32. Different Types of Research Papers in Software Engineering

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http://st.inf.tu-dresden.de/teaching/acse

1) Shaw's classification of Hypothesis and Questions
2) Types of papers

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Obligatory Literature

- [Shaw-Research] Mary Shaw. What makes good research in software engineering? Int. Journal of Software Tools for Technology Transfer (STTT), 4(1):1-7, 2002.
- [Shaw-ETAPS02] Mary Shaw. Slide set of key note at ETAPS 2002. Good summary of [Shaw-Research]
- [Gonzalez] Fabio A. Gonzalez. Writing a Research Paper Depto. de Ing. de Sistemas e Industrial Universidad Nacional de Colombia, Bogota

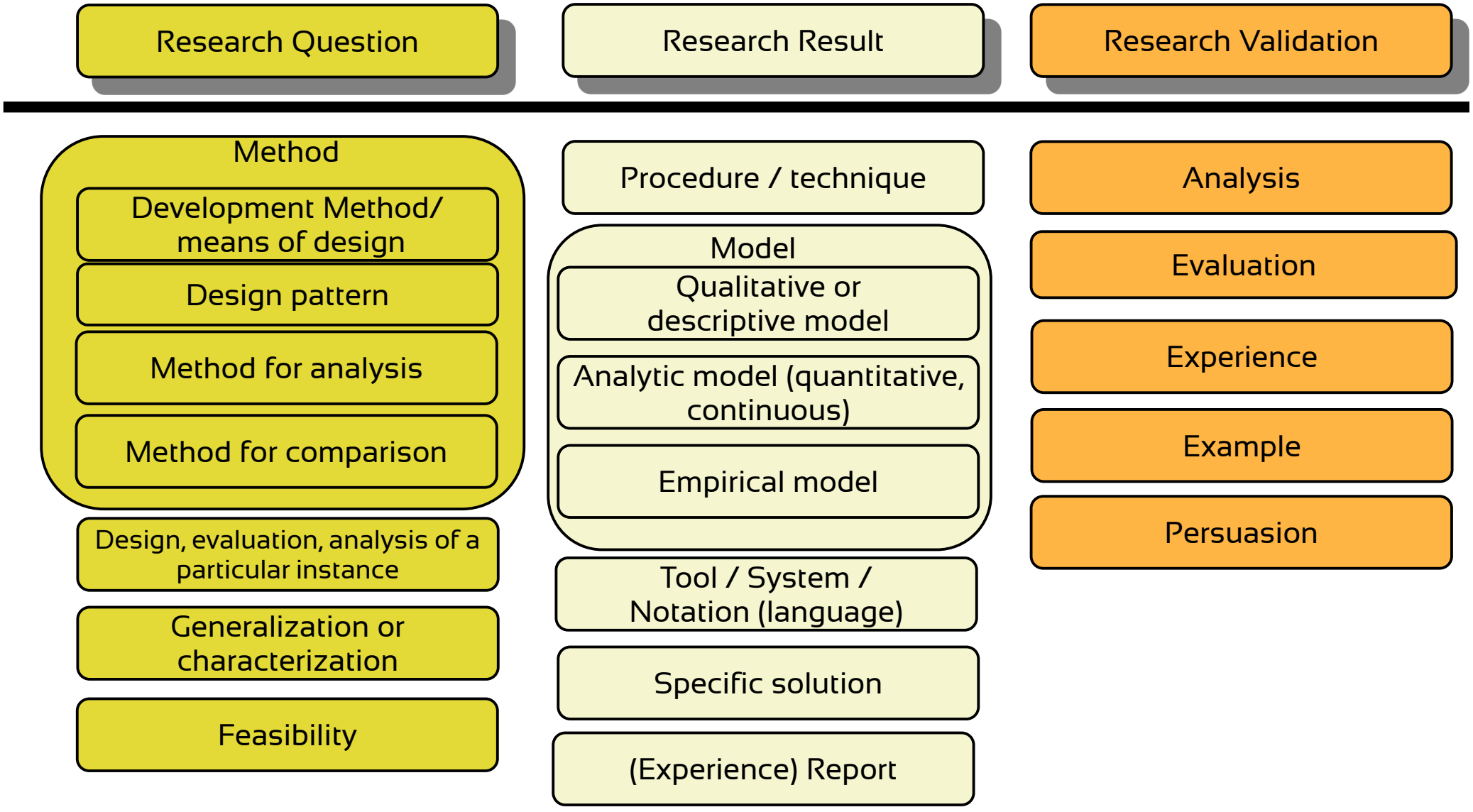
References

- Dieter Rombach. Klaus Endres. A Handbook of Software and Systems Engineering. Addison-Wesley.
- [Xu-Nygard] Dianxiang Xu and Kendall E. Nygard. Threat-driven modeling and verification of secure software using aspect-oriented petri nets. IEEE Trans. Software Eng, 32(4):265-278, 2006.

32.1 Shaw's Classification of Research Hypotheses in Software Engineering

.. and how to make more template abstracts out of the classes

Shaw's Original Facet Classification



Research Questions

Type of Question		Examples of Research Questions
New Development Method or means of development		How can we do/create (or automate doing) X? Is there a best practice how to do X? A design pattern?
	Optimized Development Method	What is a better way to do/create X?
Method for analysis		How can I evaluate the quality/efficiency/correctness of X? How do I choose between X and Y?
	Method for comparison	How do I systematically compare between X and Y? What are the criteria for comparison and contrast?
Design, evaluation, or analysis of a particular instance		What is a (better) design or implementation for application X? What is property X of artifact/method Y? How does X compare to Y? What is the current state of X / practice of Y?
Generalization or characterization		Given X, what will Y (necessarily) be? What, exactly, do we mean by X? What are the important characteristics of X? What is a good formal/empirical model for X? What are the varieties of X, how are they related?
	Advantages of classifications	Investigate the special features of all classes of a classification. Find criteria to test membership in these classes and then apply the special features. Example: AG hierarchy, XGRS classes
Feasibility		Does X even exist, and if so what is it like? Is it possible to accomplish X at all?

Research Results

Types of Research Results		**Example of Research Result**
Procedure / Technique / Process		New/better ways to do development/analysis tasks
Model	Qualitative or descriptive model	Structure/taxonomy/ontology for problem area; framework Informal guidance, informal domain analysis
	Analytic model	Structural model that permits formal analysis, automation
	Empirical model	Empirical predictive models based on real data
Tool / System		Tool that embodies model or technique
Notation (language)		New language with better X. Ex.: Gradual typing;
Specific solution		Solution to application problem applying SE principles, or result of specific analysis
(Experience) Report		Interesting observations, rules of thumb, heuristics best practices, case studies, industrial case studies
Theorem		New theorem in an existing model. Ex: Register allocation with graph cliques is polynomial (complexity), equivalence

Research Validation (Evaluation)

Type of validation		**Examples of Phrases**
Analysis		I have analyzed my result and find it satisfactory through … •for a empirical model: ..data on controlled use •for a controlled experiment: ...a carefully designed statistical experiment
	Experience	My result has been used on real examples by someone other than me, and the evidence of its correctness / usefulness / effectiveness is … •for a qualitative model: ….narrative •for a empirical model, tool: … some data, usually statistical, on practice •for a notation, technique: … a comparison of this with similar results in actual use
	Example	Here's an example of how it works on... •for a toy example: perhaps motivated by reality •for a slice of life: a system that I have been developing
	Evaluation	Given the stated criteria, my result... •for a descriptive model: .. adequately describes the phenomena of interest •for a qualitative model: ...accounts for the phenomena of interest... •for an empirical model: ...is able to predict ... because ..., or ... gives results that fit real data … Includes feasibility studies, pilot projects
Persuasion		I thought hard about this, and I believe that... •for a technique: ..if you do it the following way... •for a system: ... a system constructed like this would... •for a model: … this model seems reasonable... •for feasibility: … my working system is persuasive, even without analysis
Blatant assertion		No serious attempt to evaluate result

32.2 Types of Papers based on the Shaw Facets

32.2.1 Problem Analysis Papers

Problem-Objective Analysis Papers

- Use ZOPP, B-POPP, GQM, AO-PA, etc. to analyze the problems and goals of
  - a stakeholder
  - a domain
  - a method
- Define success factors for possible future solutions
- Indicate how solutions could look like

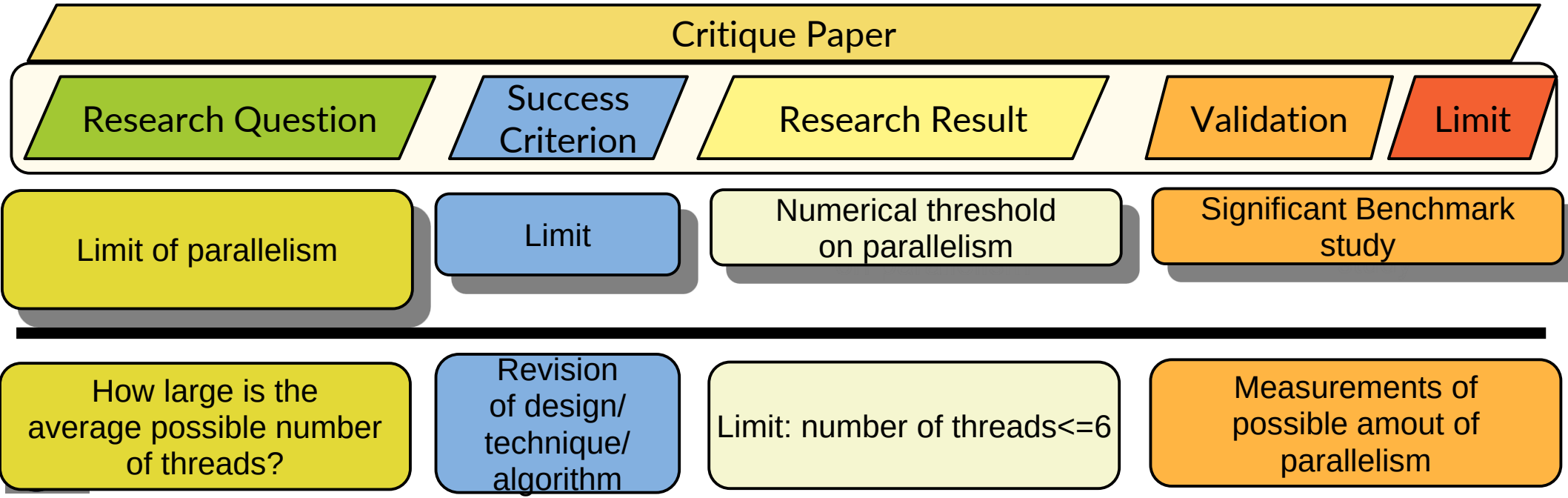
Critique Paper (Limitation Paper, Technical Problems Paper)

A critique paper contains an analysis

- why another approach is **deficient**,
  - e.g., Bug in proof found
- why it has its limits,
  - limits were not mentioned
  - limits were newly found
- why a paper used **unrealistic assumptions**
  - why an idealized research result does not work in practice
  - Invalid assumptions (invalid warrant)
  - why a paper should have used a qualifier, but didn't
- Why a technique is not **useful** or **relevant**
  - E. W. Dijkstra. Goto statement considered harmful. Communications of the ACM, 11:147-, 1968. Final judgement on unstructured programming in C and C++.
  - Per Brinch Hansen. Java's Insecure Parallelism. ACM SIGPLAN Notices, 34 (4):8, April 1999. Brinch Hansen's condemnation of Java, based on his background on monitors:
  - Per Brinch Hansen. Monitors and Concurrent Pascal: a personal history. ACM SIGPLAN Notices, 28(3):1-35, March 1993.

Critique Paper (Limitation Paper, Technical Problems Paper)

- In a well-known approach, you have identified a **technical problem**
  - a deficiency | a limit | a prerequisite or precondition
  - In your paper, you cure the technical problem, remove the limit, generalize the preconditions
- **Limit discussion:** discuss the limits of the well-known technology.
  - D. W. Wall. Limits of instruction-level parallelism. In Conference on Architectural Support of Operating Systems IV, pages 176-188. ACM, 1991.
  - Wall's paper showed that on instruction level, many programs have only up to 6 threads, which limits parallelism



32.2.2 Teaching Papers

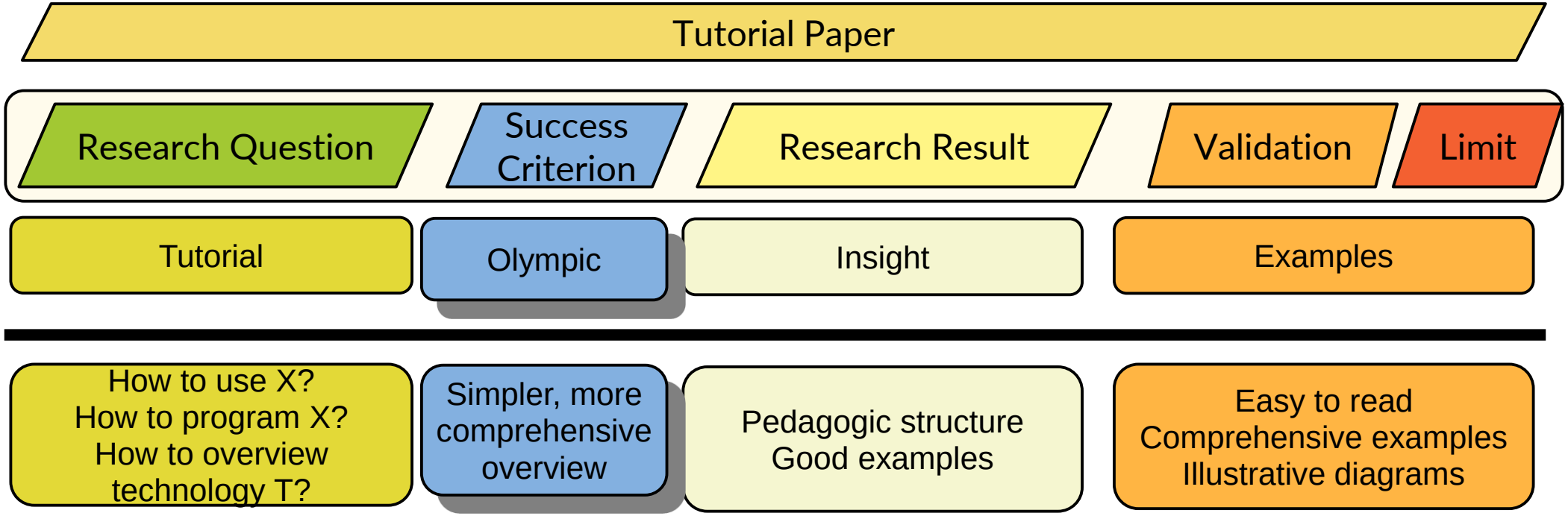
- A new language may solve some problems easier than another existing one

Tutorial Paper

- A good **tutorial paper** contains:
  - A set of running examples
  - Bottom-up explanation of concepts and ideas
  - Precise definitions of concepts
  - Classifications of concepts
  - Illustrative figures
  - Some theorems (idealistic research)
  - or case studies (practical research)
- Examples:
  - Markus Müller-Olm, David Schmidt, Bernhard Steffen. Model-Checking. A Tutorial Introduction. Springer LNCS, Volume 1694, 1999, p 848ff
    - http://www.springerlink.com/content/l437dulbgk67jl6m/
  - [BW04] Timed Automata: Semantics, Algorithms and Tools, Johan Bengtsson and Wang Yi. In Lecture Notes on Concurrency and Petri Nets. W. Reisig and G. Rozenberg (eds.), LNCS 3098, Springer-Verlag, 2004
    - http://www.it.uu.se/research/group/darts/papers/texts/by-lncs04.ps

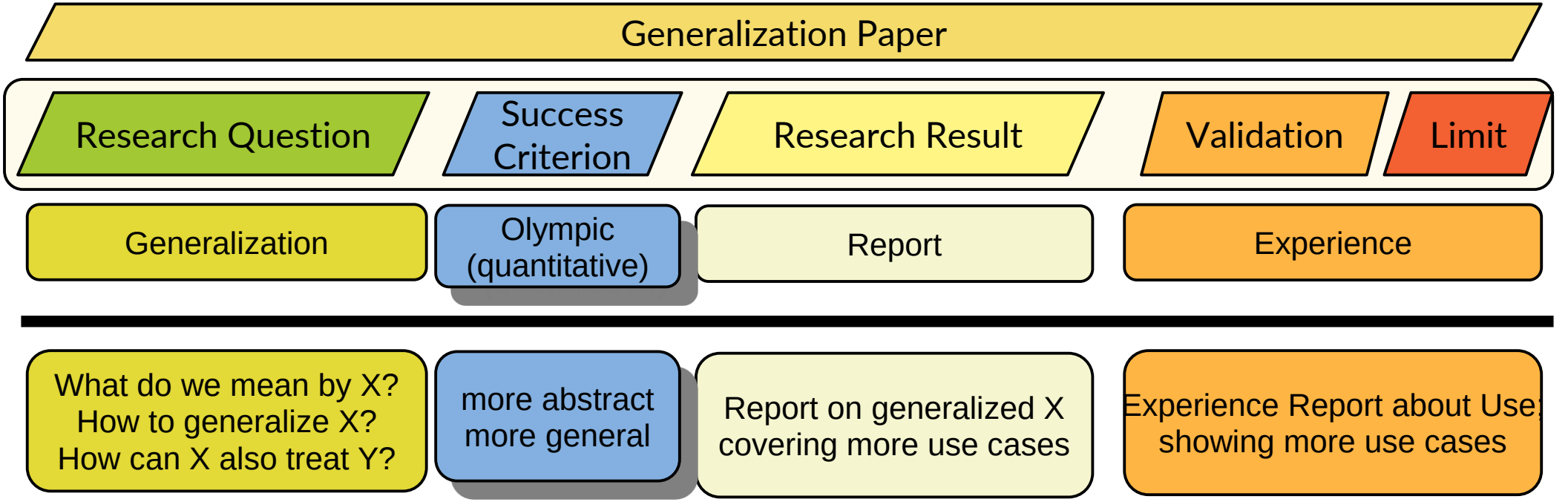
Tutorial Paper

- Speeds up comprehension



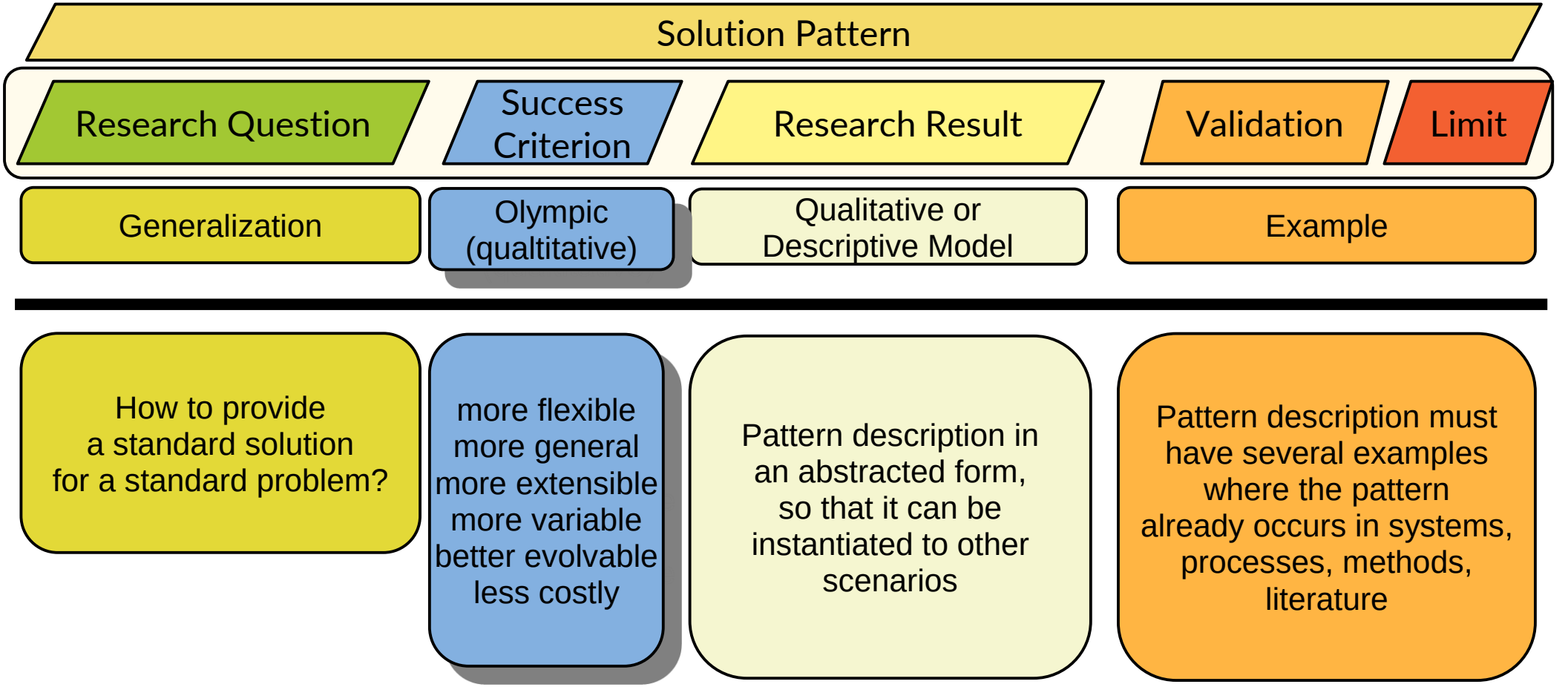
Generalization Paper, Based on Experience

- A **generalization paper** introduces a more general technique, or generalizes or abstracts several other techniques
- Difficult to write



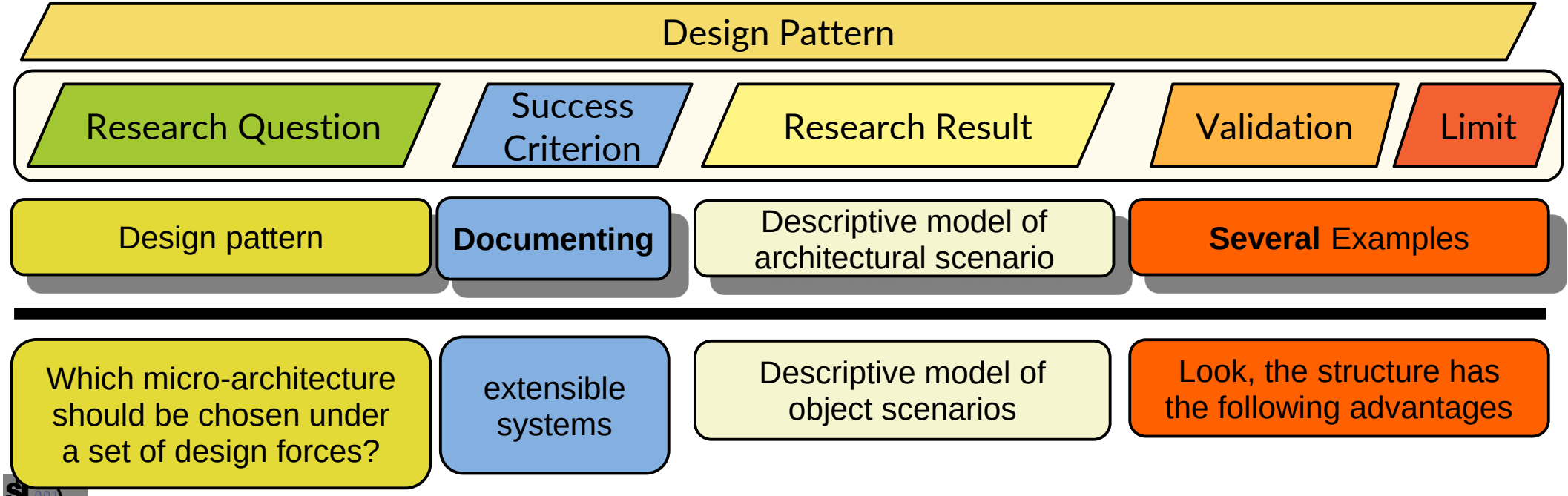
“Solution Pattern” Paper: Special form of Generalization Paper

- How can I solve a standard problem in a specific context with a standard solution?
  - Process patterns, organizational patterns, anti-patterns, ...
  - See course “Design Patterns and Frameworks”



Design Pattern Papers

- Design papers need to discuss well-known *design* solutions for well-known problems
  - The criteria of a pattern catalogue (e.g., Gamma)
  - The forces under which they apply
  - Solution patterns
- The research hypothesis is "**documenting**" because a design pattern should not be new, but well-experienced
  - There must be several examples, because the pattern must be well-experienced



32.2.3 Typical Structures of POSE Papers

[Gonzalez] Paper Structure (Sections)

- **Title**: should already contain the controlling idea (thesis)
- **Attribution**: Author list, ev. with footnotes on supporting research organizations
- **Abstract** e.g., with MOPARC or Gul Caramel
- **Introduction** should follow a ZOPP-like problem analysis
  - Paragraphs with Background, Problem, Success criteria, Research Question, Research Method, Research Result, Solution: Way how to achieve the result, Roadmap
- **Background**: Terminology, background works
- **Solution**
  - Depends on the type of research question, method
- **Validation**, e.g., Experimental evaluation: what are the findings of the experiments or analyses?
- **Discussion**: Discuss advantages, disadvantages, limits, unique features
- **Comparison** to Related Work: what is the unique feature of the result?
- **Conclusion**: Draw a conclusion
- **Acknowledgement**: Often, research funding organizations want to be acknowledged. Do also not forget helpful colleagues or your supervisor
- **References**
- **Appendices**

Shaw's Paper Structure (Sections)

- http://spoke.compose.cs.cmu.edu/write/t/d/std-otl.htm
- **Abstract**
- **Introduction** (with motivation, problem definition, research question, overview/roadmap of the paper)
- **Related work A** (Background: what is necessary to understanding the present result)
- **Meat of the paper** (the part of the structure that depends on the result; pretty different)
- **Related work B** (relations to other work that compare this work to alternatives or otherwise require the present result as a prerequisite)
- **Summary**, **conclusions**, next steps
- **Acknowledgements**, in particular funding sources
- **Bibliography**
- **Possibly appendices** (the standard rule for appendices places them after the bibliography, which is a nuisance)

Bundy's Paper Structure

- http://homepages.inf.ed.ac.uk/bundy/how-tos/writingGuide.html
- **Title** should summarize the hypothesis (thesis, contribution) of the paper. The “controlling idea” must shine out
- **Abstract** state the contribution
- **Introduction** motivate the contribution of the paper
- **Literature Survey** allows for positioning the paper into the context
- **Background** (Background: what is necessary to understanding the present work)
- **Theory**
- **Specification**
- **Implementation**
- **Evaluation**
- **Related work** comparison with competitors
- **Further Work**
- **Conclusion**
- **Appendices**

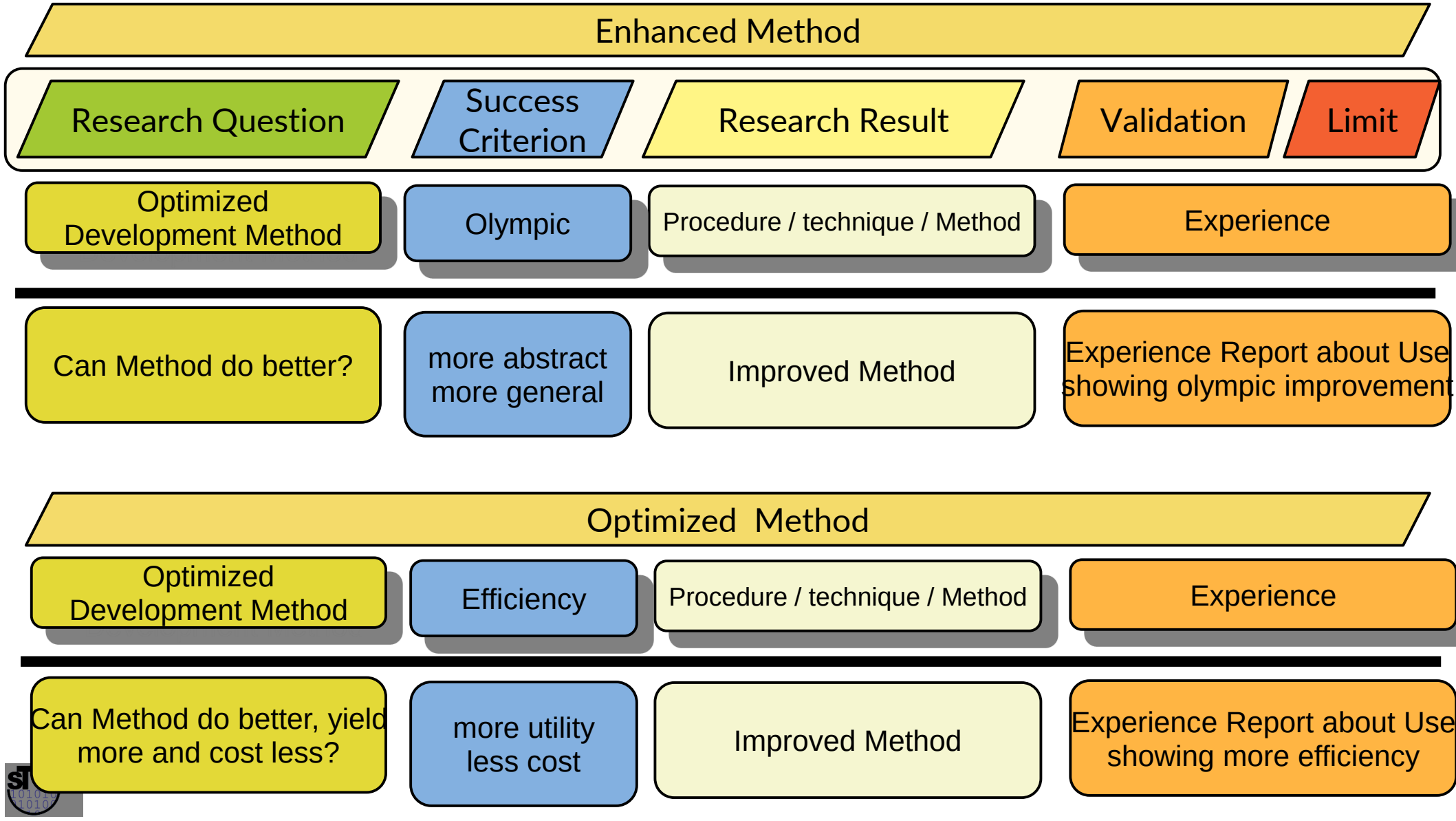
32.3 More Specific, Newman-Abstract-Like Papers

- All Newman template abstracts can be entered into the Shaw classification.

32.3.1 New Solution Paper (Enhanced Solution)

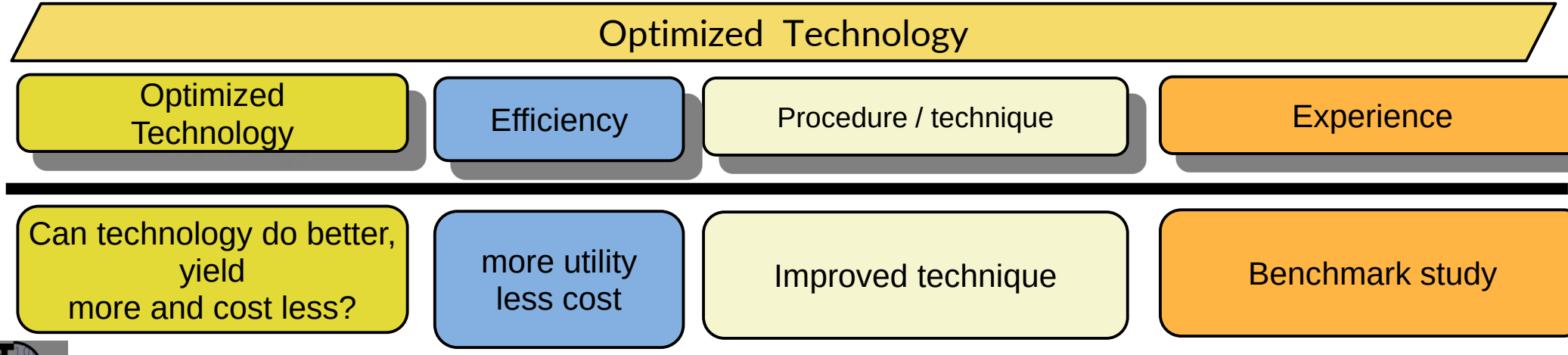
Enhanced/Improved Method (Optimization Hypothesis)

- Special subclass of “Enhanced Solution”



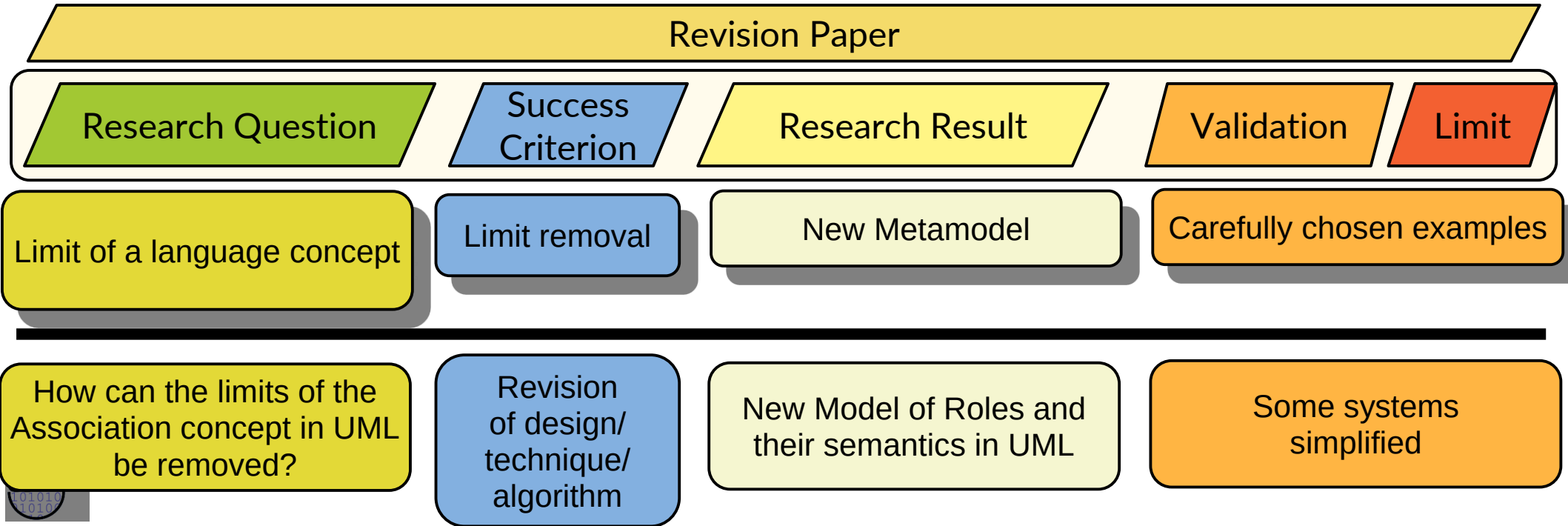
Optimization Technology Paper

- Present an optimization technology (more than an optimized algorithm)
- Show why the current technology is too slow or inefficient
- Show metamodels of optimizing technology
- Give a systems' component diagram
- Give some central algorithms
  - Prove termination
  - Analyze complexity
  - Prove quality features
- Show a case study which proves that your stuff is more efficient

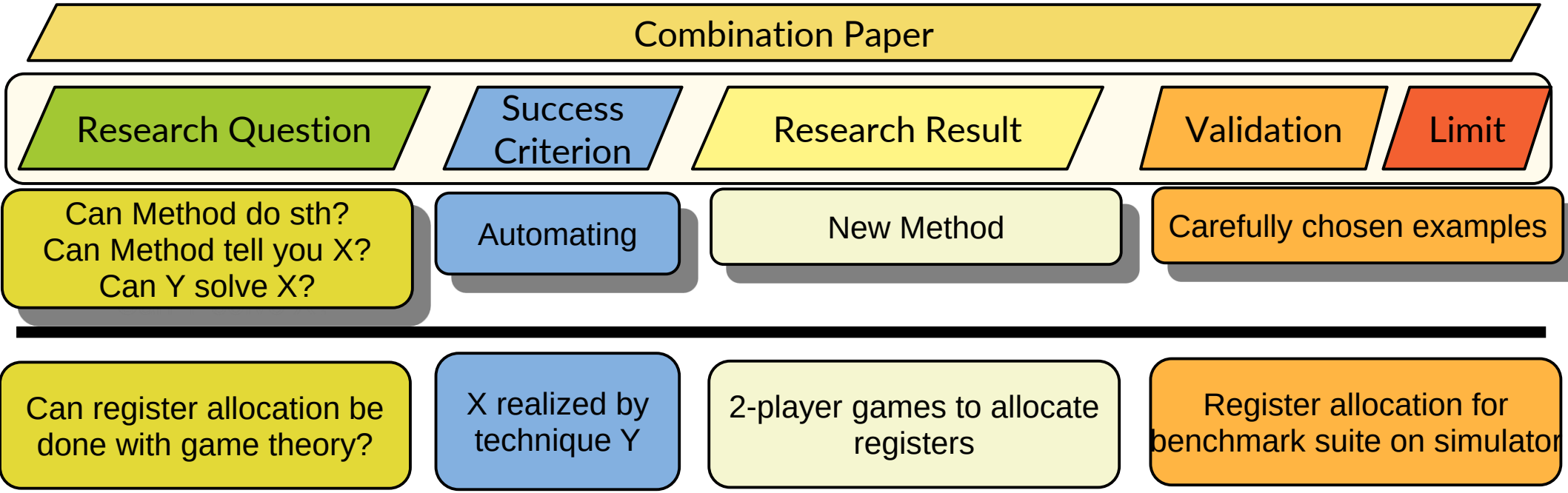


Language Revision Papers (Better Language)

- A **revision paper** extends a critique paper with a revision proposal
- Friedrich Steimann. A radical revision of UML's role concept. In Andy Evans, Stuart Kent, and Bran Selic, editors, UML 2000 - The Unified Modeling Language. Advancing the Standard. Third International Conference, York, UK, October 2000, Proceedings, volume 1939 of LNCS, pages 194-209. Springer, 2000.
- Friedrich Steimann and Thomas Kühne. A radical reduction of UML's core semantics. Lecture Notes in Computer Science, 2460:34-, 2002.

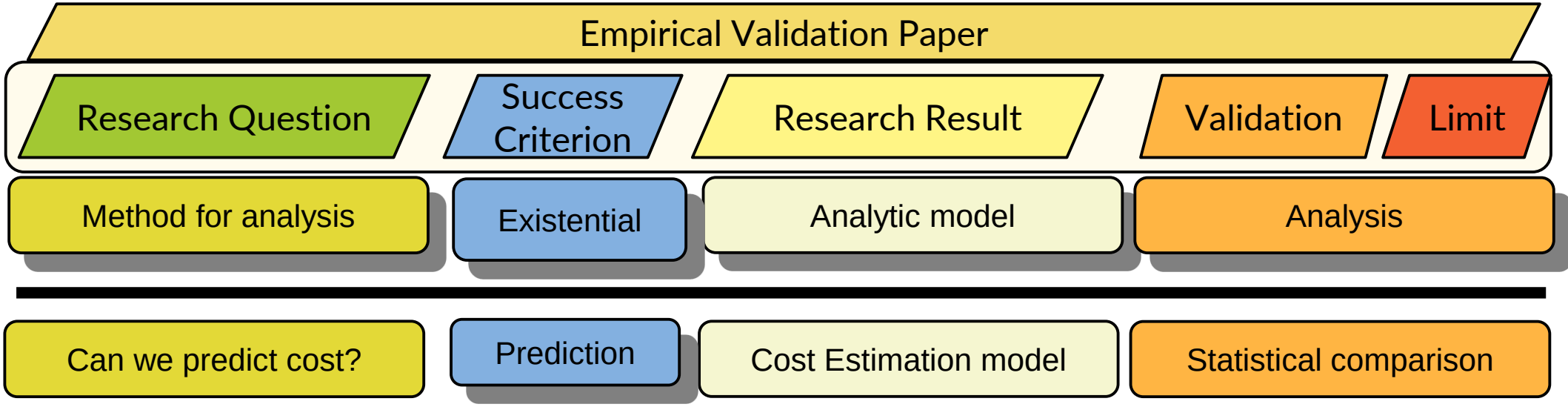


New Method (with Automation Hypothesis), Validated with Examples



- A **combination result** shows that a so far uncorrelated method from another branch in science can solve problem X
  - Ex.: Graph rewrite systems can describe program optimizations
  - How to use Datalog to solve traffic problems

Empirical Validation by Statistics

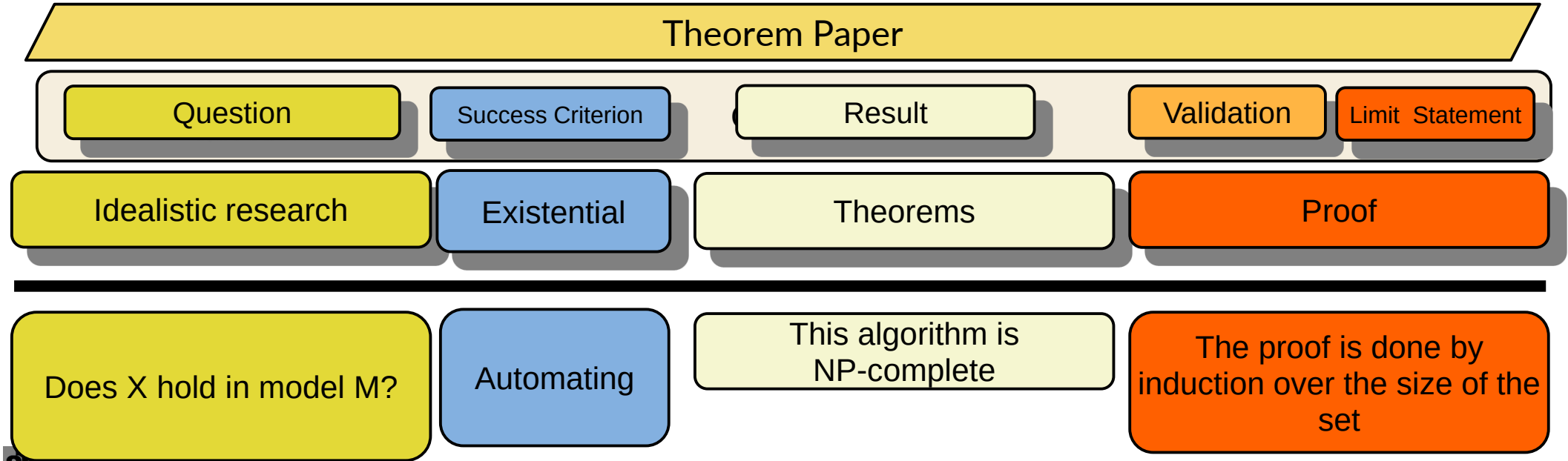


- Empirical validation is possible by
  - statistics
  - controlled experiments with user groups
  - field studies
- Example: [Xu-Nygard] reduces attack trees to aspect-oriented PetriNets and verifies absence of intrusions: first time automating intrusion checking

32.3.2 New Knowledge Paper (Enhanced Idealized Model)

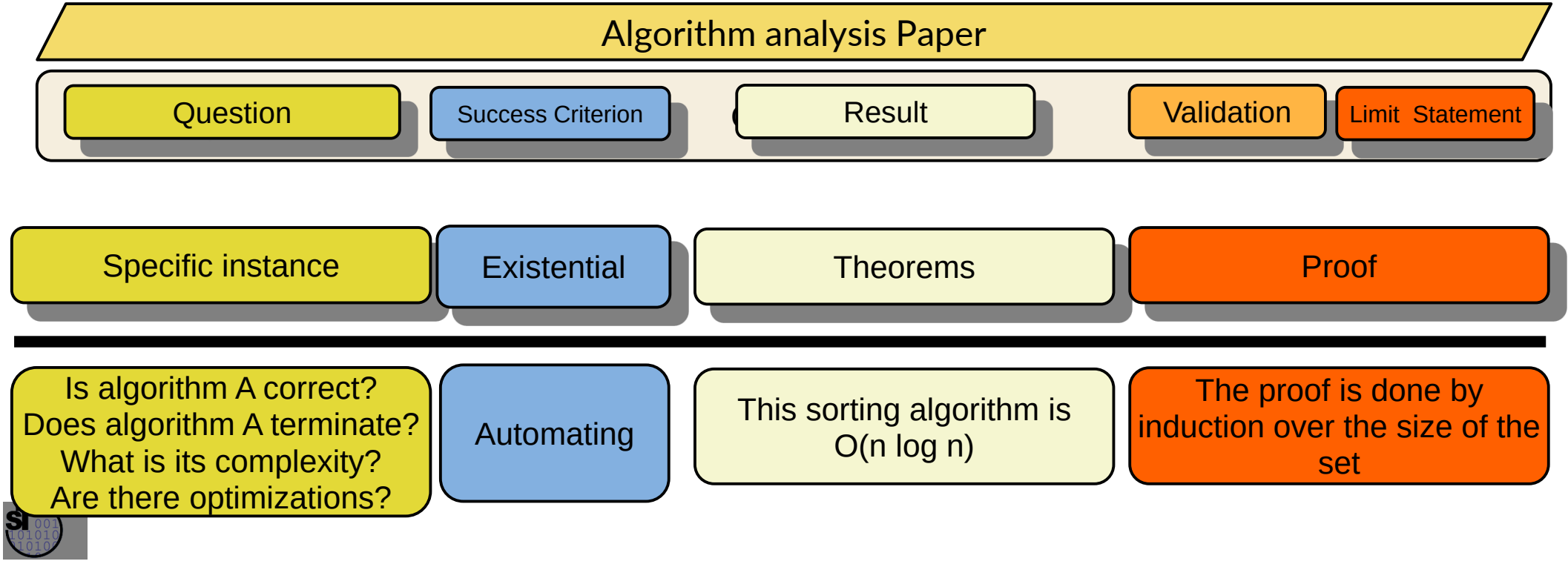
Theorem Paper

- A theorem paper is always working on an idealized research result, based on a model of reality
- LogP Papers of Löwe, Zimmermann, Eisenbiegler discuss the LogP-model of distributing data and computations on distributed machines
  - Much better than the usual PRAM model, because parallel distributed machine is modeled more realistically (L – latency, o - overhead, g - gap)
- Wolf Zimmermann and Welf Löwe. Foundations for the integration of scheduling techniques into compilers for parallel languages. IJCSE, 1(2/ 3/4):99-109, 2005.



Algorithm Analysis/Design Paper

- Papers presenting a new or optimized algorithm need to discuss:
  - Correctness
  - Termination
  - Complexity on a RAM, PRAM or on a logp-machine
  - NP-completeness, decidability
  - for practical algorithms: linearity, n log n, quadratic, cubic
- Prove quality features, such as memory consumption, energy consumption



32.3.3. Writing a Systems Paper (Enhanced Tool)

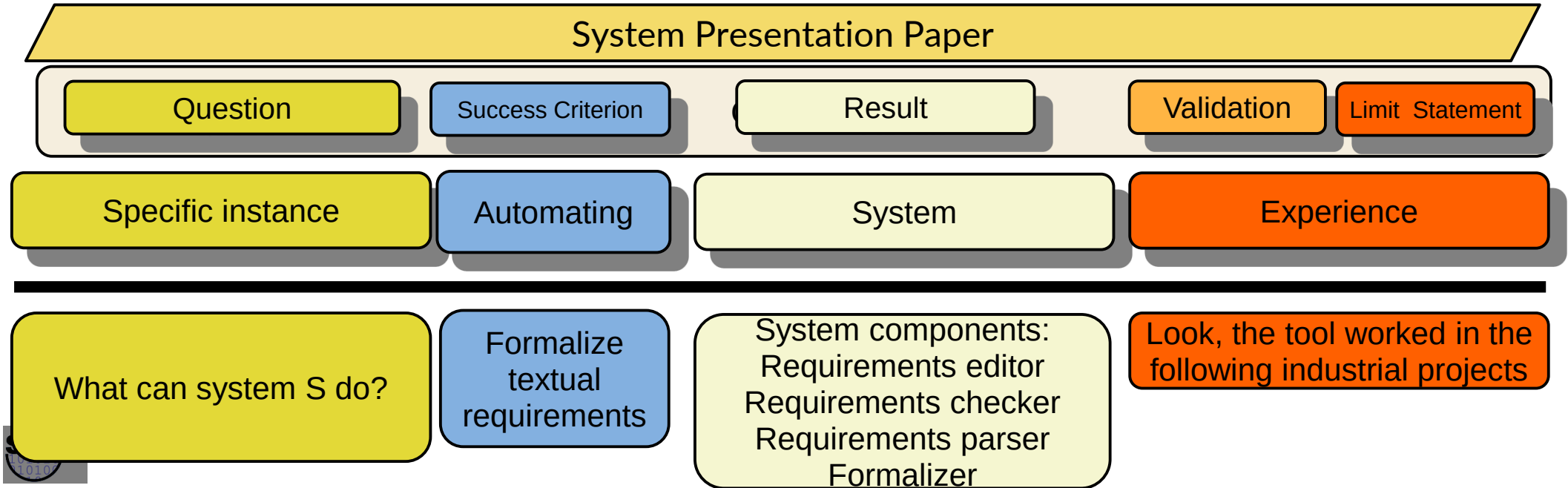
Roy Levin and David D. Redell. An Evaluation of the Ninth SOSP Submissions or How (and How Not) to Write a Good Systems Paper. ACM SIGOPS Operating Systems Review, Vol. 17, No. 3 (July, 1983), pages 35-40

http://infolab.stanford.edu/~widom/paper-writing.html.

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

System and Tool Papers

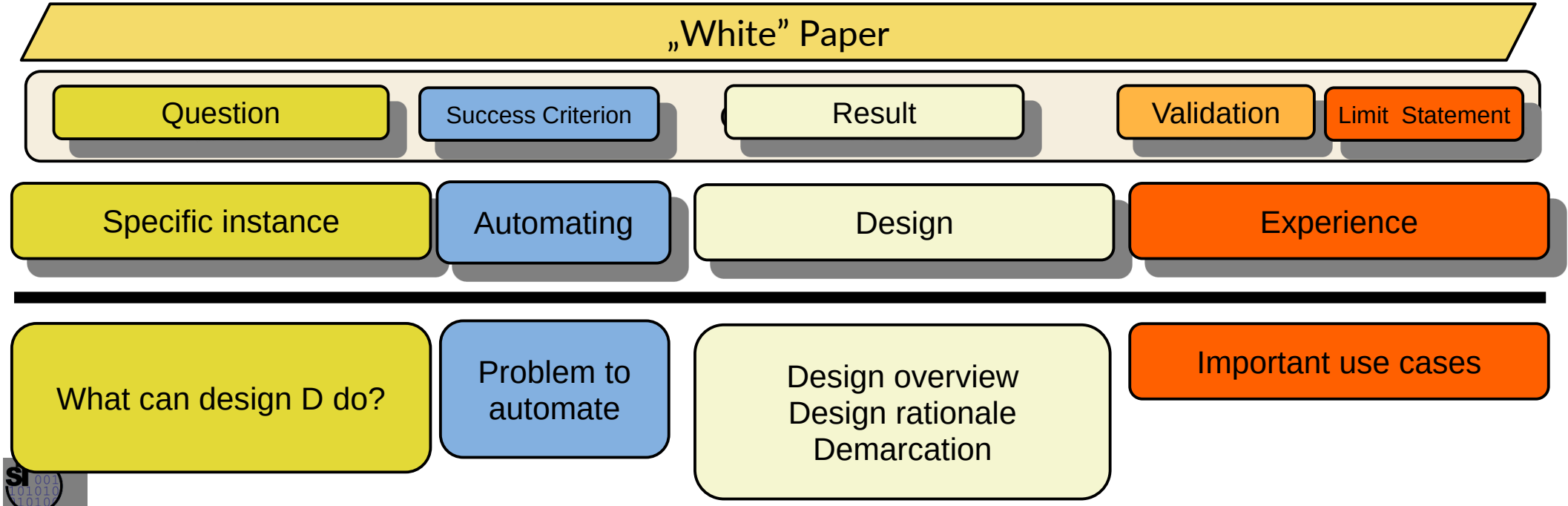
- System papers need to discuss:
  - Deficiencies or limits of other systems
  - Market data or studies of economical need
  - Success factors and requirements for the system
  - Unique features not available in other systems
  - Components of the system that contribute to the unique features
  - why is automation with a tool important?
  - Important use cases, limits of the system, empirical evaluation
- Tools are special systems which automate things that should otherwise be done by hand
  - Aching factors: what aches if the tool is not available?



32.3.4. Experience and Heuristics

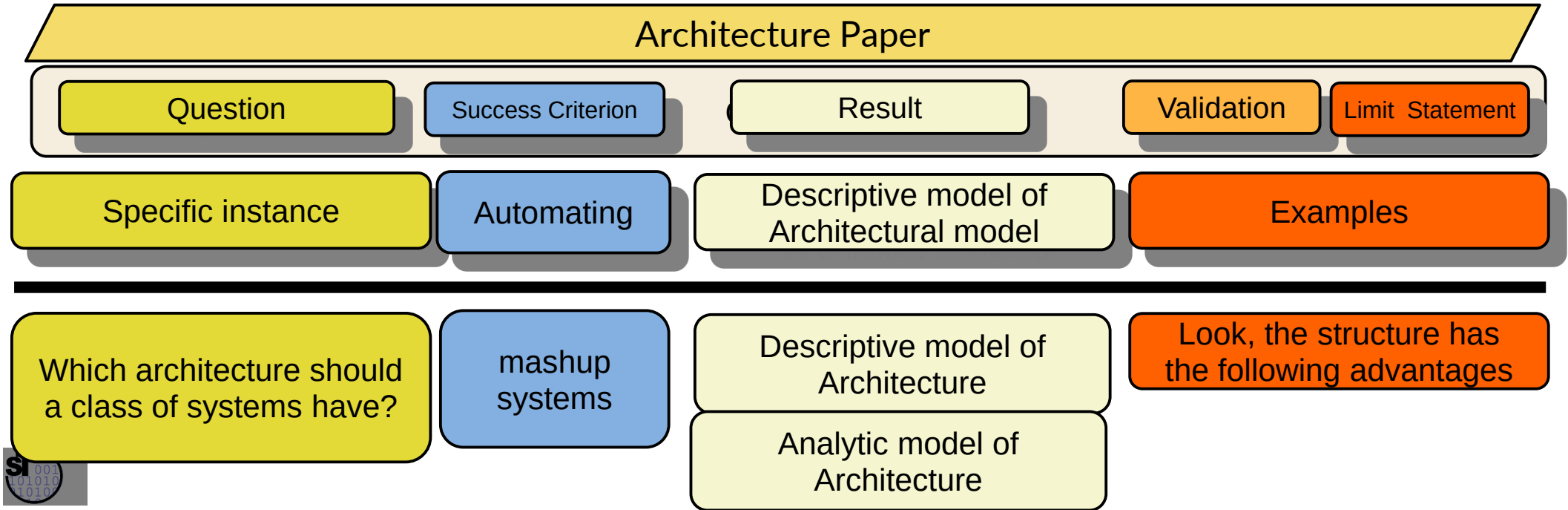
Design Papers ("White Paper", "Red Book")

- Design papers describing the design of a new technology can describe:
  - Basic concepts of the domain
  - Success factors and requirements for the design
  - Deficiencies or limits of other designs
  - Overview of the design
  - Design rationale (why was the design chosen like that? Which other solutions were rejected?)
  - Unique features not available in other designs
  - Important use cases



Architecture Papers

- Architecture papers need to discuss
  - Deficiencies or limits of other systems
    - Market data or studies of economical need
  - Success factors and requirements for the system
  - Unique features not available in other systems
    - Components of the system that contribute to the unique features
    - why is automation with a tool important?
  - Important use cases, limits of the system, empirical evaluation



Experiment Papers

- Experimental papers measure with benchmarks olympic or efficiency features of programs, processes, techniques
- Benchmark suites, such as:
- Java Grande Benchmark
- Spec benchmark
- Java Qualitas Corpus
  - Ewan D. Tempero, Craig Anslow, Jens Dietrich, Ted Han, Jing Li, Markus Lumpe, Hayden Melton, and James Noble. The Qualitas Corpus: A curated collection of java code for empirical studies. In Jun Han and Tran Dan Thu, editors, APSEC, pages 336-345. IEEE Computer Society, 2010.
  - Roberto Tonelli, Giulio Concas, Michele Marchesi, and Alessandro Murgia. An analysis of SNA metrics on the Java Qualitas Corpus. In Arun Bahulkar, K. Kesavasamy, T. V. Prabhakar, and Gautam Shroff, editors, ISEC, pages 205-213. ACM, 2011.

32.3.5. Experimental Analysis Papers

Experimental Analysis Papers

- Experimental analysis papers measure features of software with analysis techniques.
- Metric papers:
  - Santonu Sarkar, Avinash C. Kak, and Girish Maskeri Rama. Metrics for Measuring the Quality of Modularization of Large-Scale Object-Oriented Software. IEEE Transactions On Software Engineering, Vol. 34, No. 5, September/October 2008.

The End

- What have we learned?
  - Different types of research papers
  - Their typical structure