Quality Prediction for Component-Based Software Development: Techniques and A Generic Environment

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Dec. 17, 2001

Outline

- Introduction
- Technical Background and Related Work
- A Quality Assurance Model for CBSD
- A Generic Quality Assessment Environment: ComPARE
- Experiment and Discussion
- Conclusion

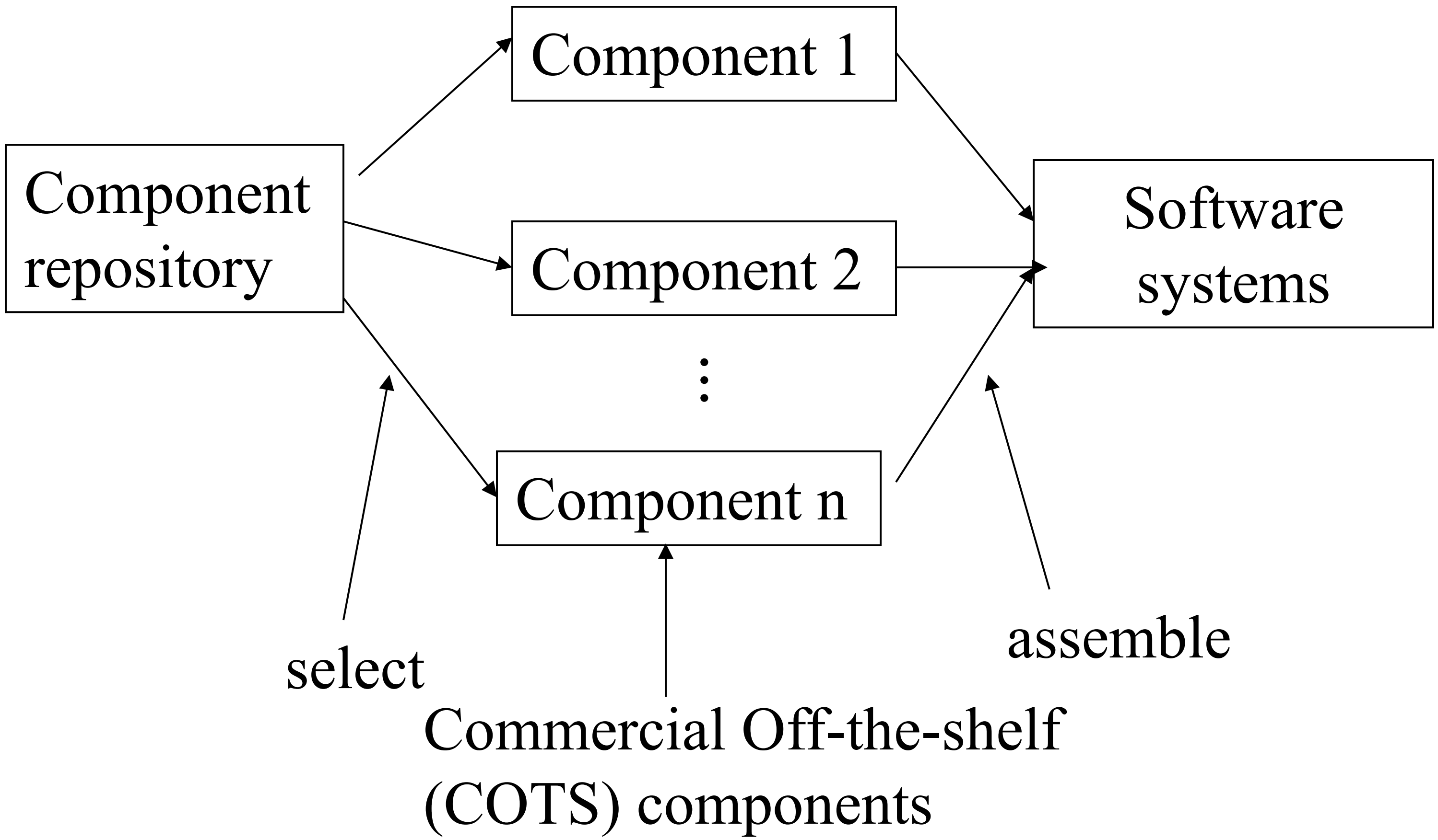
Introduction

- The most promising solution for large-scale, complex and uneasily controlled modern software system is component-based software development (CBSD) approach
- The concept, process, life cycle and infrastructure of CBSD are different from traditional systems
- Quality Assurance (QA) is very important for component-based software systems

Introduction

- Component-based software development (CBSD) is to build software systems using a combination of components
- CBSD aims to encapsulate function in large components that have loose couplings.
- A component is a unit of independent deployment in CBSD.
- The over quality of the final system greatly depends on the quality of the selected components.

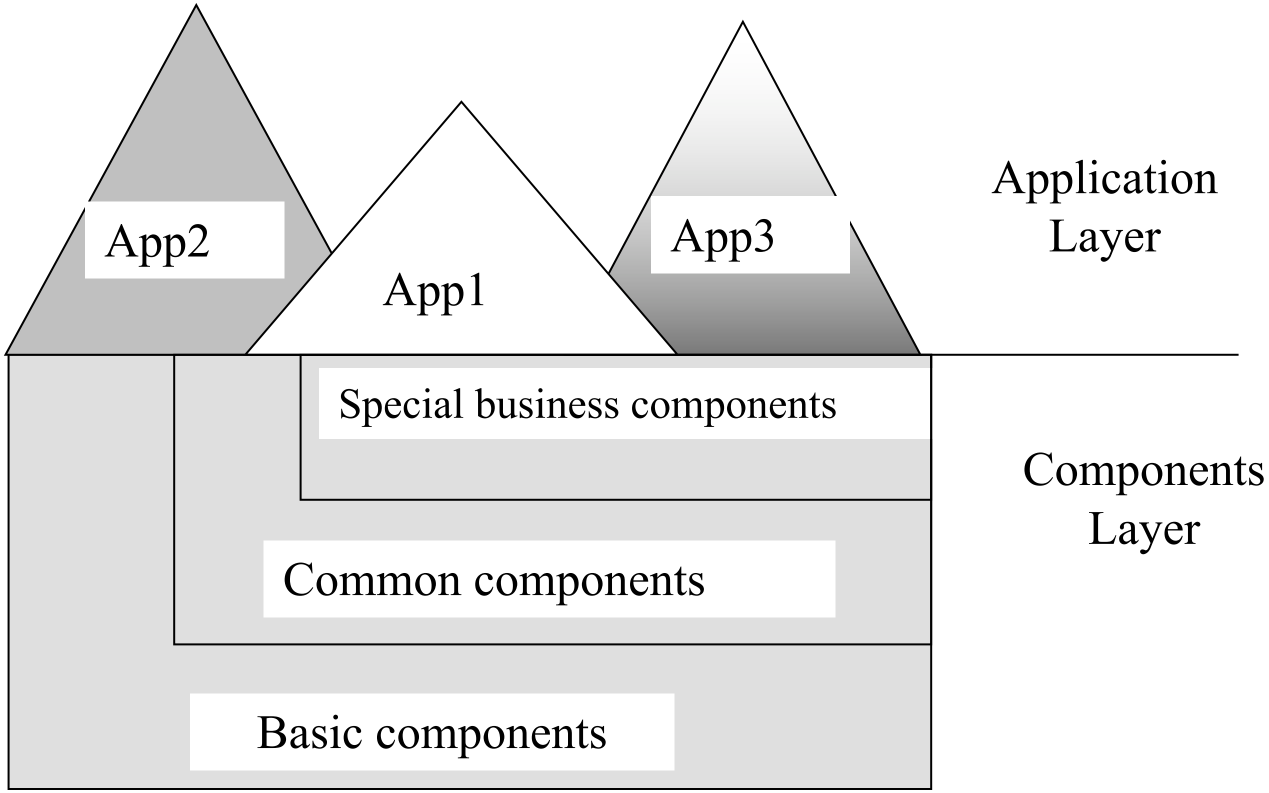
What is Component-Based Software Development ?



What is A Component?

- A component is an independent and replaceable part of a system that fulfills a clear function
- A component works in the context of a well-defined architecture
- It communicates with other components by the interfaces

System Architecture



Problem Statement

- Due to the special feature of CBSD, conventional SQA techniques and methods are uncertain to apply to CBSD.

- We address the investigation of most efficient and effective approach suitable to CBSD

Our Contributions

- A QA model for CBSD which covers eight main processes.
- A quality assessment environment (ComPARE) to evaluate the quality of components and software systems in CBSD.
- Experiments on applying and comparing different quality predicted techniques to some CBSD programs.

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Technical Background and Related Work: Development Frameworks

- A framework can be defined as a set of constraints on components and their interactions, and a set of benefits that derive from those constraints.
- Three somehow standardized component frameworks: CORBA, COM/DCOM, JavaBeans/EJB.

Comparison of Component Frameworks

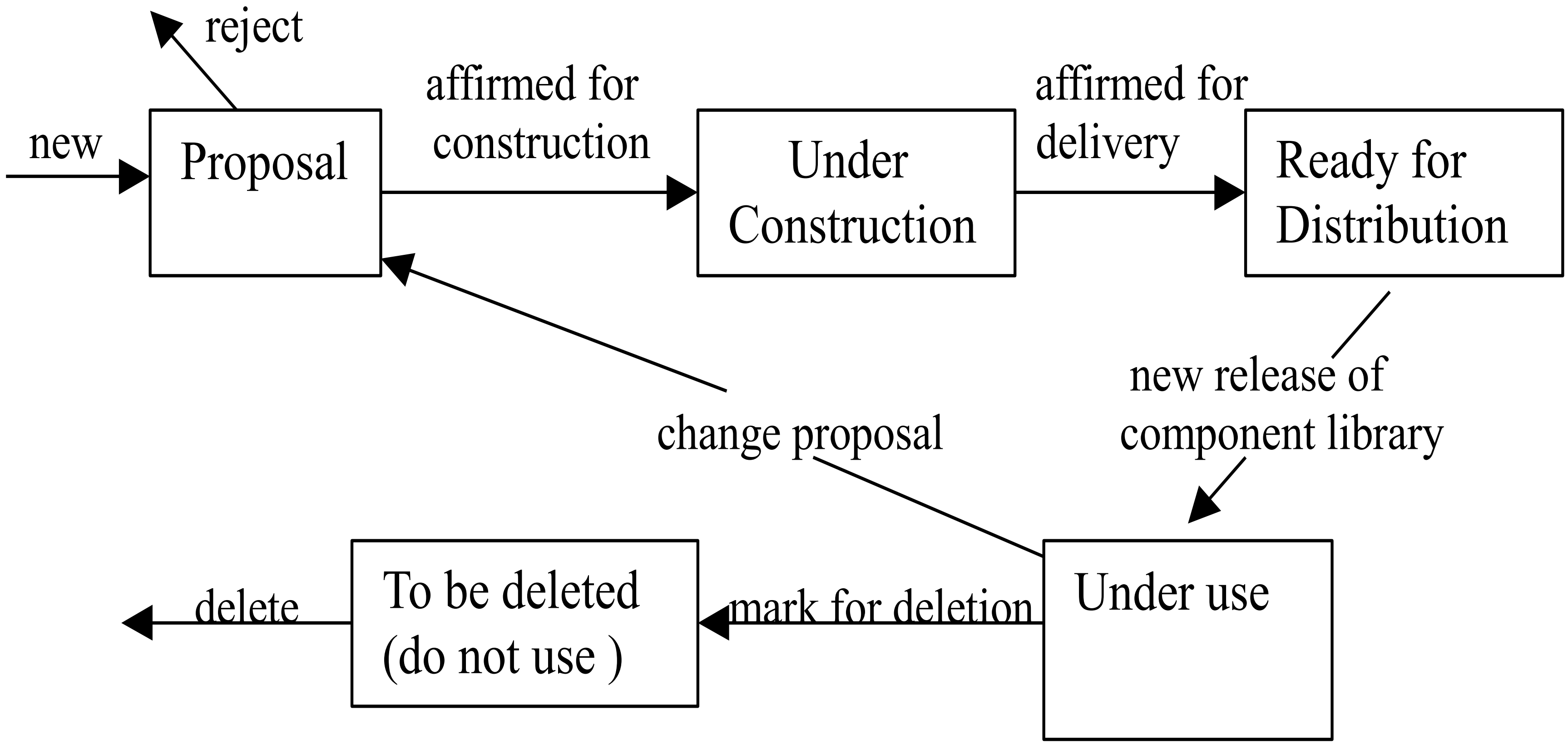
	CORBA	EJB	COM/DCOM
Development environment	Underdeveloped	Emerging	Supported by a wide range of strong development environments
Binary interfacing standard	Not binary standards	Based on COM; Java specific	A binary standard for component interaction is the heart of COM
Compatibility & portability	Strong in standardizing language bindings; but not so portable	Portable by Java language spec; but not very compatible.	Not having any concept of source-level standard of standard language binding.
Modification & maintenance	CORBA IDL for defining component interfaces	Not involving IDL files	Microsoft IDL for defining component interfaces
Services provided	A full set of standardized services; lack of implementations	Neither standardized nor implemented	Recently supplemented by a number of key services
Platform dependency	Platform independent	Platform independent	Platform dependent
Language dependency	Language independent	Language dependent	Language independent
Implementation	Strongest for traditional enterprise computing	Strongest on general Web clients.	Strongest on the traditional desktop applications

Technical Background and Related Work: QA Issues

- How to certify quality of a component?
  - Size
  - complexity
  - reuse frequency
  - reliability

- How to certify quality of a component-based software system?

Life Cycle of A Component



Life Cycle of CBSD

- Requirements analysis
- Software architecture selection, creation, analysis and evaluation
- Component evaluation, selection and customization
- Integration
- Component-based system testing
- Software maintenance

Technical Background and Related Work:

Quality Prediction Techniques

- Case-Based Reasoning
- Classfication Tree Model
- Bayesian Belief Network
- Discriminant Analysis
- Pattern recoginition

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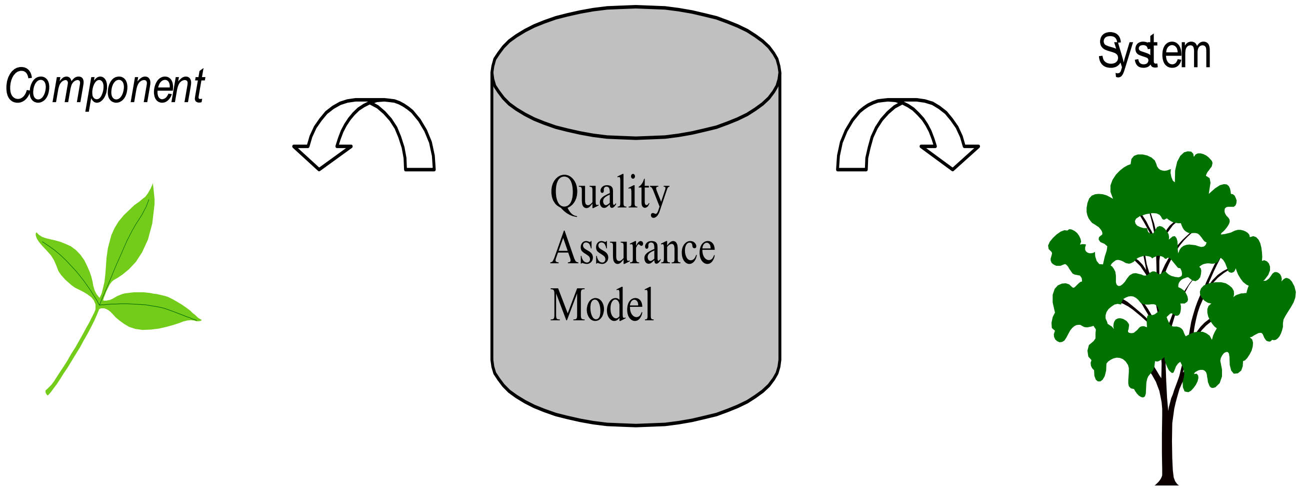
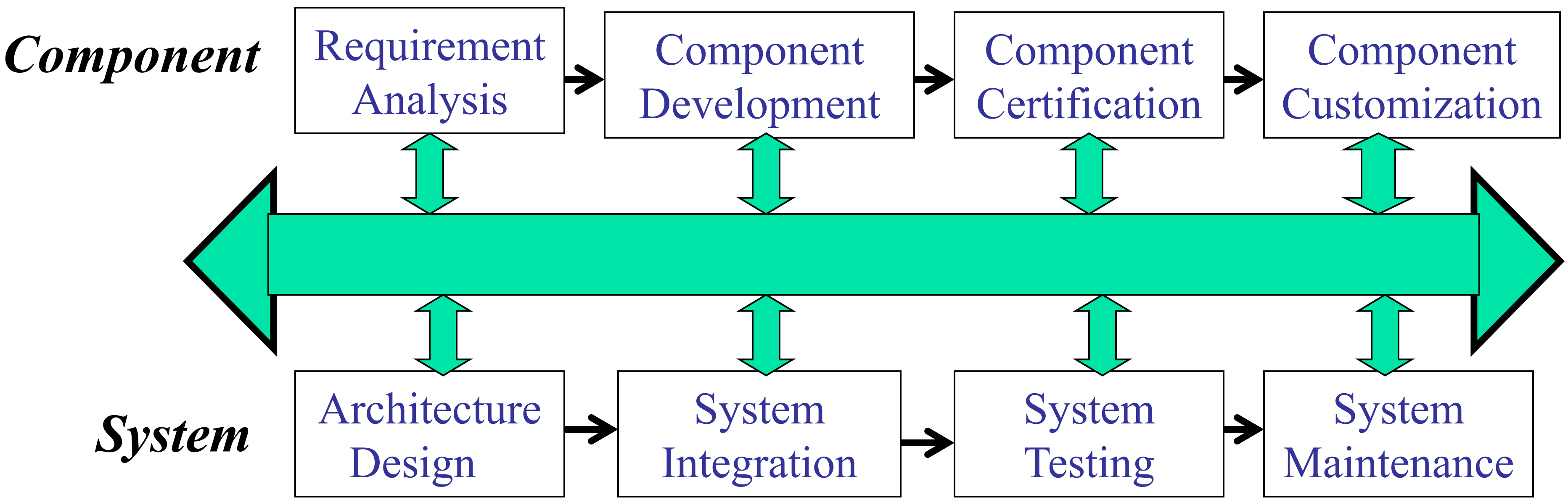
A QA Model for CBSD

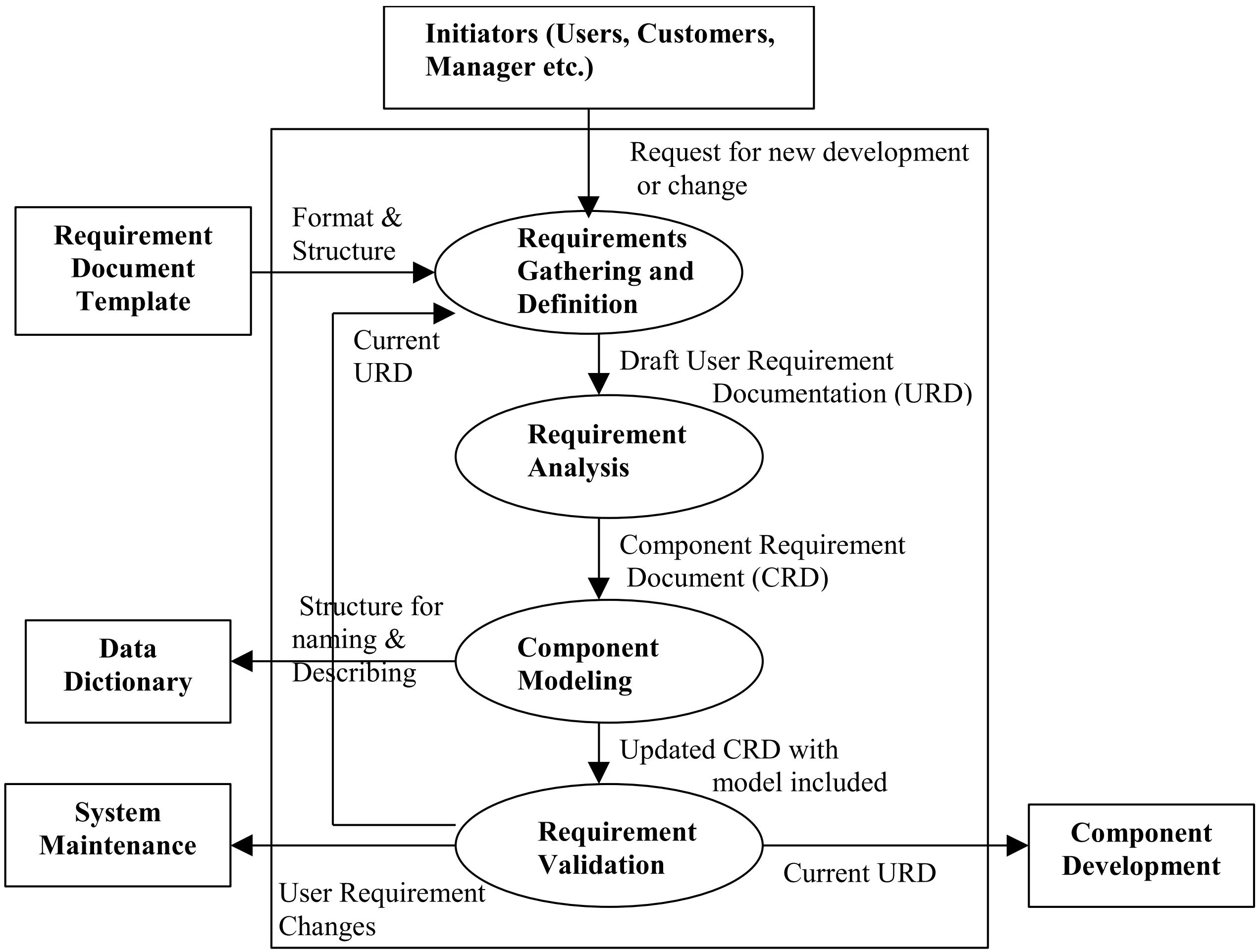
- Component
- System



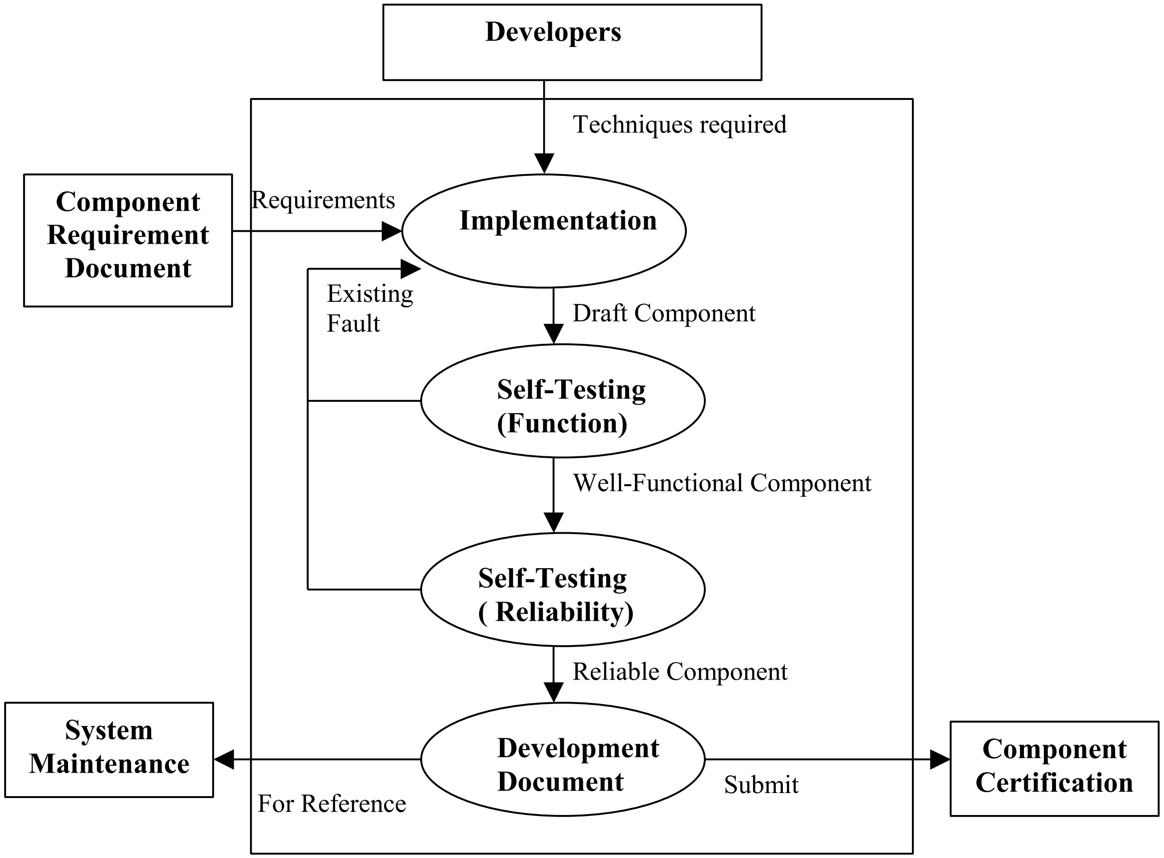
Main Practices



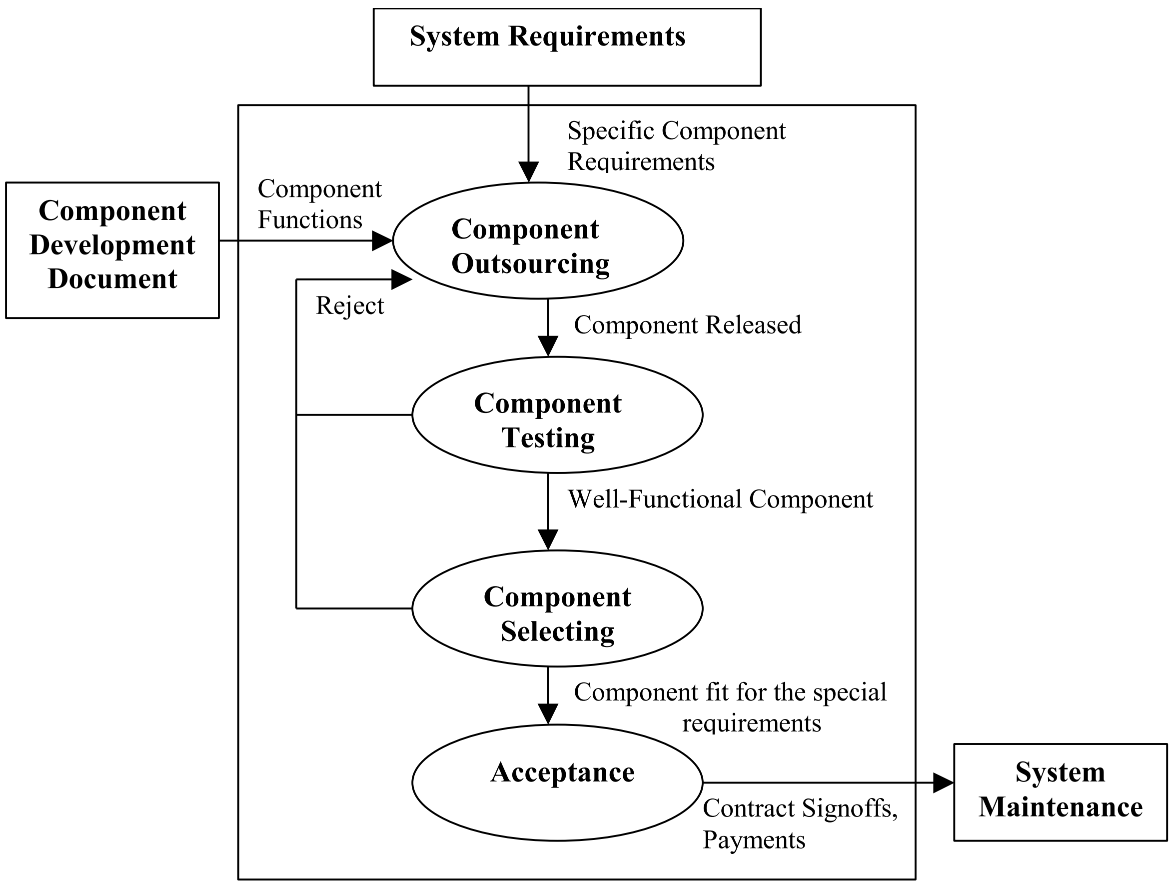
Process Overview:
Component Requirement Analysis



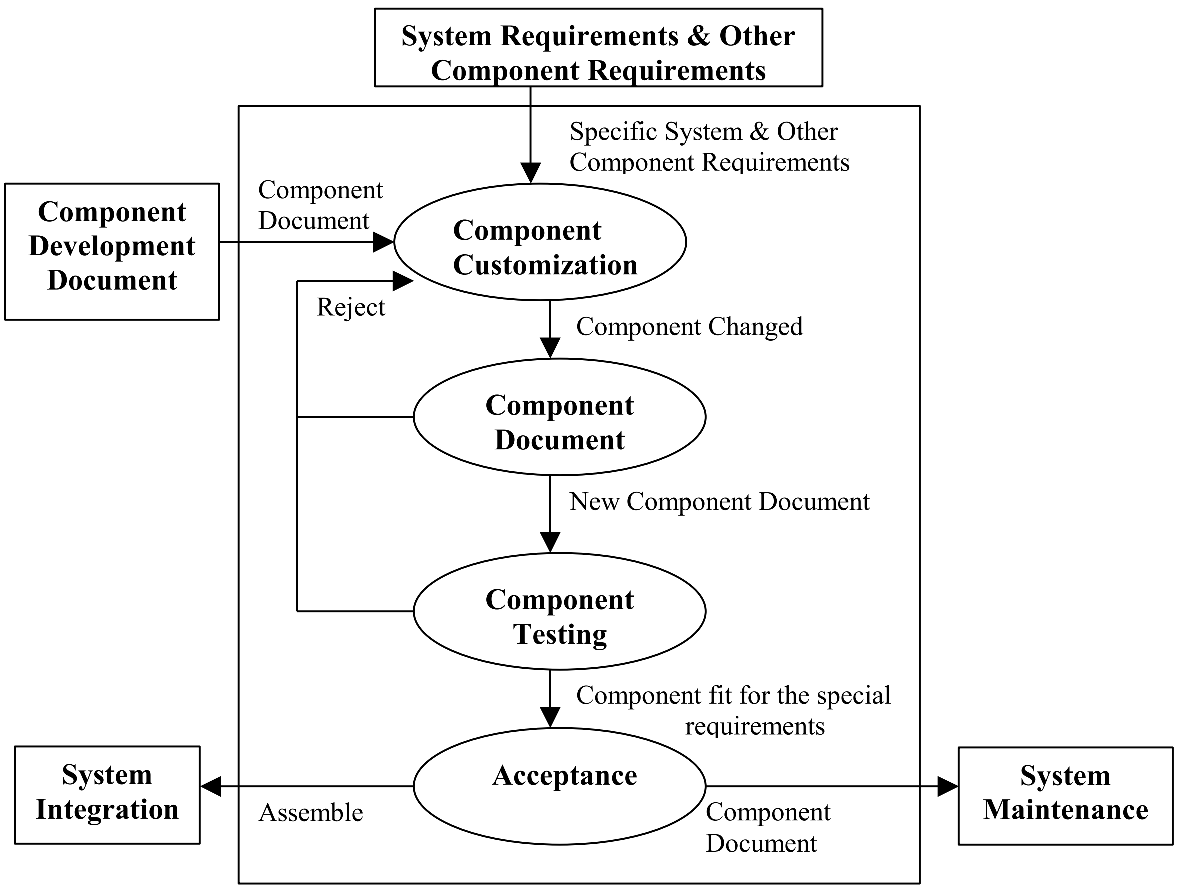
Process Overview:
Component Development



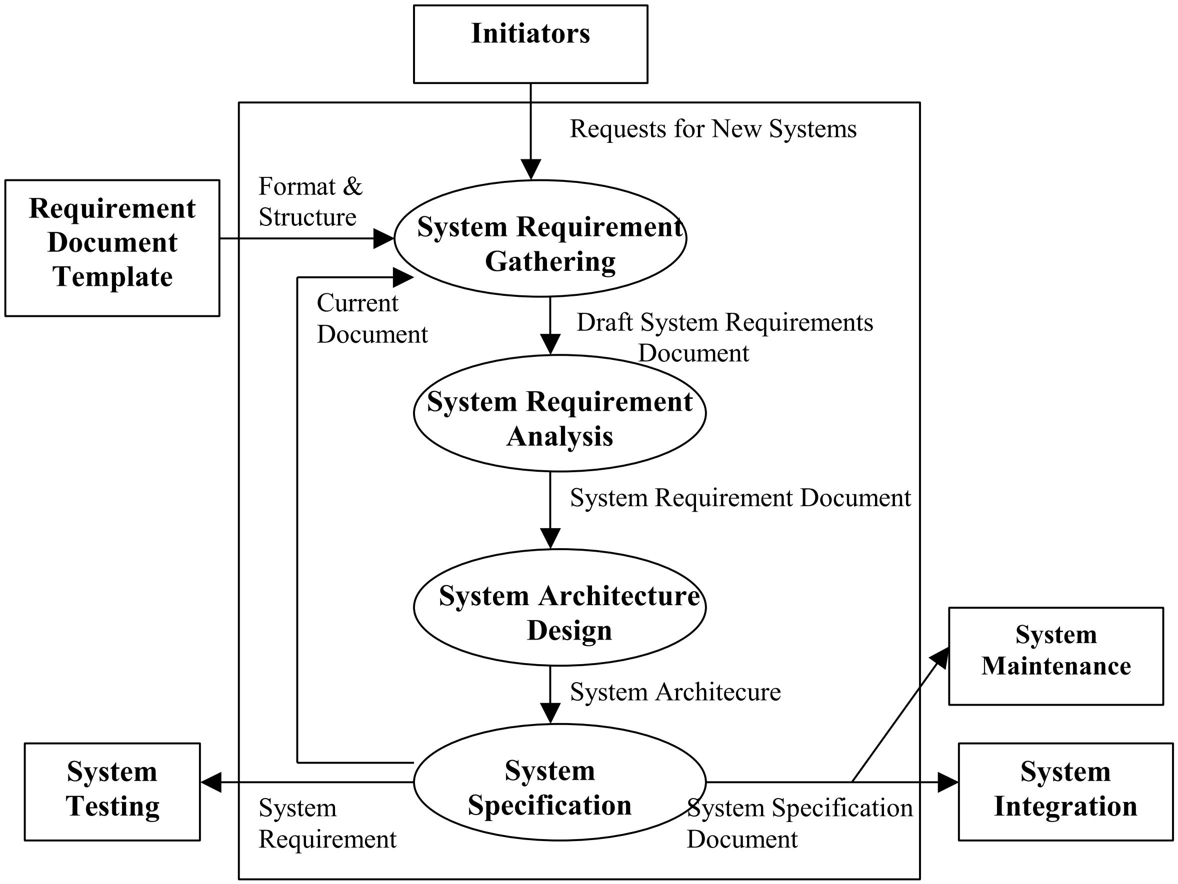
Process Overview:
Component Certification



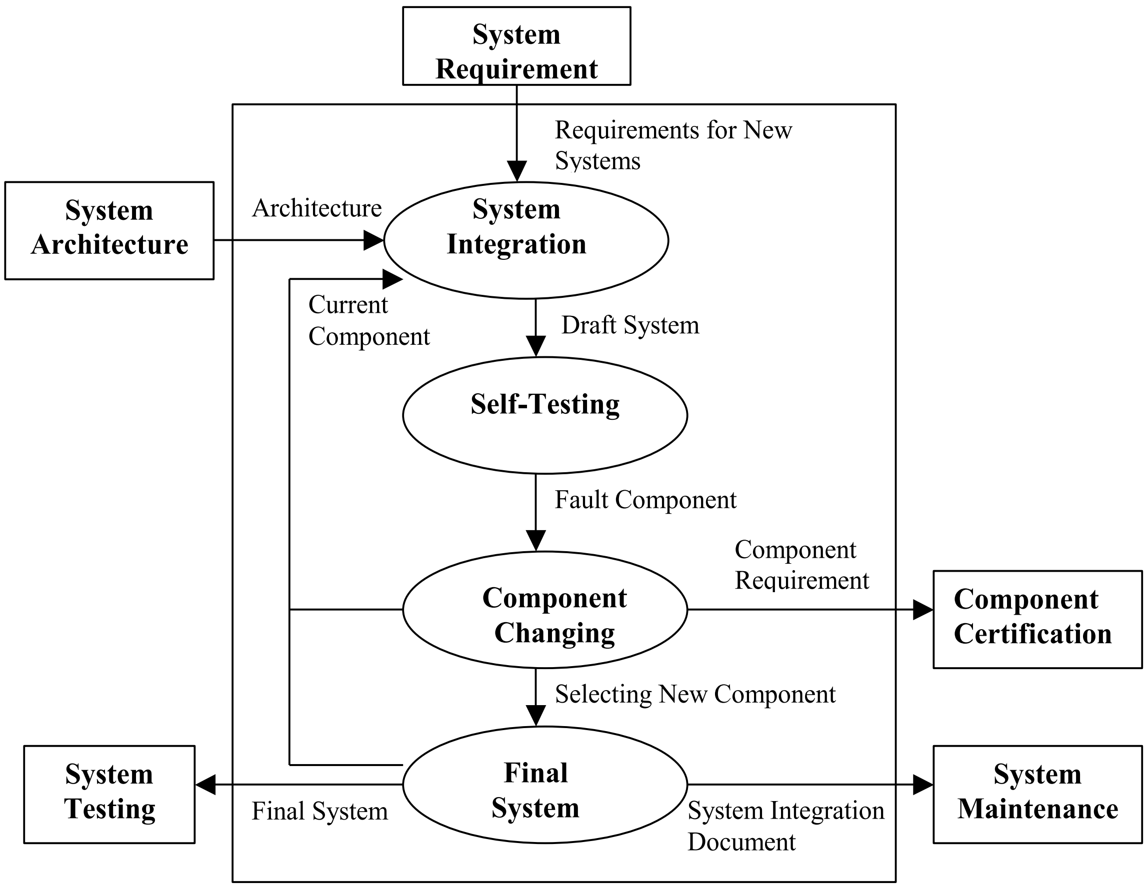
Process Overview:
Component Customization



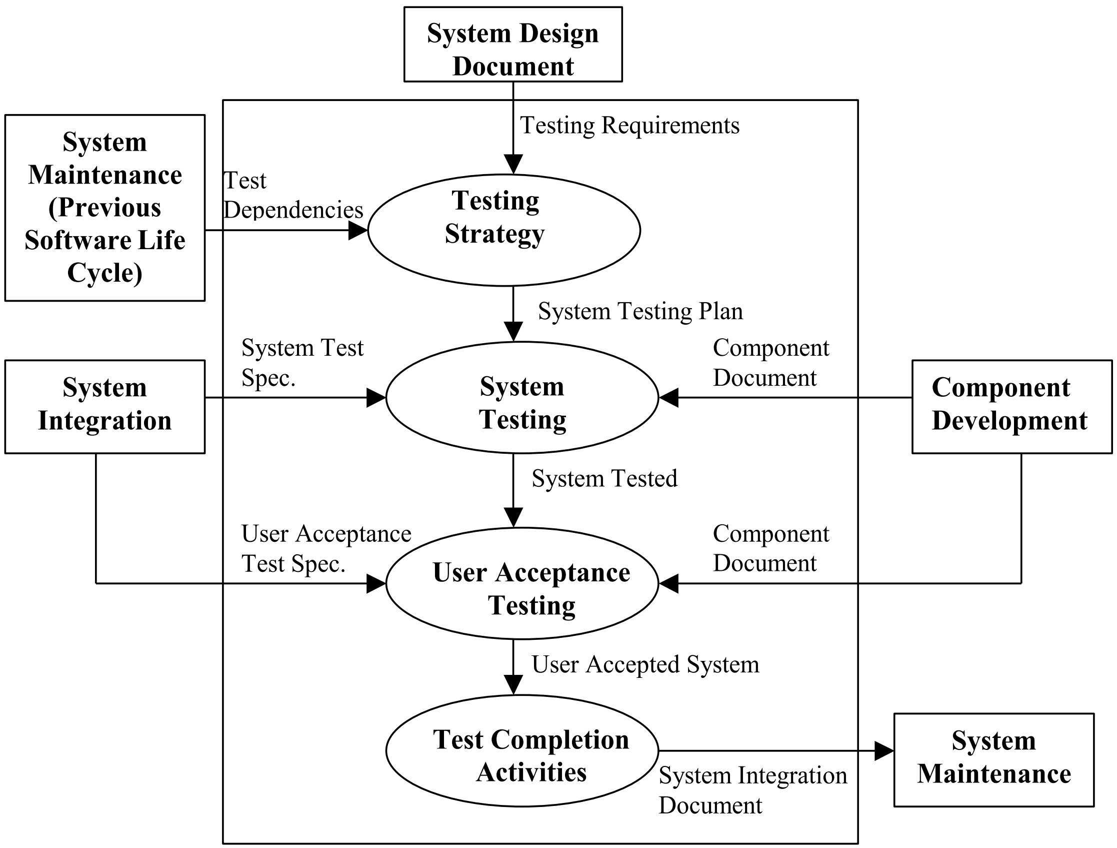
Process Overview:
System Architecture Design



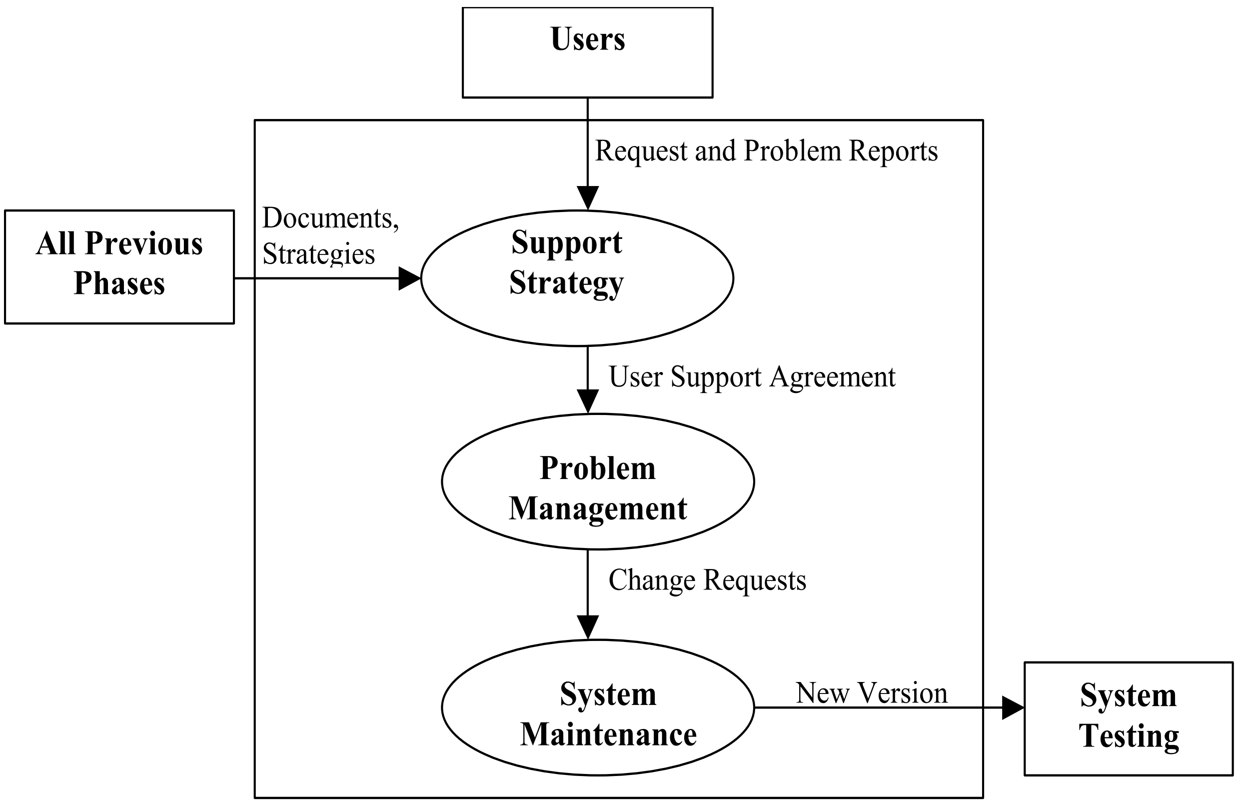
Process Overview:
System Integration



Process Overview:
System Testing



Process Overview:
System Maintenance



The Feature of Our QA Model

Compared with other existing models:

- Simple, easy to apply
- Design for local component vendors (small to medium size)
- Focused on development process, according to the life cycle of CBSD
- Not focused on the measure/predict the quality of components/systems

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ComPARE: A Generic Quality Assessment Environment

- Component-based Program Analysis and Reliability Evaluation
- Automates the collection of metrics, the selection of prediction models, the validation of the established models according to fault data collected in the development process
- Integrates & encapsulate the quality control for different processes defined in our QA model

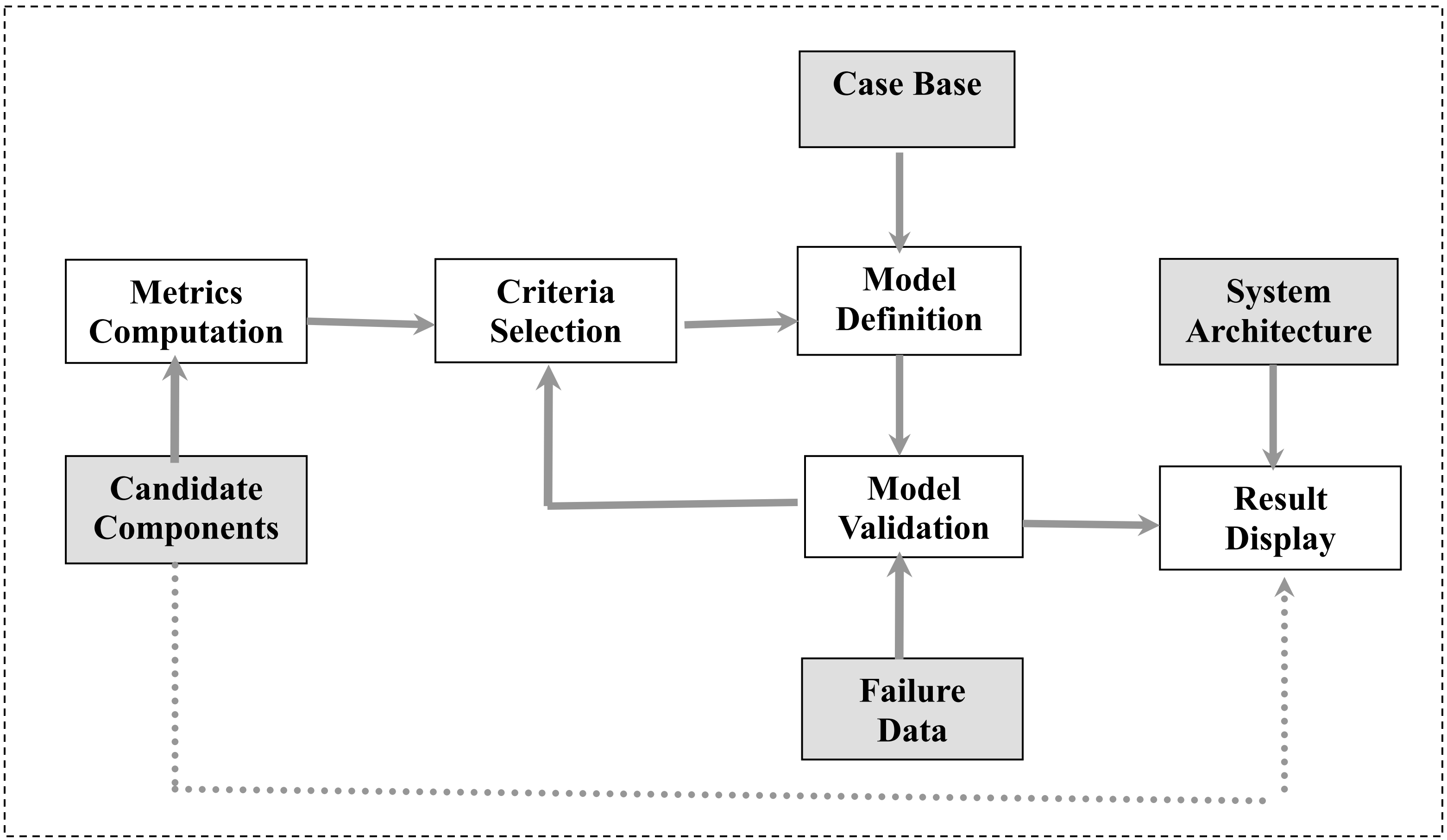
Objective of ComPARE

- To predict the overall quality by using process metrics, static code metrics as well as dynamic metrics.
- To integrate several quality prediction models into one environment and compare the prediction result of different models
- To define the quality prediction models interactively

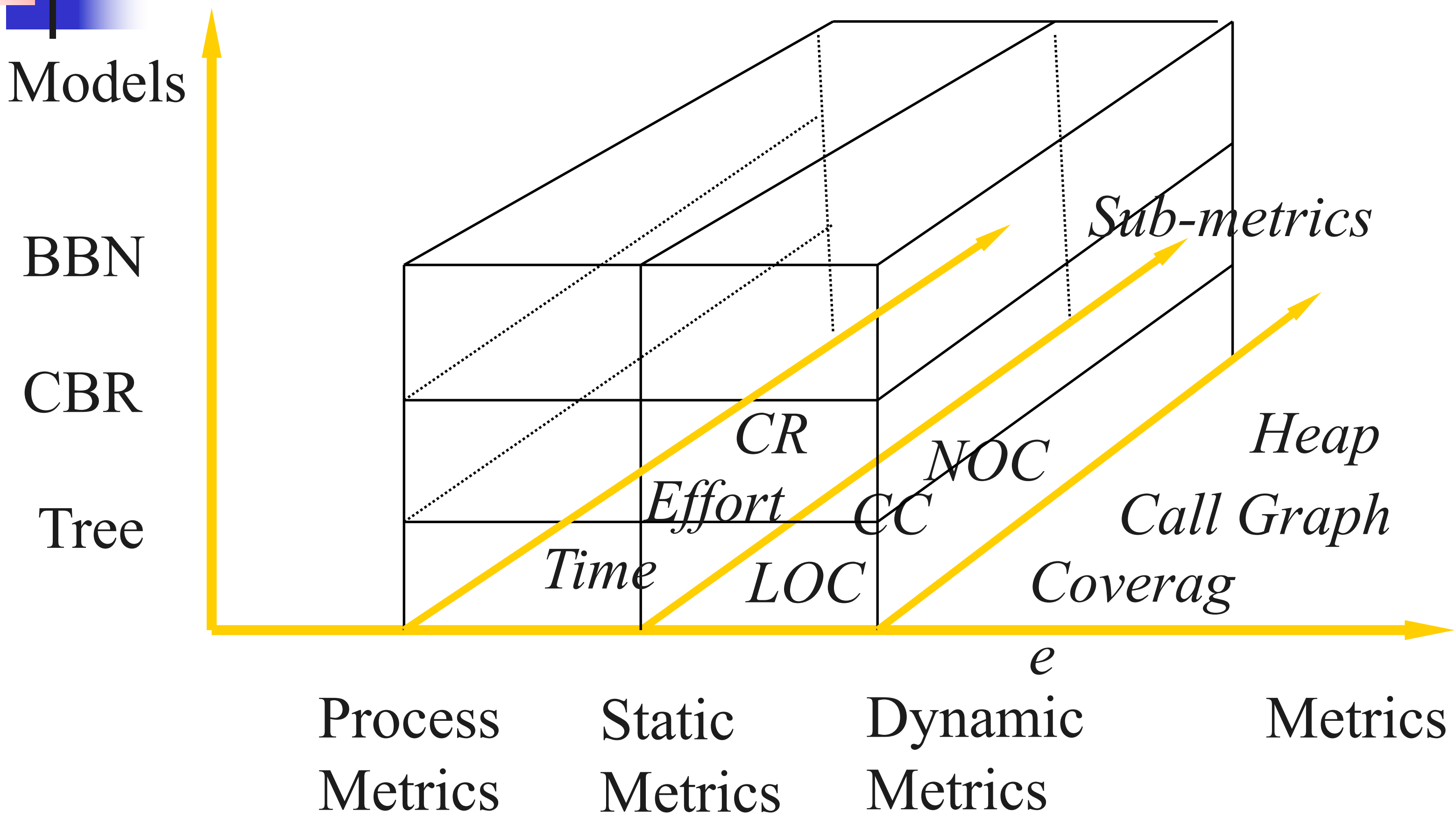
Objective of ComPARE

- To display quality of components by different categories
- To validate reliability models defined by user against real failure data
- To show the source code with potential problems at line-level granularity
- To adopt commercial tools in accessing software data related to quality attributes

Architecture of ComPARE



Combination of Metrics & Models



Quality Control Methods

- Existing Software Quality Assurance (SQA) techniques and methods have explored to measure or control the quality of software systems or process.
  - Management/process control
  - Software testing
  - Software metrics
  - Quality prediction techniques

Quality Assessment Techniques

- Software metrics:
  - Process metrics
  - Static code metrics
  - Dynamic metrics

- Quality prediction model:
  - Classification tree model
  - Case-based reasoning method
  - Bayesian Belief Network

Progress and Dynamic Metrics

Metric	Description
Time	Time spent from the design to the delivery (months)
Effort	The total human resources used (man*month)
Change Report	Number of faults found in the development

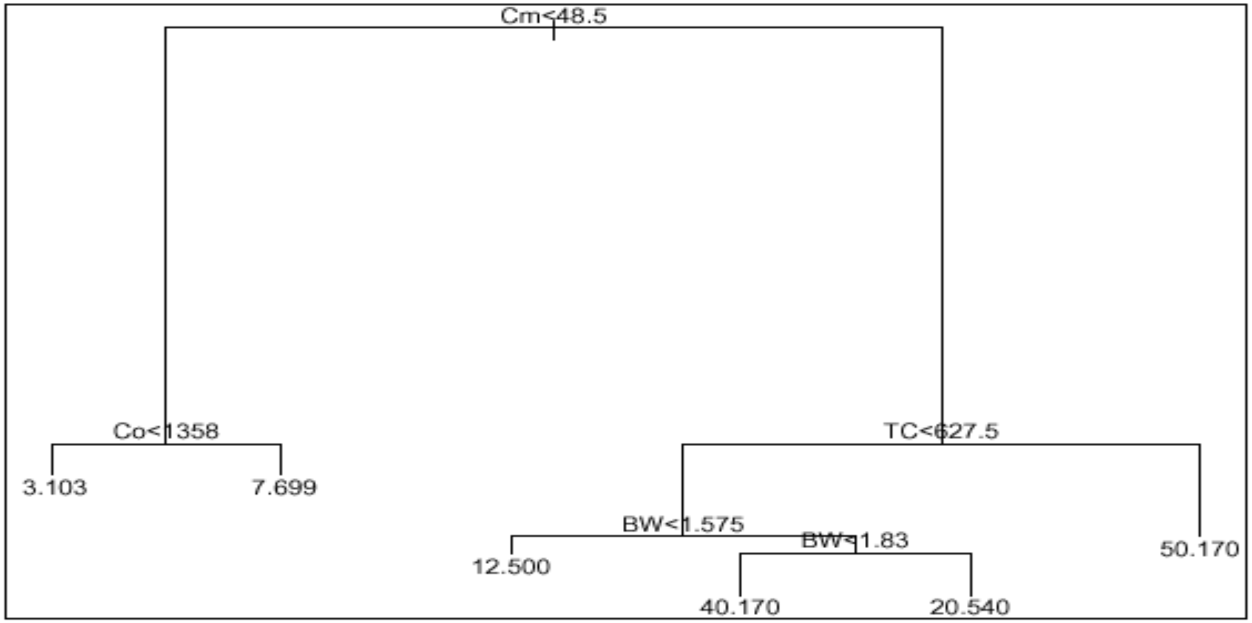
Metric	Description
Test Case Coverage	The coverage of the source code when executing the given test cases. It may help to design effective test cases.
Call Graph metrics	The relationships between the methods, including method time (the amount of time the method spent in execution), method object count (the number of objects created during the method execution) and number of calls (how many times each method is called in you application).
Heap metrics	Number of live instances of a particular class/package, and the memory used by each live instance.

Static Code Metrics

Abbreviation	Description
Lines of Code (LOC)	Number of lines in the components including the statements, the blank lines of code, the lines of commentary, and the lines consisting only of syntax such as block delimiters.
Cyclomatic Complexity (CC)	A measure of the control flow complexity of a method or constructor. It counts the number of branches in the body of the method, defined by the number of WHILE statements, IF statements, FOR statements, and CASE statements.
Number of Attributes (NA)	Number of fields declared in the class or interface.
Number Of Classes (NOC)	Number of classes or interfaces that are declared. This is usually 1, but nested class declarations will increase this number.
Depth of Inheritance Tree (DIT)	Length of inheritance path between the current class and the base class.
Depth of Interface Extension Tree (DIET)	The path between the current interface and the base interface.
Data Abstraction Coupling (DAC)	Number of reference types that are used in the field declarations of the class or interface.
Fan Out (FANOUT)	Number of reference types that are used in field declarations, formal parameters, return types, throws declarations, and local variables.
Coupling between Objects (CO)	Number of reference types that are used in field declarations, formal parameters, return types, throws declarations, local variables and also types from which field and method selections are made.
Method Calls Input/Output (MCI/MCO)	Number of calls to/from a method. It helps to analyze the coupling between methods.
Lack of Cohesion Of Methods (LCOM)	For each pair of methods in the class, the set of fields each of them accesses is determined. If they have disjoint sets of field accesses then increase the count P by one. If they share at least one field access then increase Q by one. After considering each pair of methods, LCOM = (P > Q) ? (P - Q) : 0

Quality Prediction Techniques

- Classfication Tree Model
  - classify the candidate components into different quality categories by constructing a tree structure



Quality Prediction Techniques

- Case-Based Reasoning
  - A CBR classifier uses previous “similar” cases as the basis for the prediction. case base.
  - The candidate component that has a similar structure to the components in the case base will inherit a similar quality level.
  - Euclidean distance, z-score standardization, no weighting scheme, nearest neighbor.

Quality Prediction Techniques

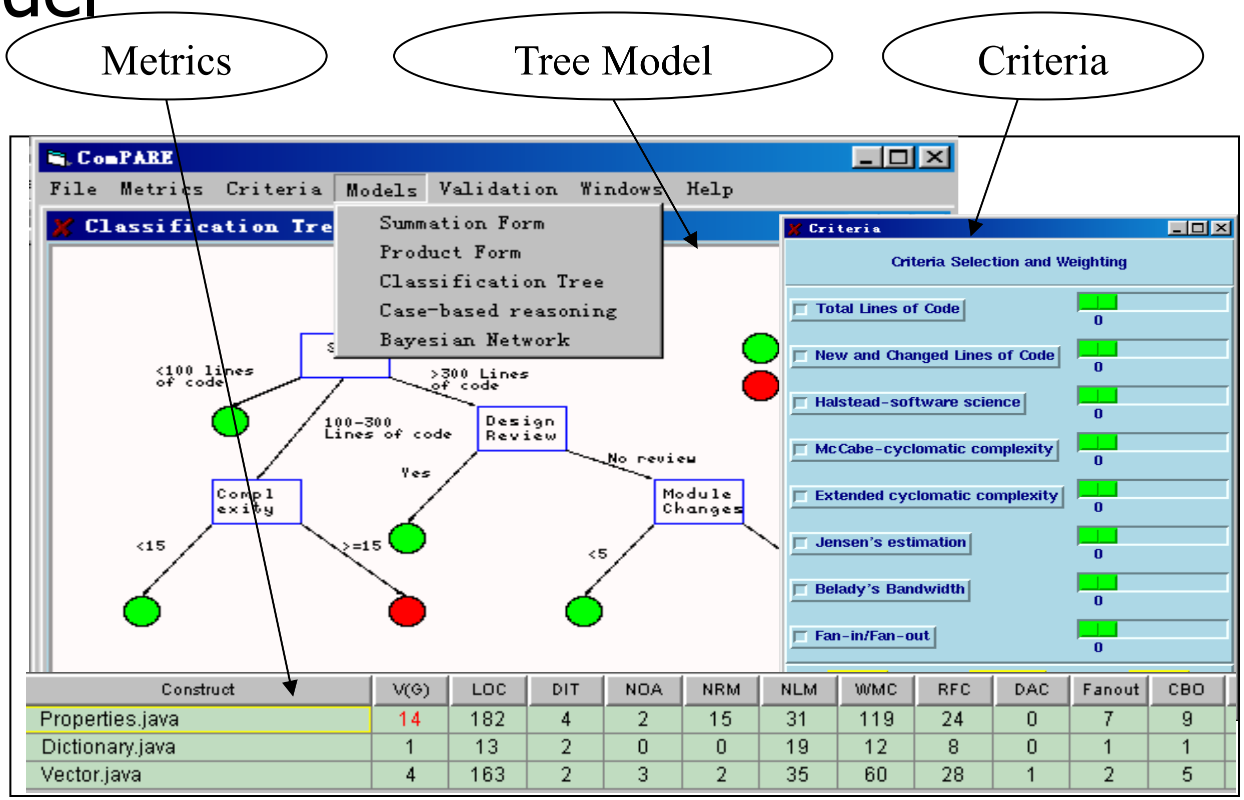
- Bayesian Network
  - a graphical network that represents probabilistic relationships among variables
  - enable reasoning under uncertainty
  - The foundation of Bayesian networks is the following theorem known as Bayes' Theorem:

$$P(H|E,c) = \frac{P(H|c)P(E|H,c)}{P(E|c)}$$

where H, E, c are independent events, P is the probability of such event under certain circumstances

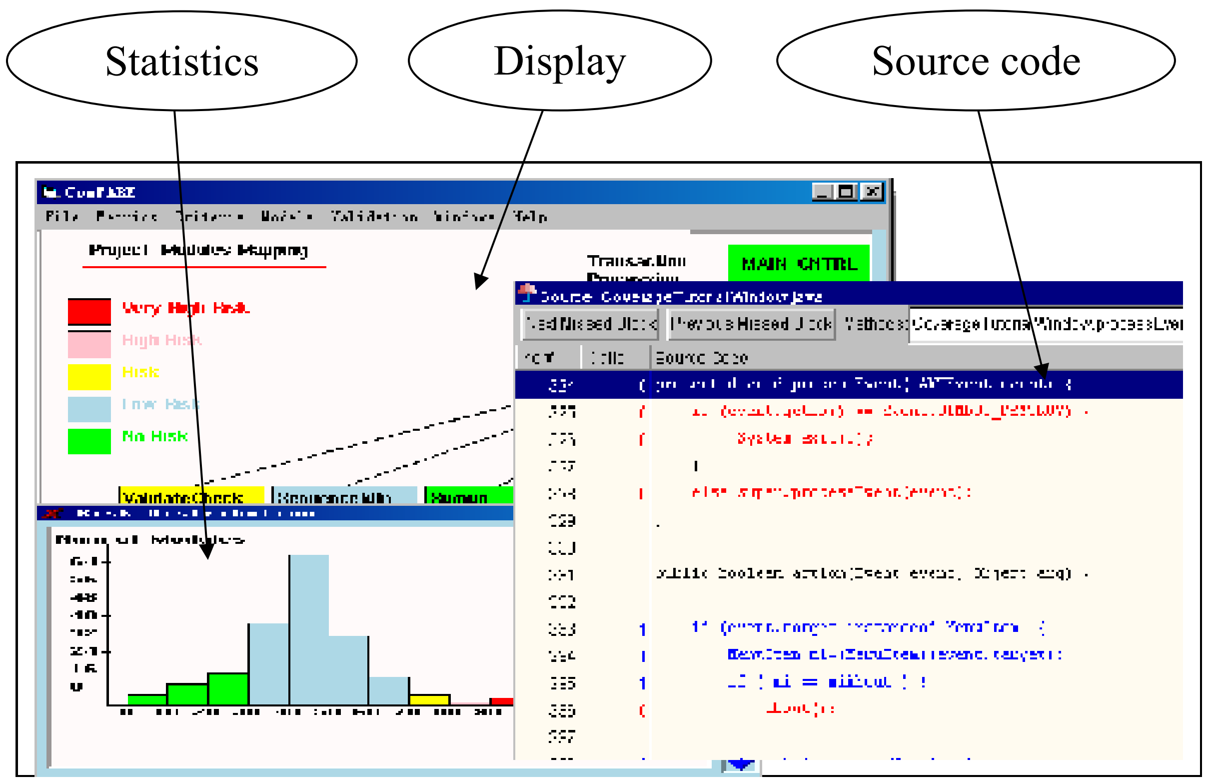
Prototype

- GUI of ComPARE for metrics, criteria and tree model



Prototype

- GUI of ComPARE for prediction display, risky source code and result statistics



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Experiment: Objective

- Apply various existing quality prediction models to component-based programs to see if they are applicable
- Evaluate/validate the prediction results to CBSD
- Investigate the relationship between metrics and quality indicator

Experiment: Data Description

- Real life project --- Soccer Club Management System
- A distributed system for multiple clients to access a Soccer Team Management Server for 10 different operations
- CORBA platform
- 18 set of programs by different teams
- 57 test cases are designed: 2 test cases for each operation: one for normal operation and the other for exception handling.

Experiment: Data Description

Team	TLOC	CLOC	SLOC	CClass	CMethod	SClass	SMethod	Fail	Maybe	R	R1
P2	1129	613	516	3	15	5	26	7	6	0.77	0.88
P3	1874	1023	851	3	23	5	62	3	6	0.84	095
P4	1309	409	900	3	12	1	23	3	12	0.74	0.95
P5	2843	1344	1499	4	26	1	25	2	1	0.95	0.96
P6	1315	420	895	3	3	1	39	13	10	0.60	0.77
P7	2674	1827	847	3	17	5	35	3	14	0.70	0.95
P8	1520	734	786	3	24	4	30	1	6	0.88	0.98
P9	2121	1181	940	4	22	3	43	4	2	0.89	0.93
P10	1352	498	854	3	12	5	41	2	2	0.93	0.96
P11	563	190	373	3	12	3	20	6	3	0.84	0.89
P12	5695	4641	1054	14	166	5	32	1	4	0.91	0.98
P13	2602	1587	1015	3	27	3	32	17	19	0.37	0.70
P14	1994	873	1121	4	12	5	39	4	6	0.82	0.93
P15	714	348	366	4	11	4	33	2	5	0.88	0.96
P16	1676	925	751	3	3	23	44	30	0	0.47	0.47
P17	1288	933	355	6	25	5	35	3	3	0.89	0.95
P18	1731	814	917	3	12	3	20	4	9	0.77	0.93
P19	1900	930	970	3	3	2	20	35	1	0.37	0.39

Experiment: Data Description

- TLOC: the total length of whole program;
- CLOC: lines of codes in client program;
- SLOC: lines of codes in server program;
- CClass: number of classes in client program;
- CMethod: number of methods in client program;
- SClass: number of classes in server program;
- SMethod: number of methods in server program;

Experiment: Data Description

- Fail: the number of test cases that the program fails to pass
- Maybe: the number of test cases, which are designed to raise exceptions, can not apply to the program because the client side of the program deliberately forbids it.
- R: pass rate, defined by $R_j = \frac{P_j}{C}$.
- R1: pass rate 2, defined by $R1_j = \frac{P_j + M_j}{C}$,

C is the total number of test cases applied to the programs (i.e., 57);

P_j is the number of "Pass" cases for program j, P_j = C – Fail – Maybe;

M_j is the number of "Maybe" cases for program j.

Experiment: Procedures

- Collect metrics of all programs: Metamata & JProbe
- Design test cases, use test results as indicator of quality
- Apply on different models
- Validate the prediction results against test results

Experiment: Modeling Methodology

- Classification Tree Modeling

  - CART: Classification and Regression Trees

- Bayesian Belief Network

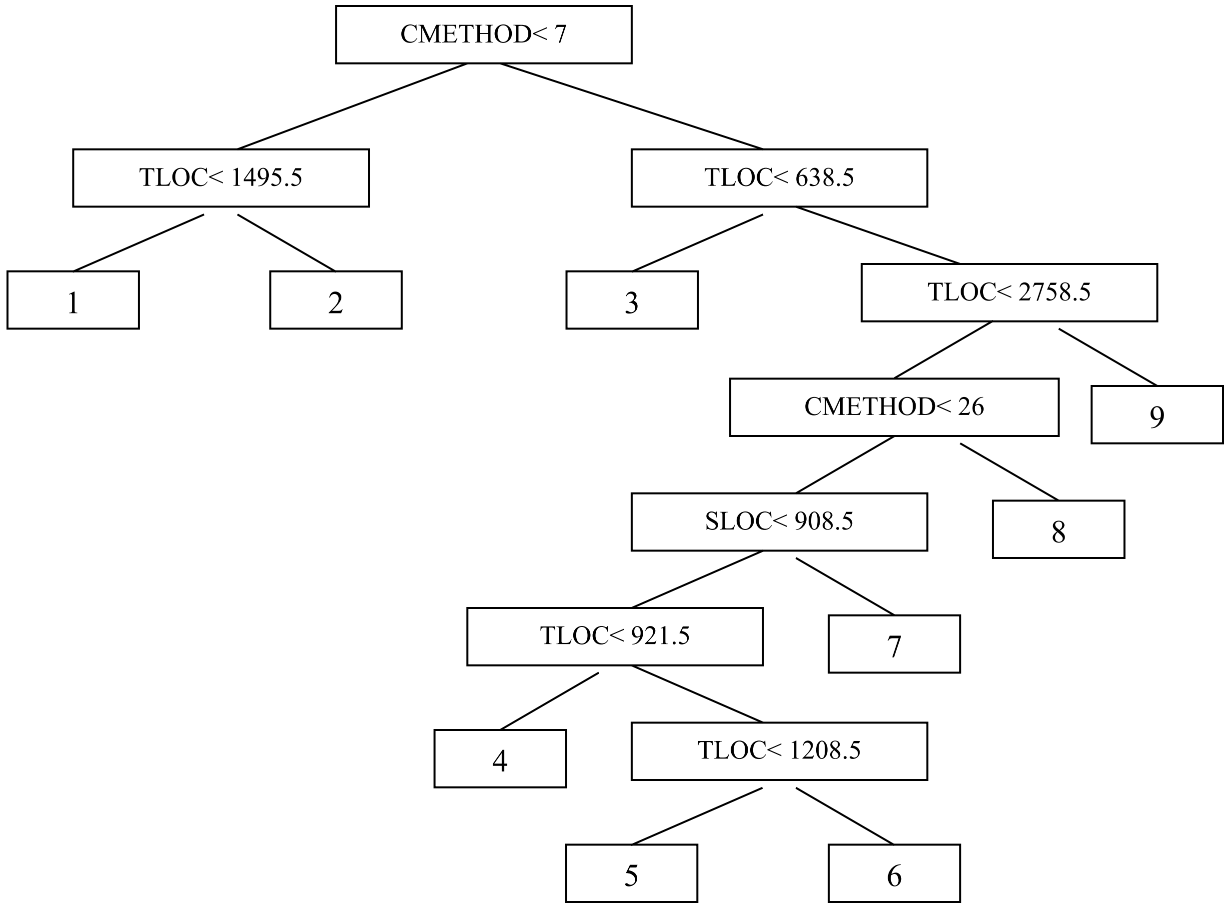
  - Hugin system

CART

- Splitting Rules: all possible splits
- Choosing a split: GINI, gwoing, ordered twoing, class probability, least squares, least abosolute deviation
- Stopping Rules: too few cases
- Cross Validation: 1/10

  for smaller datasets and cases

CART: Tree Structure



CART: Node Information

Parent Node	Wgt Count	Count	Median	MeanAbsDev	Complexity
1	1.00	1	13.000	0.000	17.000
2	2.00	2	35.000	2.500	17.000
3	1.00	1	6.000	0.000	6.333
4	1.00	1	2.000	0.000	2.500
5	1.00	1	7.000	0.000	4.000
6	6.00	6	3.000	0.500	4.000
7	3.00	3	4.000	0.000	3.000
8	1.00	1	17.000	0.000	14.000
9	2.00	2	2.000	0.500	8.000

CART: Variable Importance

Metrics	Relative Importance	Number Of Categories	Minimum Category
CMETHOD	100.000		
TLOC	45.161		
SCLASS	43.548		
CLOC	33.871		
SLOC	4.839		
SMETHOD	0.000		
CCLASS	0.000		

N of the learning sample = 18

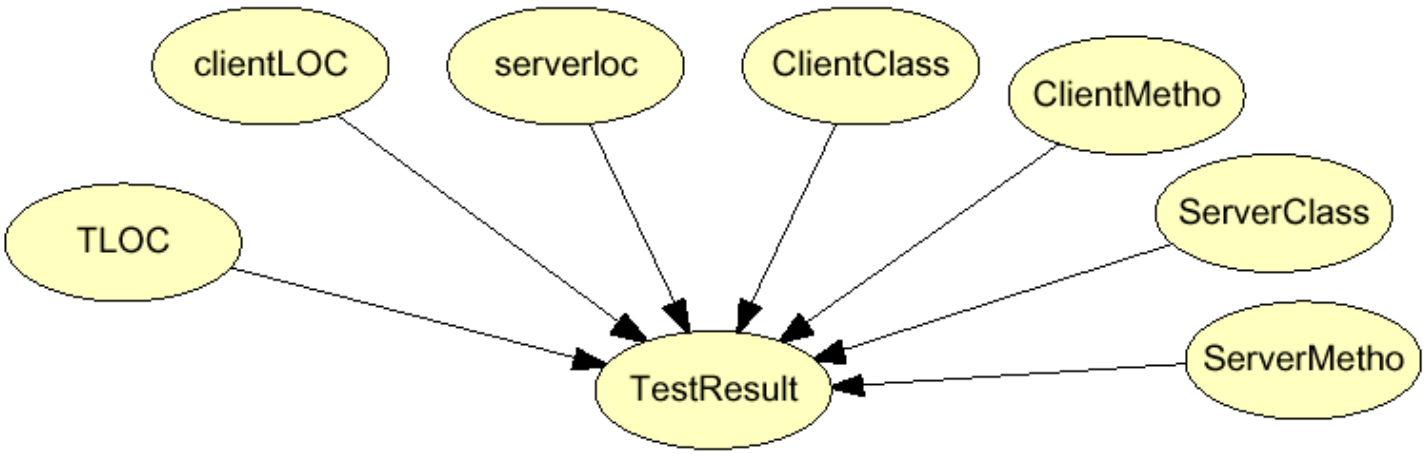
CART: Result Analysis

Terminal Node	Mean Faults	CMethod	TLOC	SLOC
4	2	7~26	638.5~921.5	<=908.5
9	2	>7	<=638.5	-
6	3	7~26	1208.5~2758.5	<=908.5
7	4	7~26	638.5~921.5	>908.5
3	6	>7	<=638.5	-
5	7	7~26	638.5~921.5	<=908.5
1	13	<=7	<=1495.5	-
8	17	>26	638.5~921.5	-
2	35	<=7	>1495.5	-

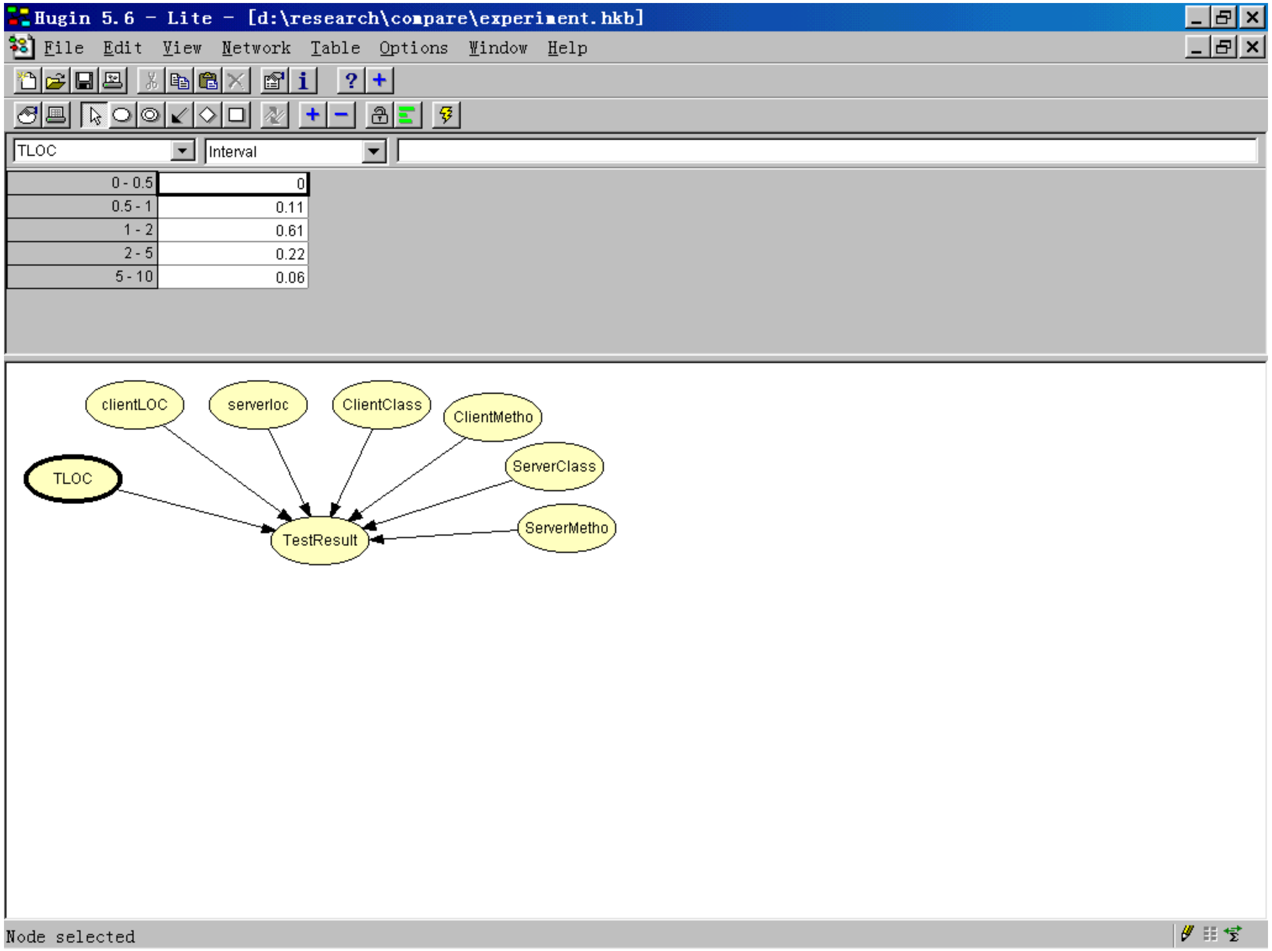
Hugin Explorer System

- Construct model-based decision support systems in domains characterized by inherent uncertainty.
- Support Bayesian belief networks and their extension influence diagrams.
- Define both discrete nodes and continuous nodes

Hugin: Influence Diagram



Hugin: Probability Description



Hugin: Propagation

- The sum propagation shows the true probability of state of nodes with the total summation 1
- For the max propagation, if a state of a node belongs to the most probable configuration it is given the value 100, all other states are given the relative value of the probability of the most probable configuration they are found in compared to the most probable configuration.

Hugin: Propagation

- Using max propagation instead of sum propagation, we can find the probability of the most likely combination of states under the assumption that the entered evidence holds. In each node, a state having the value 100.00 belongs to a most likely combination of states.

Hugin: Run Result (sum prop.)

ClientClass

88.00	1 - 5
6.00	5 - 10
6.00	10 - 15

ClientMethod

17.00	1 - 10
78.00	10 - 50
-	50 - 100
5.00	100 - 200

ServerClass

94.00	1 - 5
-	5 - 10
6.00	10 - 15

ServerMethod

-	1 - 10
94.00	10 - 50
6.00	50 - 100
-	100 - 200

TLOC

-	0 - 0.5
11.00	0.5 - 1
61.00	1 - 2
22.00	2 - 5
6.00	5 - 10

TestResult

35.78	0 - 5
23.11	5 - 10
20.45	10 - 20
20.65	20 - 40

clientLOC

28.00	0 - 0.5
38.00	0.5 - 1
28.00	1 - 2
6.00	2 - 5
-	5 - 10

serverloc

17.00	0 - 0.5
61.00	0.5 - 1
22.00	1 - 2
-	2 - 5
-	5 - 10

ClientClass

91.27	1 - 5
4.53	5 - 10
4.19	10 - 15

ClientMethod

9.53	1 - 10
86.98	10 - 50
-	50 - 100
3.49	100 - 200

ServerClass

95.89	1 - 5
-	5 - 10
4.11	10 - 15

ServerMethod

-	1 - 10
94.96	10 - 50
5.04	50 - 100
-	100 - 200

TLOC

-	0 - 0.5
7.91	0.5 - 1
67.18	1 - 2
20.72	2 - 5
4.19	5 - 10

TestResult

* 100.00	0 - 5
-	5 - 10
-	10 - 20
-	20 - 40

clientLOC

32.07	0 - 0.5
37.98	0.5 - 1
25.76	1 - 2
4.19	2 - 5
-	5 - 10

serverloc

12.44	0 - 0.5
65.13	0.5 - 1
22.43	1 - 2
-	2 - 5
-	5 - 10

ClientClass

87.20	1 - 5
6.31	5 - 10
6.49	10 - 15

ClientMethod

14.75	1 - 10
79.84	10 - 50
-	50 - 100
5.41	100 - 200

ServerClass

93.64	1 - 5
-	5 - 10
6.36	10 - 15

ServerMethod

-	1 - 10
93.95	10 - 50
6.05	50 - 100
-	100 - 200

TLOC

-	0 - 0.5
12.24	0.5 - 1
60.83	1 - 2
20.44	2 - 5
6.49	5 - 10

TestResult

-	0 - 5
* 100.00	5 - 10
-	10 - 20
-	20 - 40

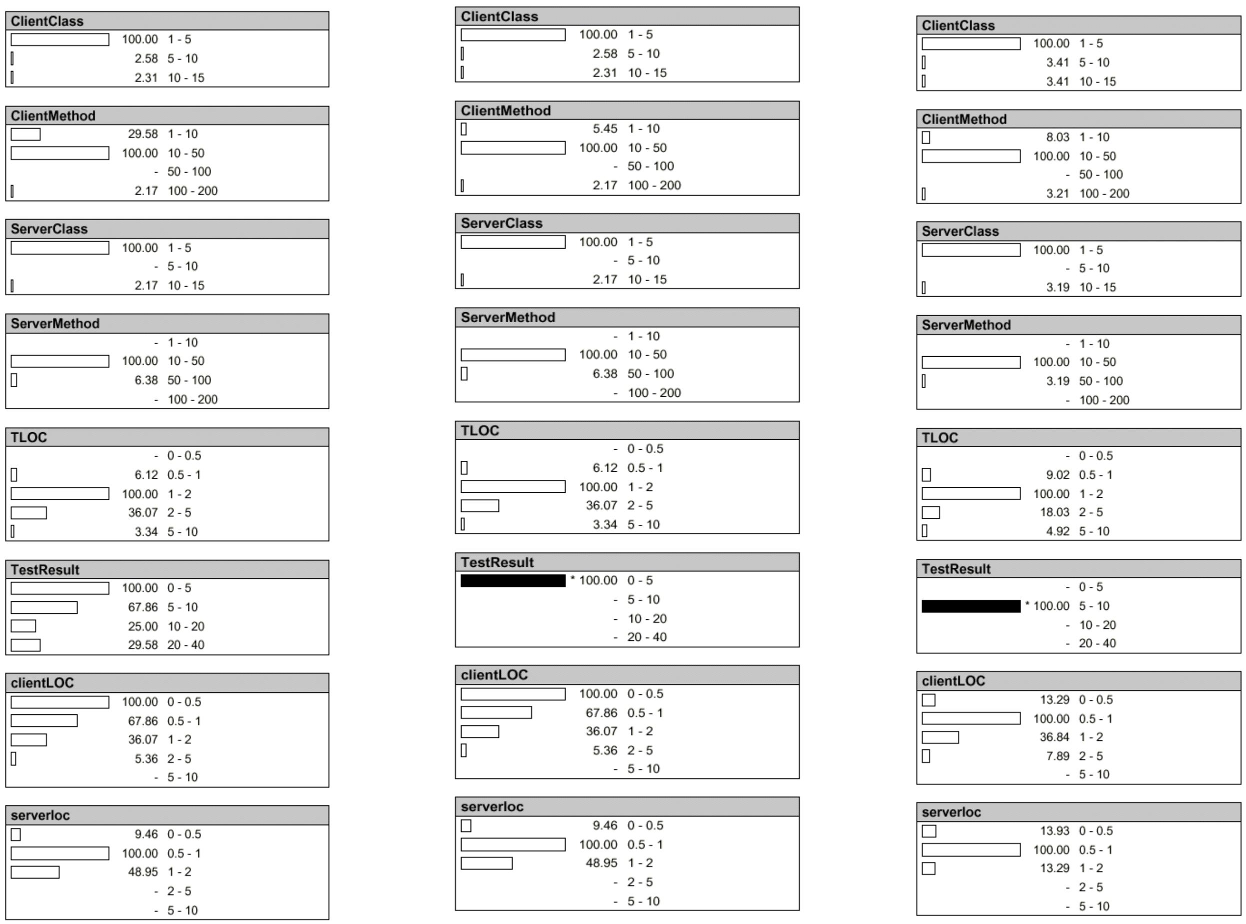
clientLOC

22.31	0 - 0.5
44.71	0.5 - 1
26.50	1 - 2
6.49	2 - 5
-	5 - 10

serverloc

18.56	0 - 0.5
61.88	0.5 - 1
19.56	1 - 2
-	2 - 5
-	5 - 10

Hugin: Run Result (max prop.)



Hugin: Result Analysis

TestResu lt	CCLASS	CMethod	SCLASS	SMethod	TLOC	CLOC	SLOC
0-5	1-5	10-50	1-5	10-50	1-2K	0-0.5K	0.5-1K
5-10	1-5	10-50	1-5	10-50	1-2L	0.5-1K	0.5-1K

Comparison

Modeling	Advantage	Disadvantage
Classification Tree	Very accurate if the learning sample is large enough	Need large learning data and data description
Bayesian Belief Network	Can suggest the best combination of metrics for the faults in a specific range	Need expert acknowledge in a specific domain to construct a correct influence diagram

Discussion

- For testing result between 0-5, the range of CMethod, TLOC and SLOC is very close in the two modeling methods.
- For our experiment, the learning data set is limited to 18 teams.
- The prediction results will be more accurate and representative if the learning data set is larger.

Discussion

- If more learning data and more metrics are available, the results will be more complex and hard to analysis.
- This will raise the need for an automatic and thorough modeling and analysis environment to integrate and encapsulate such operations. That's exactly what ComPARE aims at.

Discussion

- Case-based reasoning is not applied in our experiment because the lack of tool, yet it can be simulated by the results of the classification tree.
- Dynamic metric is not collected because of the complex and confliction of the CORBA platform and existing metric-collected tool.

Conclusion

- Problem: conventional SQA techniques are not applicable to CBSD.
- We propose a QA model for CBSD which covers eight main processes.
- We propose an environment to integrate and investigate most efficient and effective approach suitable to CBSD.

Conclusion

- Experiments of applying and comparing different quality predicted techniques to some CBSD programs have been done.
- Not enough component-based software programs and results collected for our experiment
- Validation/evaluation of different models should be done if learning data set is large enough

Thank you!