Program Comprehension and Software Migration Strategies

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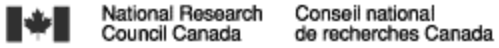
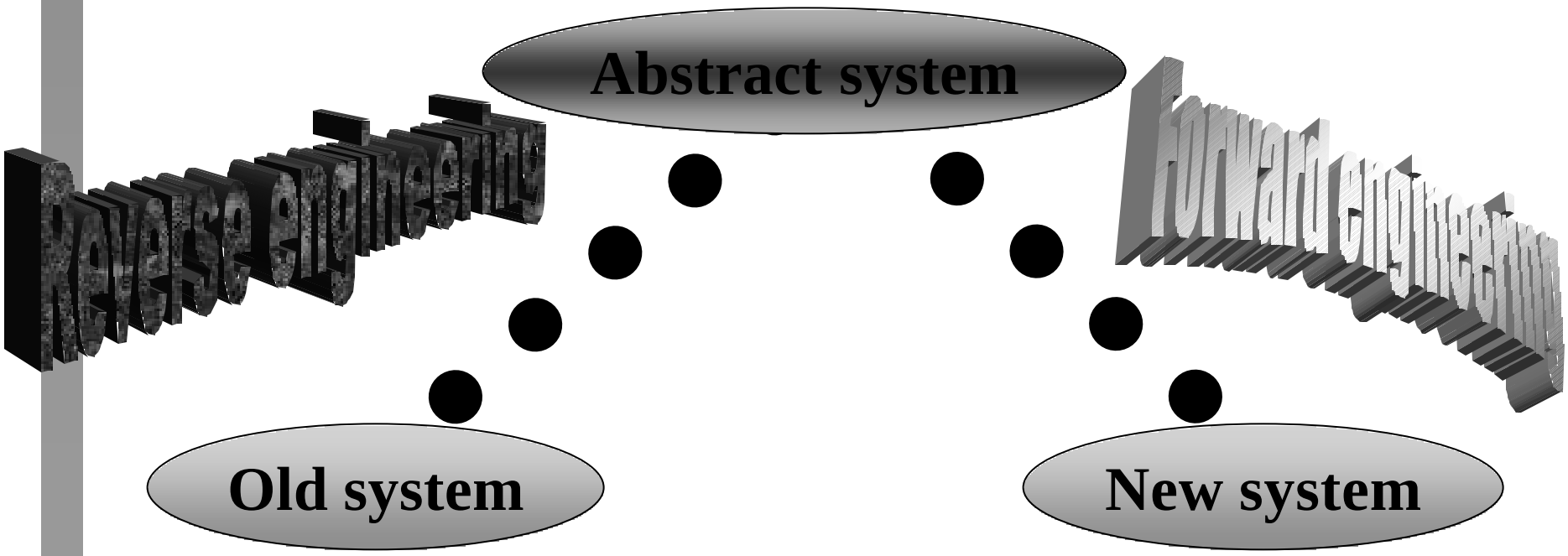
Outline

- *Reengineering categories*
- *Comprehension strategies*
- *Migration strategies*
- *Language migration*
- *Program comprehension education*
- *Mt. St. Helens Theory*
- *Key research pointers*
- *Conclusions*

Research Support



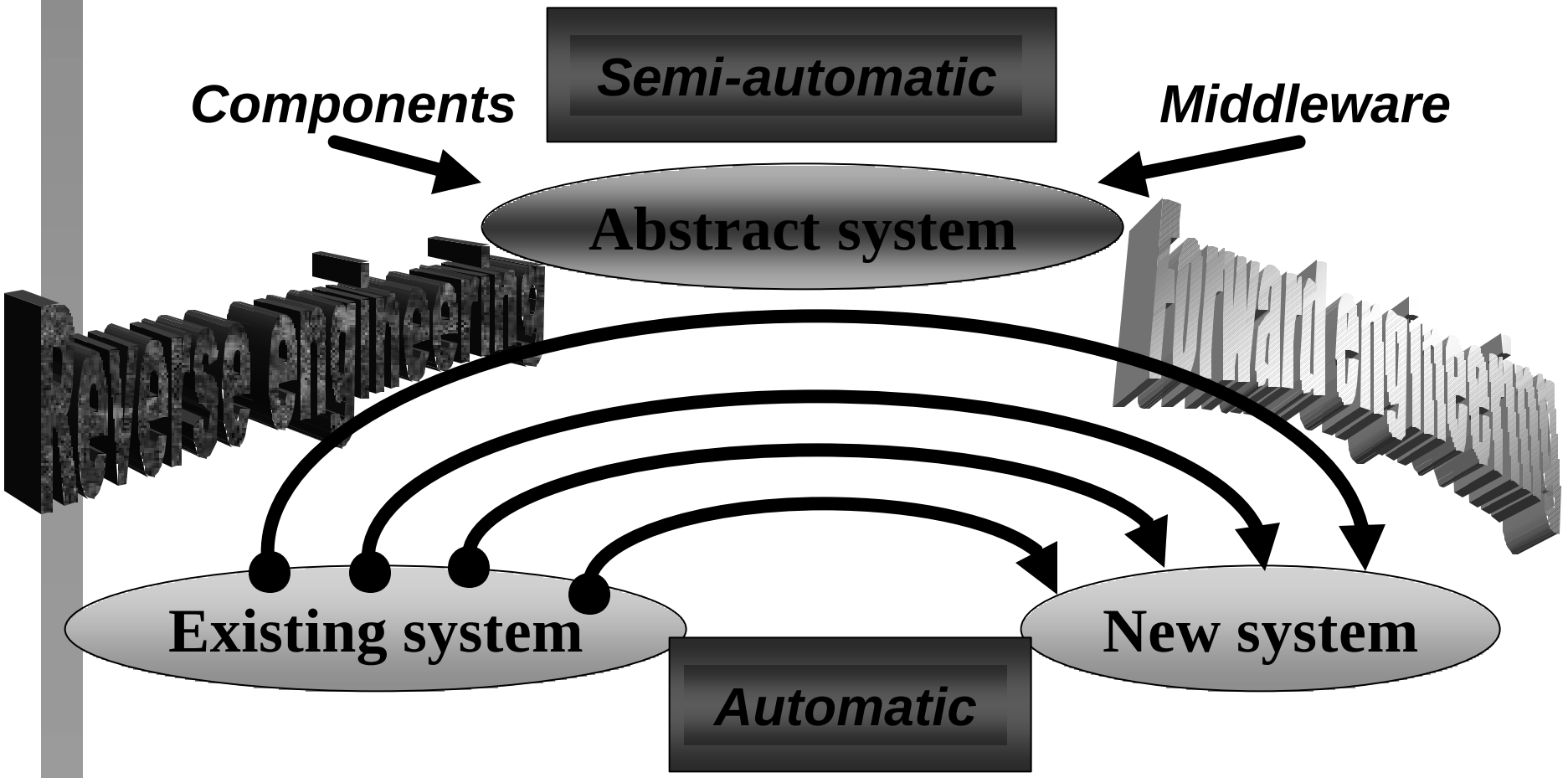
The Horseshoe Model of Software Migration



Reengineering Categories

- *Automatic restructuring*
- *Automatic transformation*
- *Semi-automatic transformation*
- *Design recovery and reimplementation*
- *Code reverse engineering and forward engineering*
- *Data reverse engineering and schema migration*
- *Migration of legacy systems to modern platforms*

The Horseshoe Model



Reengineering Categories...

- *Automatic restructuring*
  - *to obtain more readable source code*
  - *enforce coding standards*
- *Automatic transformation*
  - *to obtain better source code*
  - *HTML'izing of source code*
  - *simplify control flow (e.g., dead code, goto's)*
  - *refactoring and remodularizeing*
  - *Y2K remediation*

Reengineering Categories...

- *Semi-automatic transformation*
  - *to obtain better engineered system (e.g., rearchitect code and data)*
  - *semi-automatic construction of structural, functional, and behavioral abstractions*
  - *re-architecting or re-implementing the subject system from these abstractions*

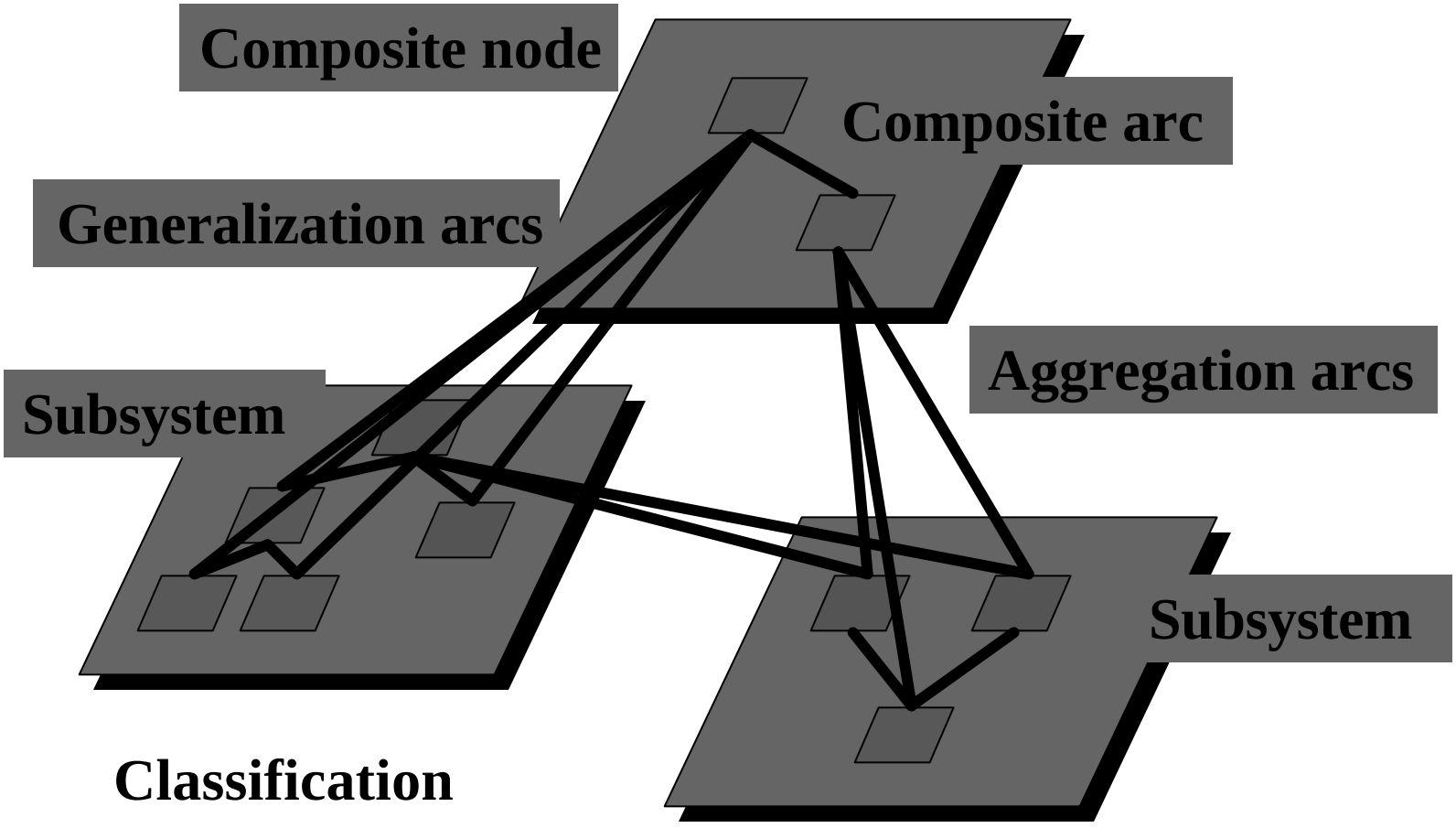
Design Recovery Levels of Abstractions

- *Application*
  - *Concepts, business rules, policies*
- *Function*
  - *Logical and functional specifications, non-functional requirements*
- *Structure*
  - *Data and control flow, dependency graphs*
  - *Structure and subsystem charts*
  - *Architectures*
- *Implementation*
  - *AST's, symbol tables, source text*

Synthesizing Concepts

- *Build multiple hierarchical mental models*
- *Subsystems based on SE principles*
  - *classes, modules, directories, cohesion, data & control flows, slices*
- *Design and change patterns*
- *Business and technology models*
- *Function, system, and application architectures*
- *Common services and infrastructure*

The Ubiquitous Graph Model



Classification

Typed nodes and arcs

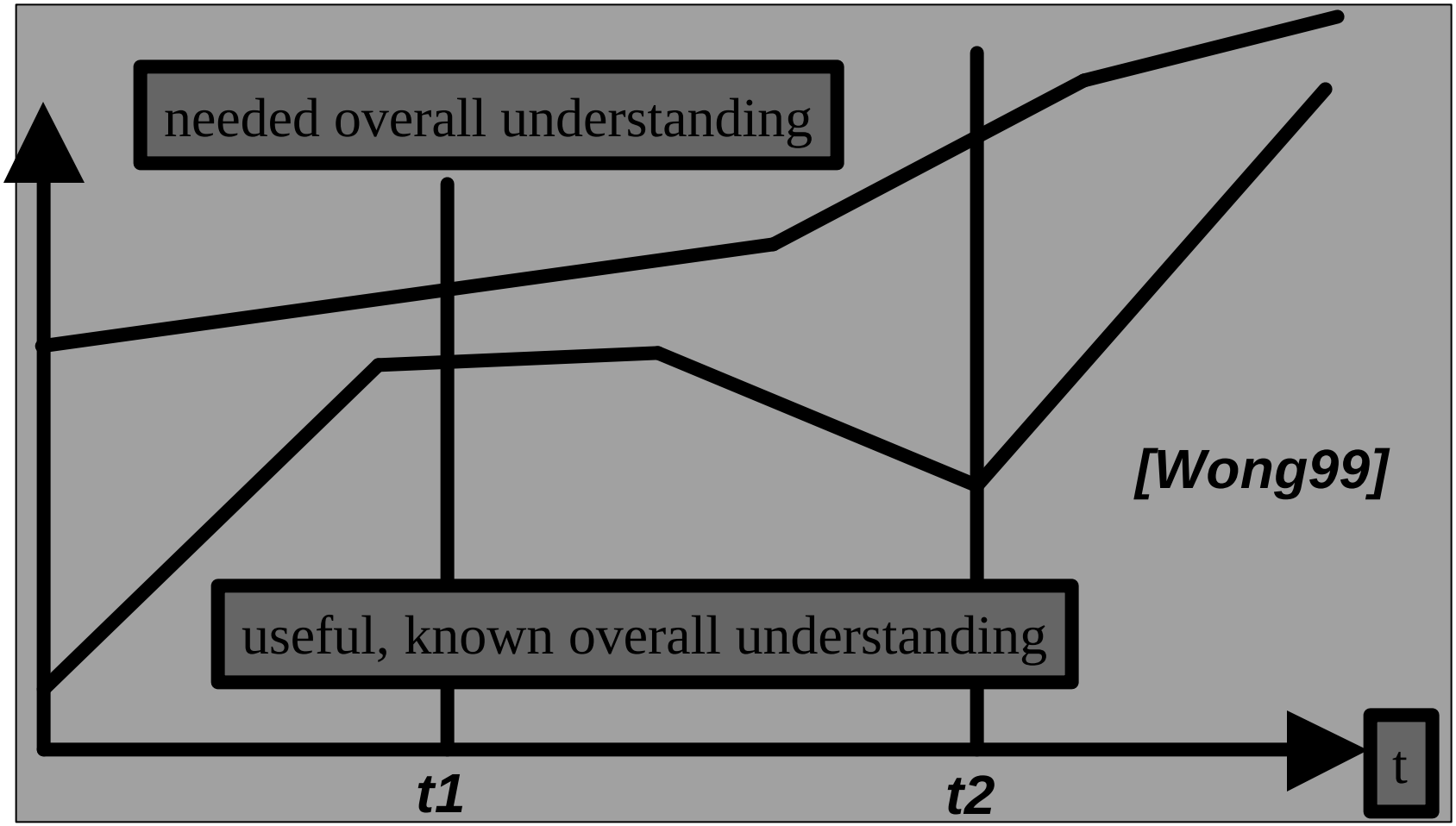
Program Comprehension Technology

- *Program understanding technology*
  - *Cognitive models*
  - *Levels of abstraction*
  - *Synthesizing concepts*
  - *Filtering information*
  - *Slicing and dicing*
- *Comprehension environment*
  - *Parsers and lightweight extractors*
  - *Repository and conceptual modeling*
  - *Visualization engines (graph and web based)*

The Big-Bang Comprehension Problem

- *What can we do during evolution to ease future understanding and migration of information systems?*
- *We know the knowledge we need but it is difficult to obtain from scratch*
- *"Big-bang" comprehension when the system becomes "critical" is high-risk*
- *Analysis paralysis*

The Understanding Gap



Continuous Program Comprehension

- *Apply program understanding continuously and incrementally during evolution of the software system*
- *Use software reverse engineering to re-document existing software*
- *Insert reverse engineering techniques into development [Wong99]*
- *Symbiosis: models and code [Jackson00]*

Evaluating Reverse Engineering Tools

- *The purpose of most reverse engineering tools is to increase the understanding an engineer has of the subject system*
- *No agreed-upon definition or test of understanding*
- *Several types of empirical studies that are appropriate for studying the benefits of reverse engineering tools*

Program Understanding Theses
An Emerging Discipline

- *Domain retargetable reverse engineering [Tilley95]*
- *Cognitive design elements for software exploration tools [Storey98]*
- *Continuous understanding Reverse Engineering Notebook [Wong99]*
- *Integrating static and dynamic reverse engineering models [Systa2000]*
- *Architectural Component Detection for Program Understanding [Koschke2000]*

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Migration Theses

- *Management of uncertainty and inconsistency in database reengineering [Jahnke99]*
- *Integration and migration of information systems to object-oriented platforms [Koelsch99]*
- *Migrating C++ to Java [Agrawal99, Wen2000]*
- *An Environment for Migrating C to Java [Martin2000]*

Migration Objectives Evolving Business Requirements

- *Adapt to e-commerce platform*
- *Adapt to web technology*
- *Reduce time to market*
- *Support new business rules*
- *Allow customizable billing*
- *Adapt to evolving tax laws*
- *Reengineer business processes*

Migration Objectives ... Software Evolution Requirements

- *Higher productivity*
- *Lower maintenance costs*
- *Move to object-oriented platforms*
- *Inject component technology*
- *Adapt to modern data exchange technology*
- *Leverage modern methods and tools*

Migration Objectives ... Software Architecture Requirements

- *Move to network-centric platforms*
- *Integrate cooperative information systems*
- *Leverage centralized repositories*
- *Move from hierarchical to relational db*
- *Take advantage of web user interfaces*
- *Provide interoperability via buses and gateways among applications*
- *Move to client-server architectures*

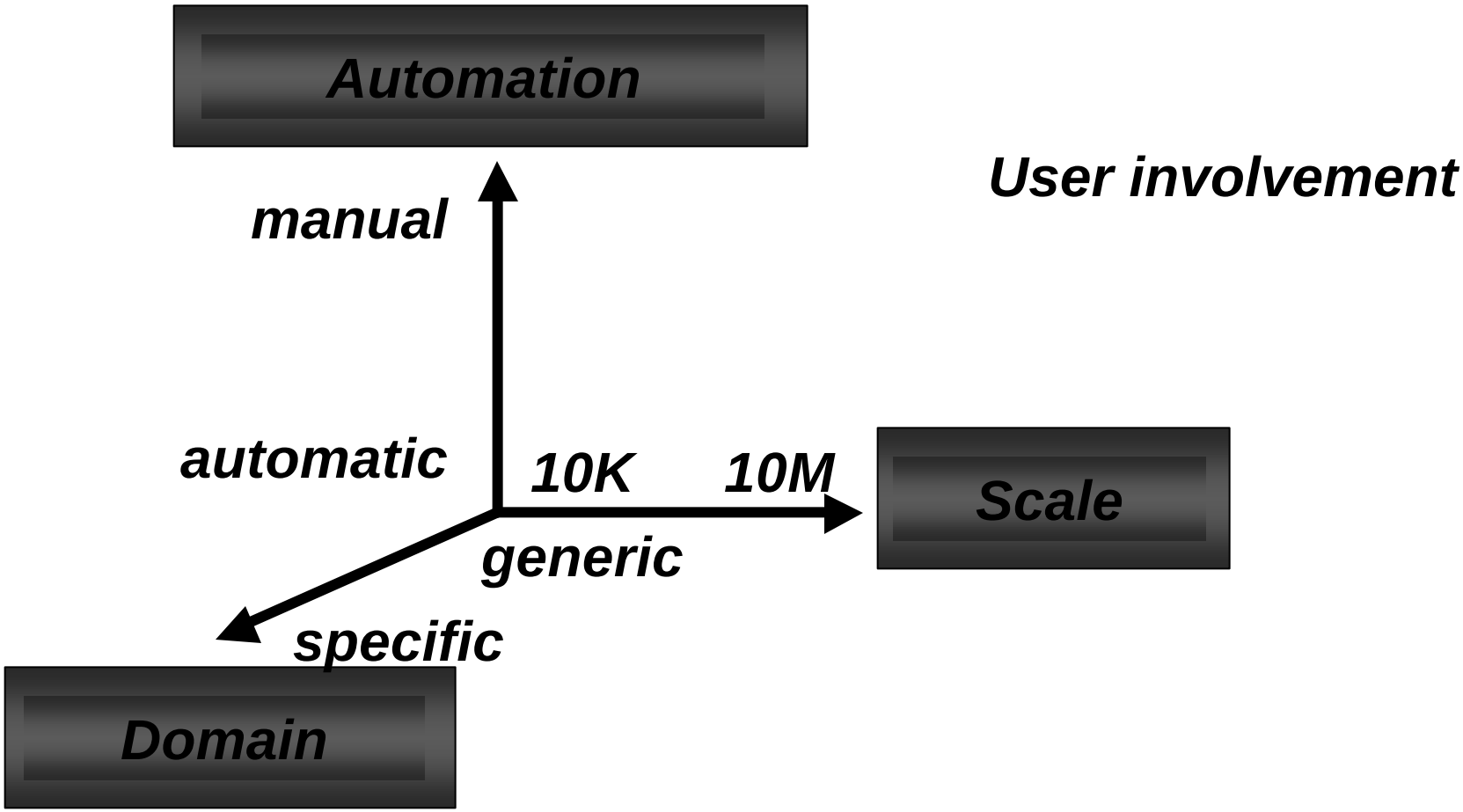
Common Requirements Migration

- *Ensure continuous, safe, reliable, robust, ready access to mission-critical functions and information*
  - *Migrate in place*
- *Minimize migration risk*
  - *Reduce migration complexity*
  - *Make as few changes as possible in both code & data*
  - *Alter the legacy code to facilitate and ease migration*
  - *Concentrate on the most important current and future requirements*

Common Migration Requirements ...

- *Minimize impact on*
  - *users*
  - *applications*
  - *databases*
  - *operation*
- *Maximize benefits of modern technology*
  - *user interfaces, dbs, middleware, COTS*
  - *automation, tools*

Dimensions of Migration Methods and Tools



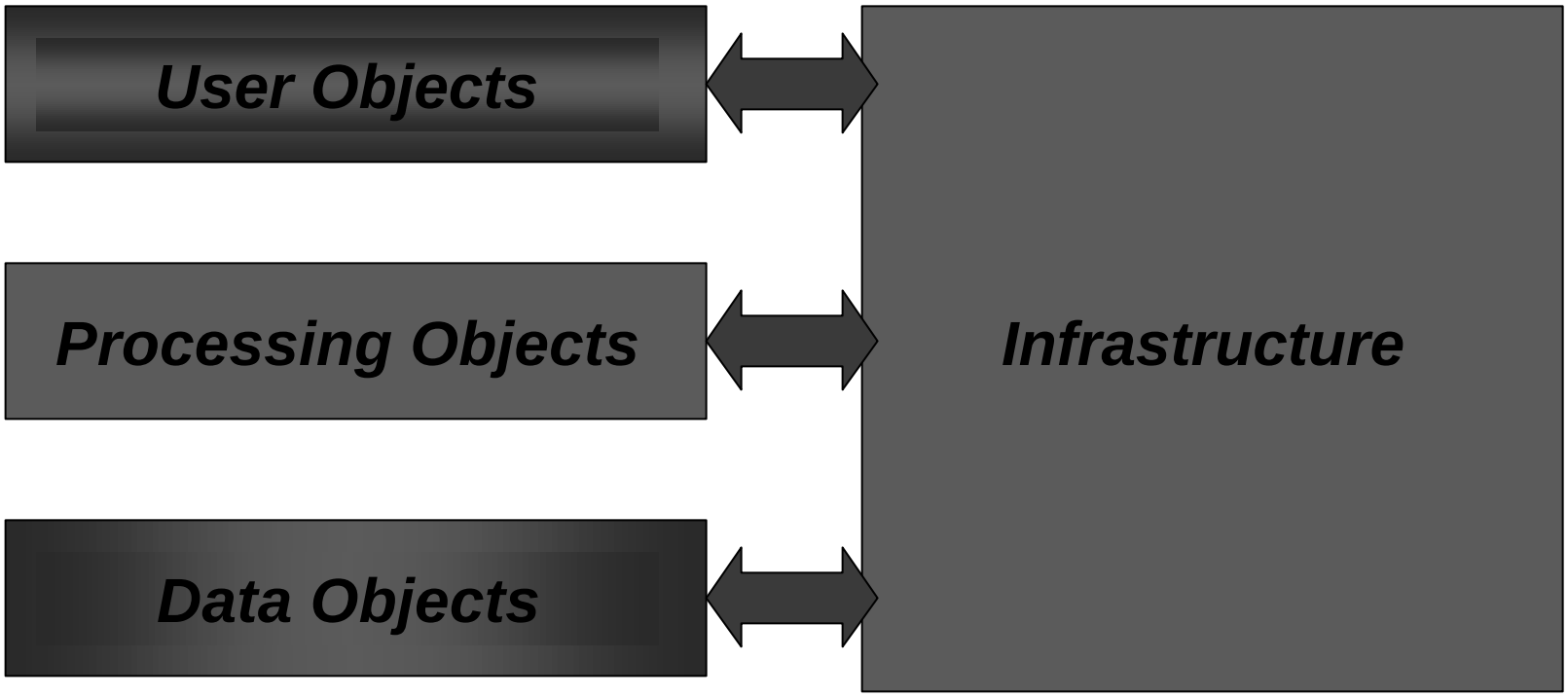
Resistance to Change

- *Are some systems more difficult to change, evolve, reengineer than others?*
- *Can we define a measure resistance based on business value, existing technology, new technology, evolution pace?*
- *We need empirical studies ...*

Separable Tiers

- *Decompose legacy system into three layers or application tiers*
  - *Presentation (interfaces: user and APIs)*
  - *Processing (application code, functions, business rules, policies)*
  - *Data services (database)*
- *Promotes interoperability, reuse, flexibility, distribution, separate evolution paths*

Application Layers



Classification of LIS Architectures

- *Decomposable*
  - *Separation of concerns*
  - *Interfaces, applications, db services are distinct components*
  - *Functional decomposition*
  - *Ideal for migration*

> *There is nothing more difficult to arrange, more doubtful of success, and more dangerous to carry through than initiating changes.*
>
> *—N. Machiavelli*

Classification of IS Architectures ...

- *Semidecomposable*
  - *Applications and db services are not readily separable*
  - *System is not easily decomposable*
- *Nondecomposable*
  - *No functional components are separable*
  - *Users directly interact with individual modules*
- *[BS95]*

Migration Strategies

- *Ignore*
  - *retire, phase out, let fail*
- *Replace with COTS applications*
- *Cold turkey*
  - *rewrite from scratch*
  - *high risk*
- *Integrate and access in place*
  - *integrate future apps into legacy apps without modifying legacy apps*
  - *IS-GTP [Koelsch99]*

Data Warehousing

- *Data is needed for several distinct purposes*
  - *on-line transaction processing (access in place)*
  - *data analysis for decision support applications (extraction of data into an application specific repository)*
- *Creates duplicate data*
- *Popular approach*

Gradual Migration or "Chicken Little"

- *Rearchitect and transition the applications incrementally*
- *Replace LIS with target application*
- *Language migration*
- *Schema and data migration*
- *User interface migration*
- *GTE [BrSt95]*

Chicken Little ...

- *The intent is to phase out legacy applications over time*
- *In place access is not economical in the long run*
- *More effective, less risky than cold turkey*
- *Allows for independent user interface and database evolution*
- *Incremental*

Chicken Little ...

- *Legacy and target applications must coexist during migration*
- *A gateway to isolate the migration steps so that the end users do not know if the info needed is being retrieved from the legacy or target system*
- *Development of gateways is difficult and costly*

Opportunistic Migration Method

- *Combination of forward and reverse migration strategies*
- *Forward or reverse migration path per*
  - *operation*
  - *application*
  - *interface*
  - *database*
  - *site*
  - *user*
- *More complex gateways are needed*

Migration Research Method

- *Perform a concrete case study with an industrial software system*
- *Investigate methods and tools to automate the process adopted in the case study*
- *Conduct user experiments to improve the effectiveness of the developed methods and tools*
- *Investigate tool adoption problems*

Language Migration—A Case Study

- *Subject system is a 300 KLOC legacy software system of highly optimized code written in PL/IX*
- *Can the system incrementally be translated to C++?*
  - *Transliteration versus object-oriented design*
- *Develop tools which semi-automate the translation process to C++*
- *The translated code must perform as well as the original code*

Manual Migration

- *First migration and integration effort was completed by hand by an expert [Uhl97]*
- *10 person-weeks to migrate 7.8 KLOC*
- *Successfully passed all regression tests*
- *Built C++ and Fortran compilers with it*
- *It works …*
  … but migrated C++ code was 50% slower than original PL/IX code

Performance Evaluation

- *Expert identified performance bottlenecks*
- *Hand-optimized migrated code*
- *Optimized version performed better than the original version [Martin98]*
  - *Up to 20% better than the original code*
  - *Now IBM was interested …*
- *Results*
  - *Correct, efficient*
  - *Translation, integration, optimization heuristics*
  - *Incremental process*

Automation

- *Can the translation, integration, and optimization heuristics discovered by experts be integrated into an automated tool?*
- *How would it affect the performance?*
- *What existing tools could be leveraged to build such a tool?*
- *Solution*
  - *Use Software Refinery, Reasoning Systems*

Transformation Process

- *Transform PLI/IX artifacts to their corresponding C++ artifacts*
- *Generate support C++ libraries (macros for reference components; class definitions for key data structures)*
- *Generate C++ source code that is structurally and behaviorally similar to the legacy source code*
- *CASCON98 Best Paper [Kontogiannis98]*

Results, Morale & Lessons Learned

- *Semi-automatic transformation of large volume of code is feasible*
- *Migrated code suffers no deterioration in performance*
- *Incremental migration process feasible*
- *Technique readily applicable to other imperative languages*
- *Tool reduces migration effort by a factor of 10 over manual migration*
- *CTAS—C++ to Java [Jackson2000]*

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Teaching program understanding

- *How many teach 4th year or graduate courses in software evolution, program understanding, comprehension, reverse engineering, reengineering?*
- *How many teach program understanding or program reading in 1st year?*

Challenges and Aspirations

- *Mary Shaw, Software Engineering Education—A Roadmap; in The Future of Software Engineering, ICSE 2000*
- *1. Discriminate among different software development roles*
- *4. Integrate an engineering point of view into CS and IS undergraduate curricula*
- *6. Exploit our own technology in support of education*

Discriminate among different software development roles

- *Available knowledge about software exceeds what any one person can know*
- *Specializing roles*
- *Comprehension versus coding skills*
- *Developing the role of a reverse engineer, program comprehender*
- *Software inspection expert*

Integrate an engineering point of view into undergraduate curricula

- *Study good examples of software systems and develop program understanding skills*
- *Teach back-of-the-envelope estimation using reverse engineering technology*
- *Teach students how to investigate non-functional requirements using program comprehension technology*

Exploit our own technology in support of education

- *Employ software exploration and reverse engineering tools in 1st year*
- *Integrated environments such as VA Java or J++ do not provide facilities to explore and record mental models*
- *Familiarize students with software exploration and conceptual modeling tools*
- *Restructure curricula to teach both fresh creation and evolutionary change*

Mt. St. Helens Theory

- *May 18, 1980 Mt. St. Helens self-destructed, setting off the biggest landslide in recorded history and losing 400 meters of its crown*
- *Forests and meadows, and mountain streams were transformed into an ash-gray wasteland*
- *Ecologists dogma—nature recreates ecosystems in a predictable fashion*

A decade later

- *A decade later even on the most sterile of landscapes brave little vegetative beachheads are formed*
- *The unpredictability of recolonization and the pivotal importance of chance in rebuilding of biological communities*
- *Wildflower gardens, which are mixes of lupine, Indian paintbrush, pearly everlasting, and fireweed, are emerging*

Encourage island-driven research

- *Is program comprehension research becoming too predictable?*
- *Do we need a cataclysmic event to rejuvenate comprehension research?*
- *There are many vegetative beachheads in the community*
- *But they tend to gravitate towards established research and tools*
- *Particularly the tools arena needs new beachheads*

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Key Research Pointers

- *Investigate infrastructure, methods, and tools for continuous program understanding to support the entire evolution of a software system from the early design stages to the long-term legacy stages*
  - *Reverse engineering notebook*

Key Research Pointers ...

- *Instrument design architecture to ease extraction of understanding architecture*
- *Store architecture artifacts in schema-based repository and as unstructured or Web-based text to ease searching*
- *Allow for incomplete semantics and partial extraction of artifacts*

Key Research Pointers ...

- *Allow user to build virtual, multiple architectures, perspectives, and views*
- *Provide tools to compare virtual and code-centric architectures (e.g., reflection models [Murphy98])*
- *Make architecture extraction tools end-user programmable and extensible*

Key Research Pointers ...

- *Develop methods and technology for computer-aided data and database reverse engineering*
  - *Integrate code and data reverse engineering methods and tools*
  - *Leverage synergy between code and data reverse engineering communities*

Key Research Pointers ...

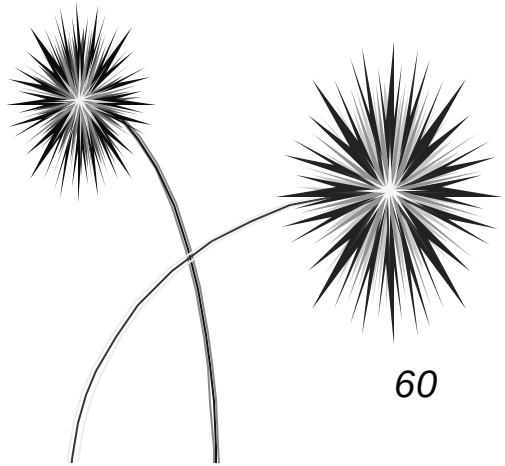
- *Develop tools that provide better support for human reasoning in an incremental and evolutionary reverse engineering process that can be customized to different application contexts*
  - *End-user programmable tools*
  - *Domain retargetable reverse engineering*

Key Research Pointers ...

- *Concentrate on the tool adoption problem by improving the usability and end-user programmability of reverse engineering tools to ease their integration into actual development processes*
  - *Start with a web-based user interface*
  - *Conduct user studies*

Conclusions

- *Mission statement*
  - *Researchers in software design and formal methods should concentrate on software evolution rather than construction*
  - *Program understanding and analysis experts should teach their methods in 1st-year*
- *Plenty of research problems*
- *Wonderful case studies*
- *Exciting research!!!!*



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