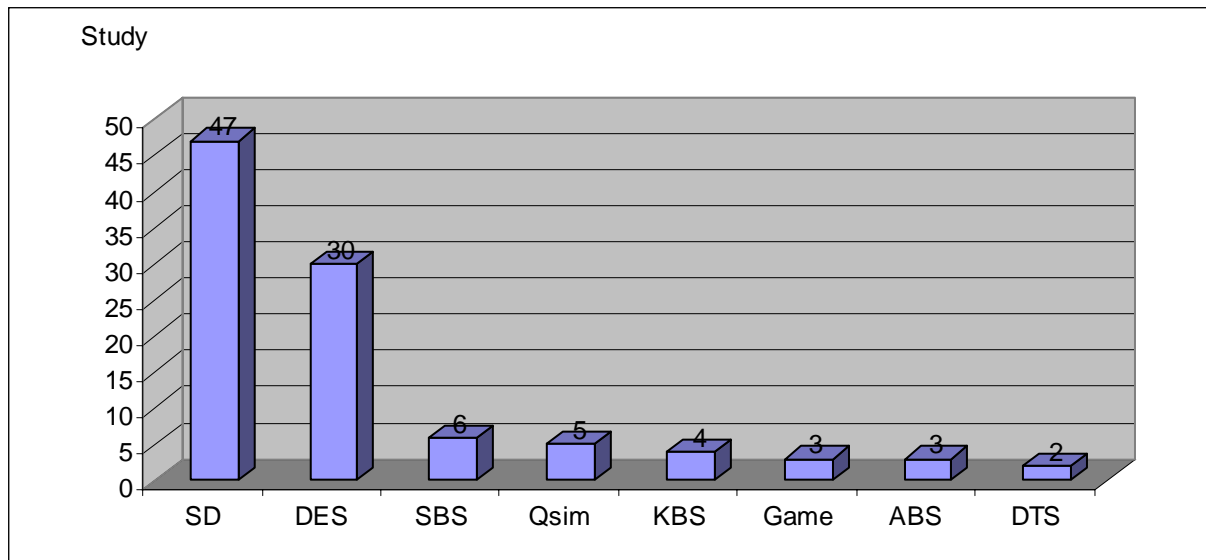
- In most cases, the quality of journal articles was better than the papers in the proceedings of the same year.
- Many Category A studies failed to explicitly address the conditions of model/simulator adoption.
- The limitations of the paradigm/method/solution were rarely discussed in Category B and C studies.

- Limitations of KMR's paper:
 - Ambiguity in purpose categorization, e.g. *“strategic management”*.
 - The purposes identified were based on a small number of examples published by 1998 (ProSim'98).
 - The research and underpinning arguments were not based on a systematic and rigorous review methodology, like the systematic literature review.
- 10 purposes for SPSM grouped into 3 levels:
 - **Cognitive level:** 1) *understanding*, 2) *communication*, 3) *process investigation*, 4) *training and learning*.
 - **Tactical and Strategic level:** 5) *prediction and planning*, 6) *control and operational management*, 7) *risk management*, 8) *process improvement*, 9) *technology adoption*, 10) *tradeoff analysis and optimizing*.

Discussion – paradigms (Q2)



- 10 simulation paradigms were found in review:



- System dynamics (SD, 49%) and Discrete-event simulation (DES, 31%) were the most widely used techniques in SPSM.
- Most of studies (10 papers) presenting the hybrid simulation focus on the combination of continuous (SD) and discrete-event simulation (DES).

Discussion – tools (Q3)



- 13 simulation tools (with number of applications):

<i>Vensim</i>	<i>Extend</i>	<i>iThink</i>	<i>QSIM</i>	<i>Netlogo</i>	<i>Repast</i>	<i>DSOL</i>
12	11	3	2	1	1	1
<i>Small-talk</i>	<i>DEVSIM++</i>	<i>DEVSJava</i>	<i>QNAP2</i>	<i>PML</i>	<i>SESAM</i>	
1	1	1	1	1	1	

- Some Category A studies did not explicitly mention the simulation tool applied.
- Vensim™ is the most popular tool for continuous simulation.
- Extend™ has been the first choice for discrete-event and hybrid modelers.

Discussion – domains & scopes (Q4)



	<i>single phase</i>	<i>multi-phase</i>	<i>project</i>	<i>multi-project</i>	<i>Product life cycle</i>	<i>evolution</i>	<i>long-term organization</i>	<i>unknown or N/A</i>	<i>Total</i>
generic development			9					1	10
SW evolution			1			7			8
SPI	1	1					1	3	6
requirement	2		1			1		1	5
incremental development	1	2	1					1	5
open-source SD	1			1		2			4
global SD			1			3			4
SW economics	1		1		1				3
SW product-line					1		1		2
agile development			1					1	2
QA		1						1	2
acquisition/outsourcing		1						1	2
SE education			2						2
SW testing	1								1
SW design	1								1
SW services					1				1
productivity analysis			1						1
SD risk mgmt			1						1
SW reliability								1	1
Subtotal	7	5	19	1	2	8	2	9	

- Conclusion
 - Categories for classifying software process models as suggested in ProSim'98 should be adjusted and refined to better capture the diversity of published studies.
 - Research improving the efficiency of SPSM is gaining importance.
 - Hybrid process simulation models have attracted interest as a possibility to more realistically capture complex real-world software processes.
 - It produced the continuation and enhancement to KMR's seminal paper.
 - The review results can help both insiders' and outsiders' understanding of the state-of-the-art of SPSM research.
 - The identified primary studies and study categorization can be used for future systematic review and meta-analysis with more specific focuses.

- Limitations

- The current process recommended for PhD candidates is not as rigorous as that adopted by multiple-researchers.
- The study categorization was mainly determined by the principal reviewer's judgment, which needs further examination.
- The missing papers may influence the integrity of this review and need to be included in the near future.

- Future work

- To perform a more detailed analysis of the studies of categories B, C and D, and an investigation of the issues raised by research questions (Q5/Q6).
- To extend our systematic review to include studies outside of the ProSim sources (Stage 2).

Questions



Thank you!

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