Examples of Existing Software Measures. Week 3.

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Initial Classification for Metrics

- Size Oriented Metrics
- Function Oriented Metrics
- Object-Oriented Metrics
- Chidamber and Kemerer (CK) Suite

Typical Size-Oriented Metrics

- Errors per KLOC (thousand lines of code)
- Defects per KLOC
- $ per LOC
- Page of documentation per KLOC
- Errors / person-month
- LOC per person-month
- $ / page of documentation

Typical Function-Oriented Metrics

- Errors per FP (thousand lines of code)
- Defects per FP
- $ per FP
- Pages of documentation per FP
- FP per person-month

Size Oriented Metrics

Lines of Code

- Need for a standard (a normalization)
  - For instance we use the count of the ";"
- Once a standard is set they can be computed automatically (Objective metrics)
- ***They MUST not be used to evaluate people productivity (easy to alter!!!)***
- When used "properly" they work!!

Example (with our definition)

```
void f() {
    while (!done){
        count++; //1
       if(count > 10){
            fixed_count = fixed_count + count; //2
            done = 1; //3
        } else if(count >5){
            fixed_count --; //4
        } else {
            fixed_count = count * 4; //5
        }
    } // while
}
```

$$LOC = 5!$$

Example (with another definition)

```
void f() { //1
    while (!done){ //2
        count++; //3
       if(count > 10){
            fixed_count = fixed_count + count; //4
            done = 1; //5
        } else if(count >5){ //6
            fixed_count --; //7
        } else { //8
            fixed_count = count * 4; //9
        } //10
    } //11
} // 12
```

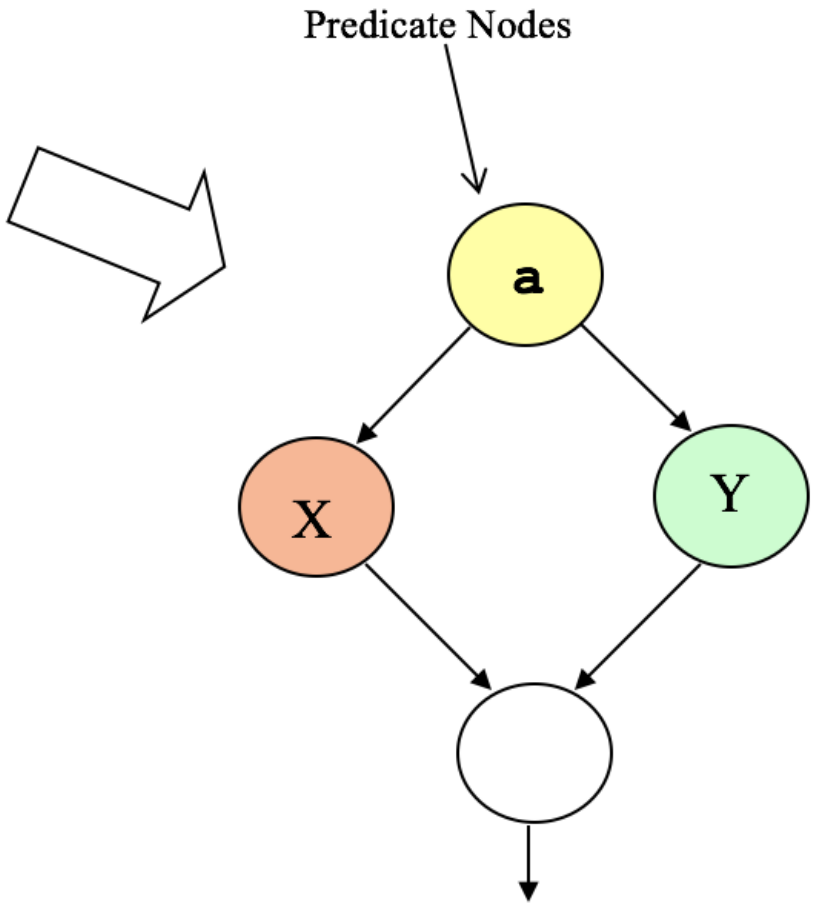
$LOC = 12!$

The quest for productivity measures

- In how many ways I can write a sequence of 10 **sqrt()s**???
- Usually productivity is defined "Output/Input"
- But what is the Output in SW? What is the Input?
- LOC/effort is evaluating the volume throughput, taking into account the input volume!

Flow Graph

```
if (a) {
        X();
} else {
        Y();
}
```

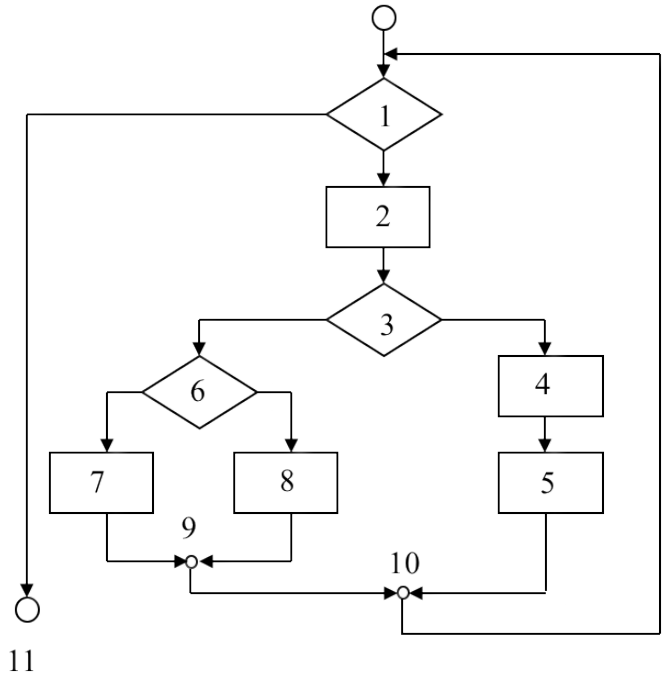


from Pressman pg 459

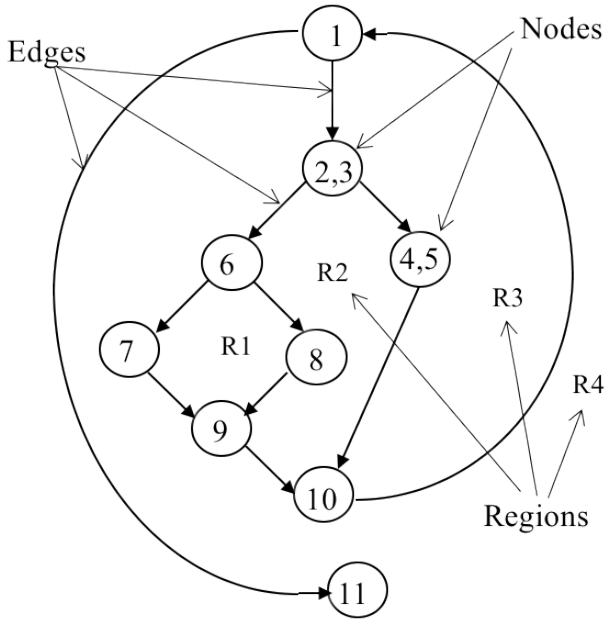
Introducing Cyclomatic Complexity

```
void f() {
    while (!done){
        count++;
       if(count > 10){
            fixed_count = fixed_count + count;
            done = 1;
        } else if(count >5){
            fixed_count --;
        } else {
            fixed_count = count * 4;
        }
    } // while
}
```

Flow Graph Notation



Flow Chart



Flow Graph

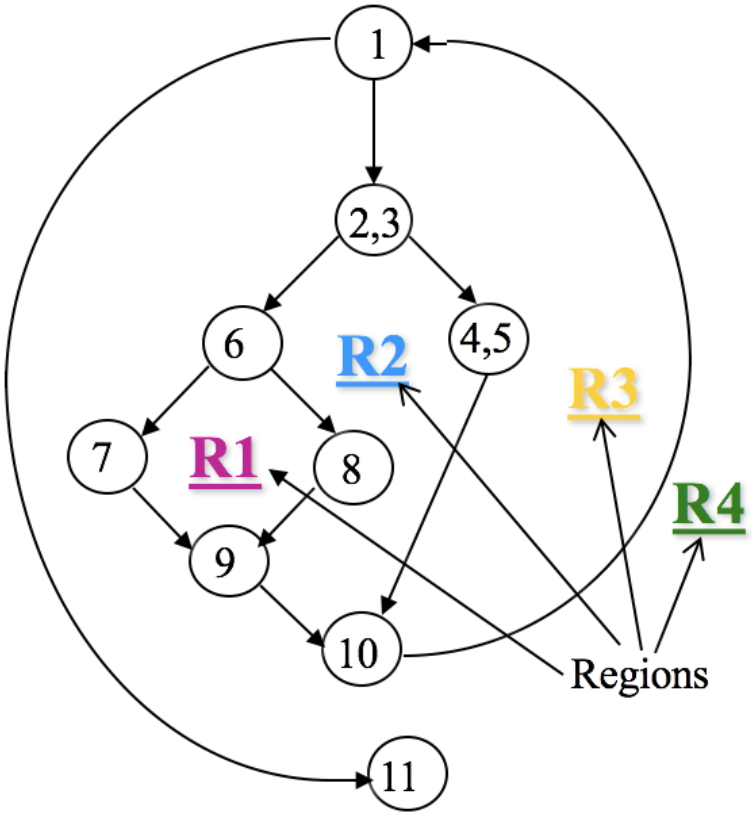
Flow Chart

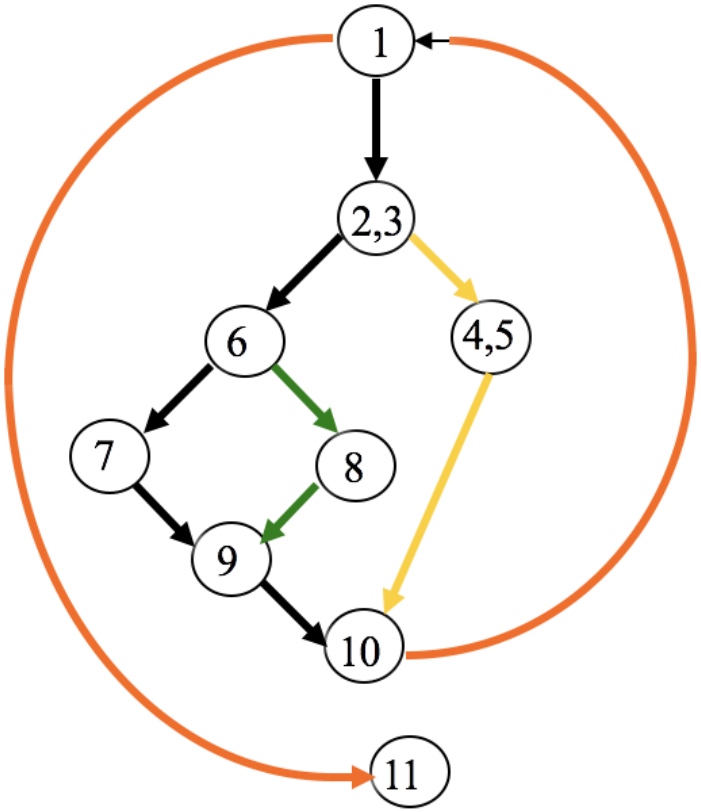
Flow Graph

Cyclomatic Complexity (Def)

$V(G) =$ Regions in the Graph
$V(G) =$ Independent Paths in the Graph
$V(G) = E - N + 2$ where $E =$ number of edges and $N =$ number of nodes
$V(G) = P + 1$ $P =$ number of predicated nodes (i.e., if, case, while, for, do)

Computing CC (definitions)

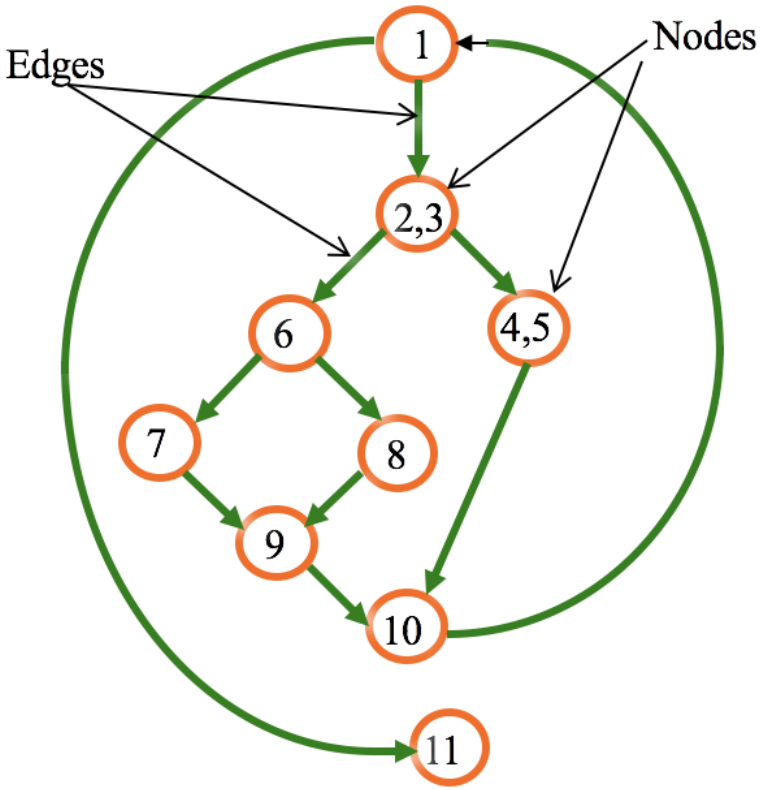


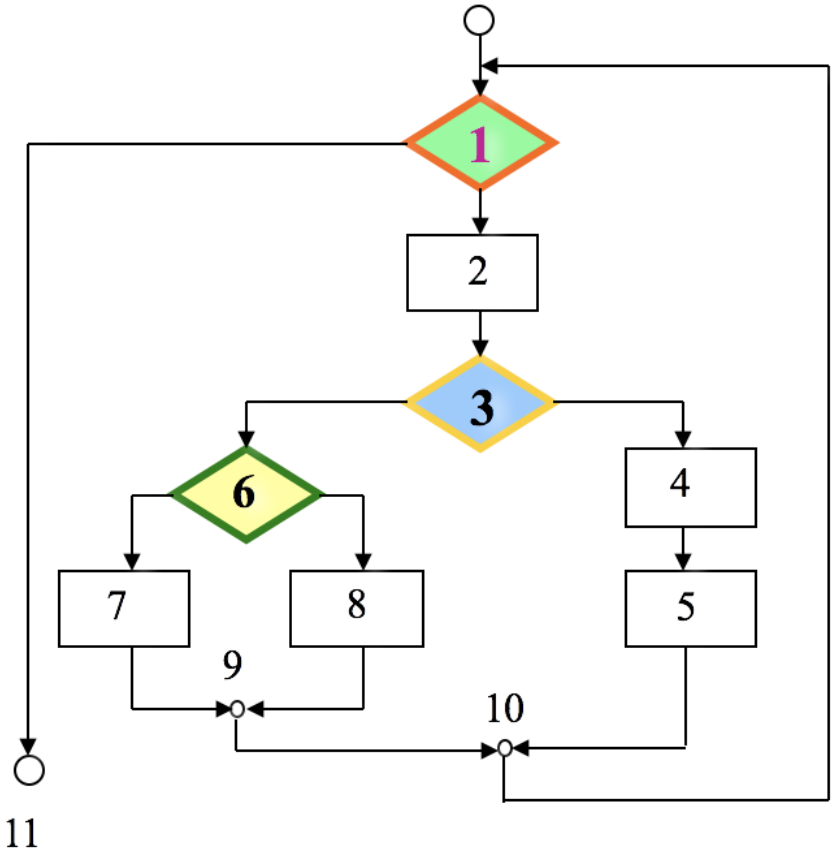


4 regions!!!

4 independent paths!!!

Computing CC (formula)





11 Edges, 9 Nodes ...
$11 - 9 + 2 = 4$!!!

$3 + 1 = 4$!!

Fan In and Fan Out

- The Fan In of a module is the amount of information that “enters” the module
- The Fan Out of a module is the amount of information that “exits” a module
- We assume all the pieces of information with the same size
- Fan In and Fan Out can be computed for functions, modules, objects, and also non-code components

Computing Fan In and Fan Out

Usually:

- Parameters passed by values count toward Fan In
- External variables used before being modifies count toward Fan In
- External variables modified in the block count toward Fan Out
- Return values count toward Fan Out
- Parameters passed by reference ... depend on their use...

Simple Example of Fan In / Fan Out

```
#define<stdio.h>
#define<math.h>

int globalInVar = 9;
int globalOutVar;

float Simple(float x, float y){
      int a;
      float z;
      z = sqrt( x + y +
            globalInVar);
      globalOutVar = int(z+2);
      return z;
}
```

	fan-in	fan-out
	2	
	1	
		1
		1
	3	2

Simple Example of Fan In / Fan Out

```
#define<stdio.h>
#define<math.h>

int globalInVar = 9;
int globalOutVar;

float Simple(float x, float y){
   int a;
   float z;
   z = sqrt( x + y +
             globalInVar);
   globalOutVar = int(z+2);
   return z;
}
```

Proposed Exercises

#define<stdio.h>		
#define<math.h>	**fan-in**	**fan-out**
int globalVarA = 0;		
int globalVarB = 3;		
float global VarC = 7.0;		
float chechValue(float x, float y){	**2**	
int a;		
float z;		
z = sqrt(x + y + globalVarC);	**1**	
globalVarA ++;	**1**	**1**
a = globalVarB;	**1**	
globalVarC = z + (float)globalVarA;		**1**
return z;		**1**
}		
Total	**5**	**3**

Proposed Exercises

Please refer to the handout

Halstead Software Science

Primitive Measures	n_1 number of distinct operators
	n_2 number of distinct operands
	N_1 total number of operator occurrences
	N_2 total number of operand occurrences
Types:	$n = n_1 + n_2$
Tokens / Length:	$N = N_1 + N_2$
Volume:	$V = Nlog_2(n)$
Volume Ratio:	$L = (2/n_1) \times (n_2/N_2)$
Program Level:	$PL = \frac{1}{(n_1/2) \times (N_2/n_2)}$
Software Science Effort:	$E = V/PL$
Time for testing:	$T = E/18$ in seconds.

Halstead's Metrics (example)

```
#define<stdio.h>
#define<math.h>

int globalVarA = 0;
int globalVarB = 3;
float global VarC = 7.0;

float chechValue( float x, float y){
        int a;
        float z;
        z = sqrt( x + y + globalVarC );
        globalVarA ++;
        a = globalVarB;
        globalVarC = z + (float)globalVarA;
        return z;
}
```

Operators:	**Count:**
()	3
	1
=	6
+	5
int	3
float	6
sqrt	1
checkValue	1
return	1
$n_1 = 9$	$N_1 = 27$

N = 44; n = 16; V = 176; PL =0.09; E = 1923.42" = 32'

Halstead's Metrics (example cont.)

```
#define<stdio.h>
#define<math.h>

int globalVarA = 0;
int globalVarB = 3;
float global VarC = 7.0;

float chechValue( float x, float y){
        int a;
        float z;
        z = sqrt( x + y + globalVarC );
        globalVarA ++;
        a = globalVarB;
        globalVarC = z + (float)globalVarA;
        return z;
}
```

Operators:	**Count:**
globalVarA	3
globalVarB	2
globalVarC	3
x	2
y	2
a	2
z	3
$n_2 = 7$	$N_2 = 17$

N = 44; n = 16; V = 176; PL =0.09; E = 1923.42" = 32'

Function Oriented Metrics

Function Points

- Function Points are a measure of "how big" is the program, independently from the actual physical size of it
- It is a weighted count of several features of the program
- Dislikers claim FP make no sense wrt the representational theory of measurement
- There are firms and institutions taking them very seriously

Function Points

Analyze information domain of the application and develop counts	Establish count for input domain and system interfaces
⇓	
Weight each count by assessing complexity	Assign level of complexity or weight to each count
⇓	
Assess influence of global factors that affect the application	Grade significance of external factors, F_i such as reuse, concurrency, OS, ...
⇓	
Compute function points	function points: $\sum = (count \times weight) \times C$ where: complexity multiplier: $C = (0.65 + 0.01 \times N)$ degree of influence: $N = \sum F_i$

Analyzing the Information Domain

Measurement parameter *(number of)*	**count**		**Weighting Factor** **simple**	**average**	**complex**		
inputs	☐	x	3	4	6	=	☐
user outputs	☐	x	4	5	7	=	☐
user inquiries	☐	x	3	4	6	=	☐
files	☐	x	7	10	15	=	☐
ext. interfaces	☐	x	5	7	10	=	☐

Assuming all inputs with the same weight, all output with the same weight, ...

Complete Formula for the Unadjusted Function Points:

$$\sum_{Inputs} W_i + \sum_{Outputs} W_o + \sum_{Inquiry} W_{in} + \sum_{IntFiles} W_{if} + \sum_{ExtInt} W_{ei}$$

Taking Complexity into Account

Factors are rated on a scale of 0 (not important) to 5 (very important):

data communications	on-line update
distributed functions	complex processing
heavily used configuration	installation ease
translation rate	operation ease
on-line data entry	multiple sites
end user efficiency	facilitate change

Formula:

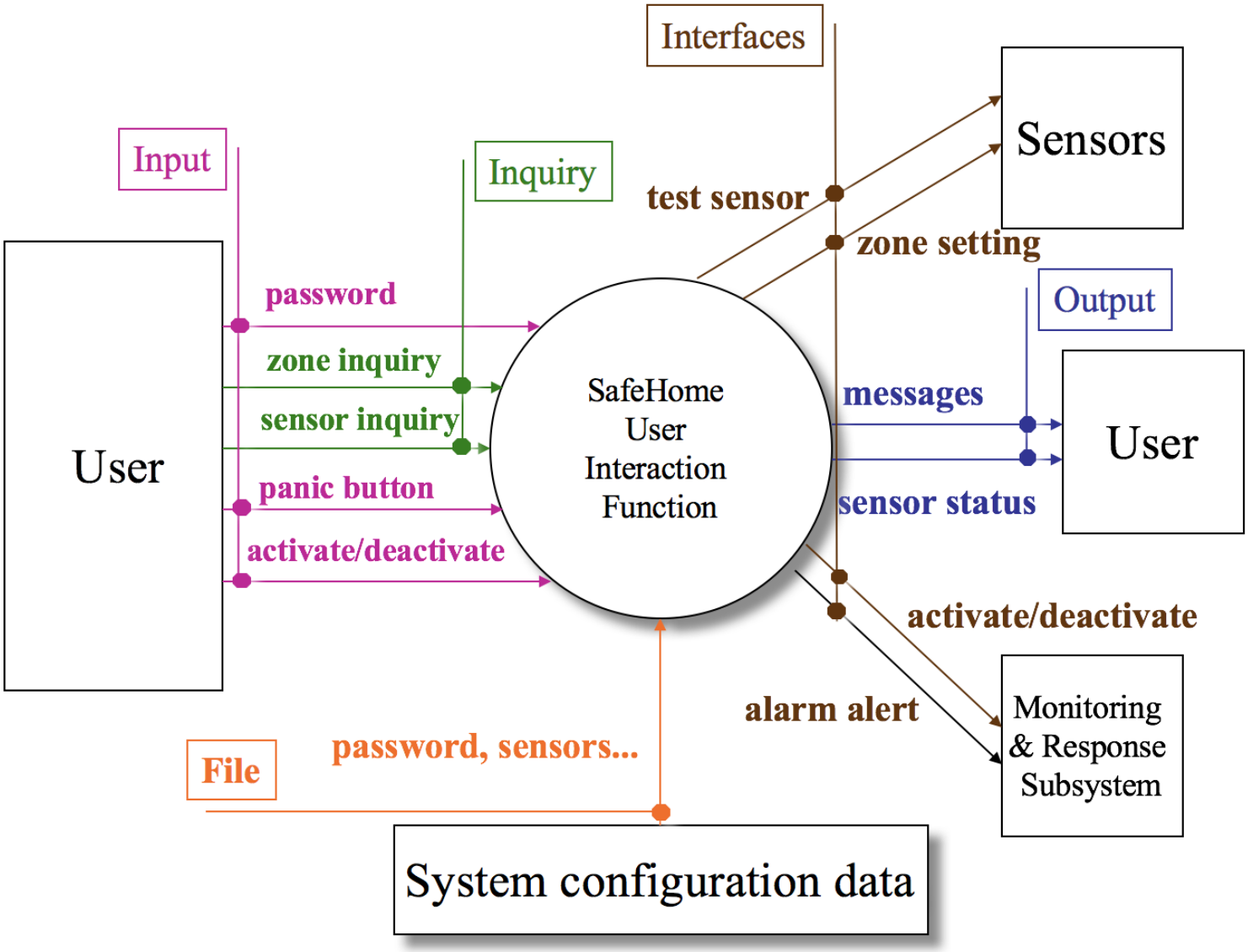
$$CM = \sum_{ComplexityMultiplier} F_{ComplexityMultiplier}$$

Complexity

Measurement parameter *(number of)*	**count**		**Weighting Factor** **simple**	**average**	**complex**		
inputs	☐	x	3	4	6	=	☐
user outputs	☐	x	4	5	7	=	☐
user inquiries	☐	x	3	4	6	=	☐
files	☐	x	7	10	15	=	☐
ext. interfaces	☐	x	5	7	10	=	☐
Unadjusted Function Points:							
count total						=	☐
complexity mpl.						=	☐
function points						=	☐

$$FP = UFP \times (0.65 + 0.01 \times CM)$$

Safe Home Example



Safe Home Example

Measurement parameter *(number of)*	**count**		**Weighting Factor** **simple**	**average**	**complex**		
inputs	3	x	3	4	6	=	9
user outputs	2	x	4	5	7	=	8
user inquiries	2	x	3	4	6	=	6
files	1	x	7	10	15	=	7
ext. interfaces	4	x	5	7	10	=	20
count total							**50**

$$\text{Using } FP = \text{count total} \times (0.65 + 0.01 \times \sum F_i)$$

$$\text{where } \sum F_i = 46, \text{ we get}$$

$$FP = 50 \times (0.65 + 0.01 \times 46)$$

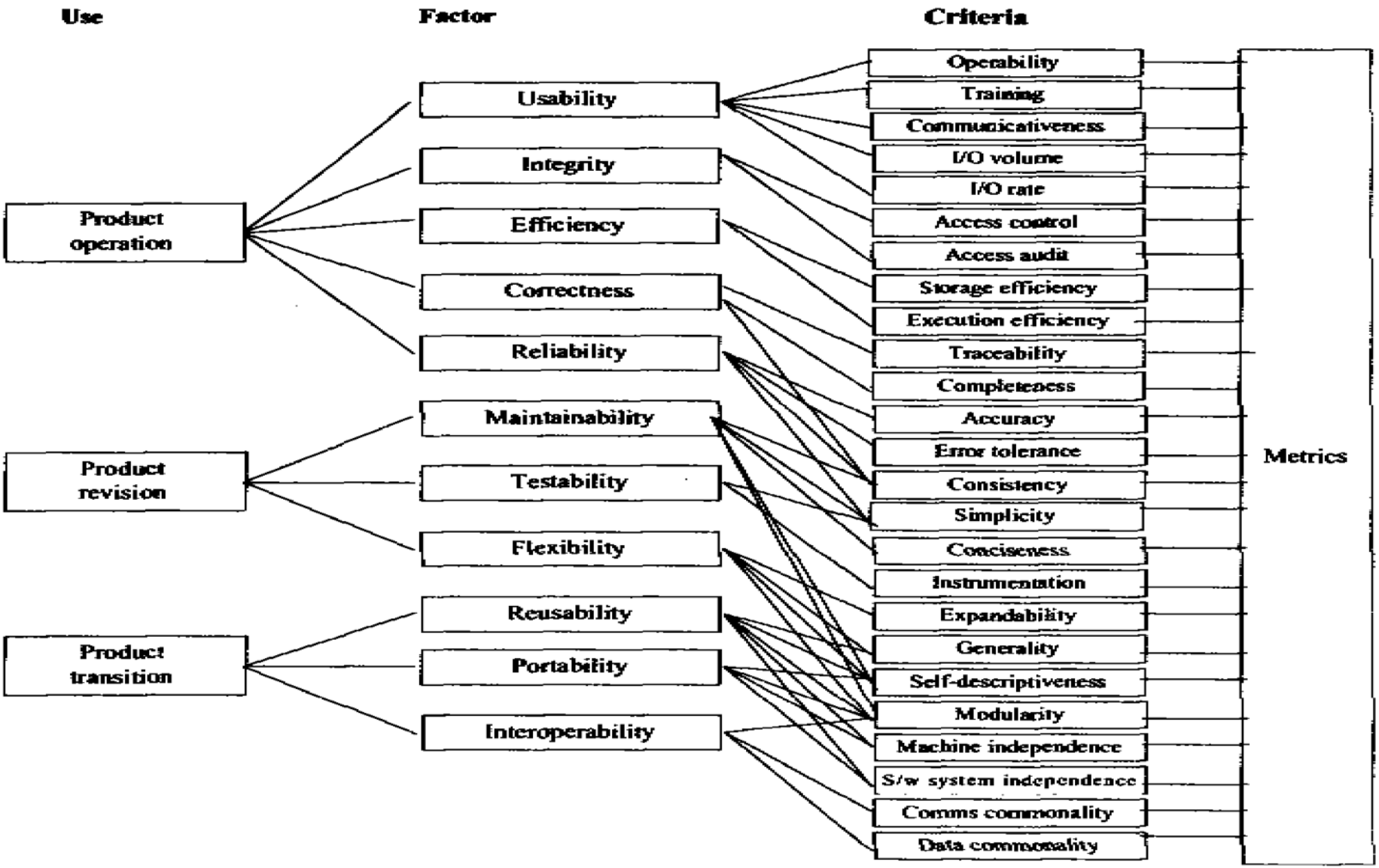
$$FP = 56$$

New stuff on function points

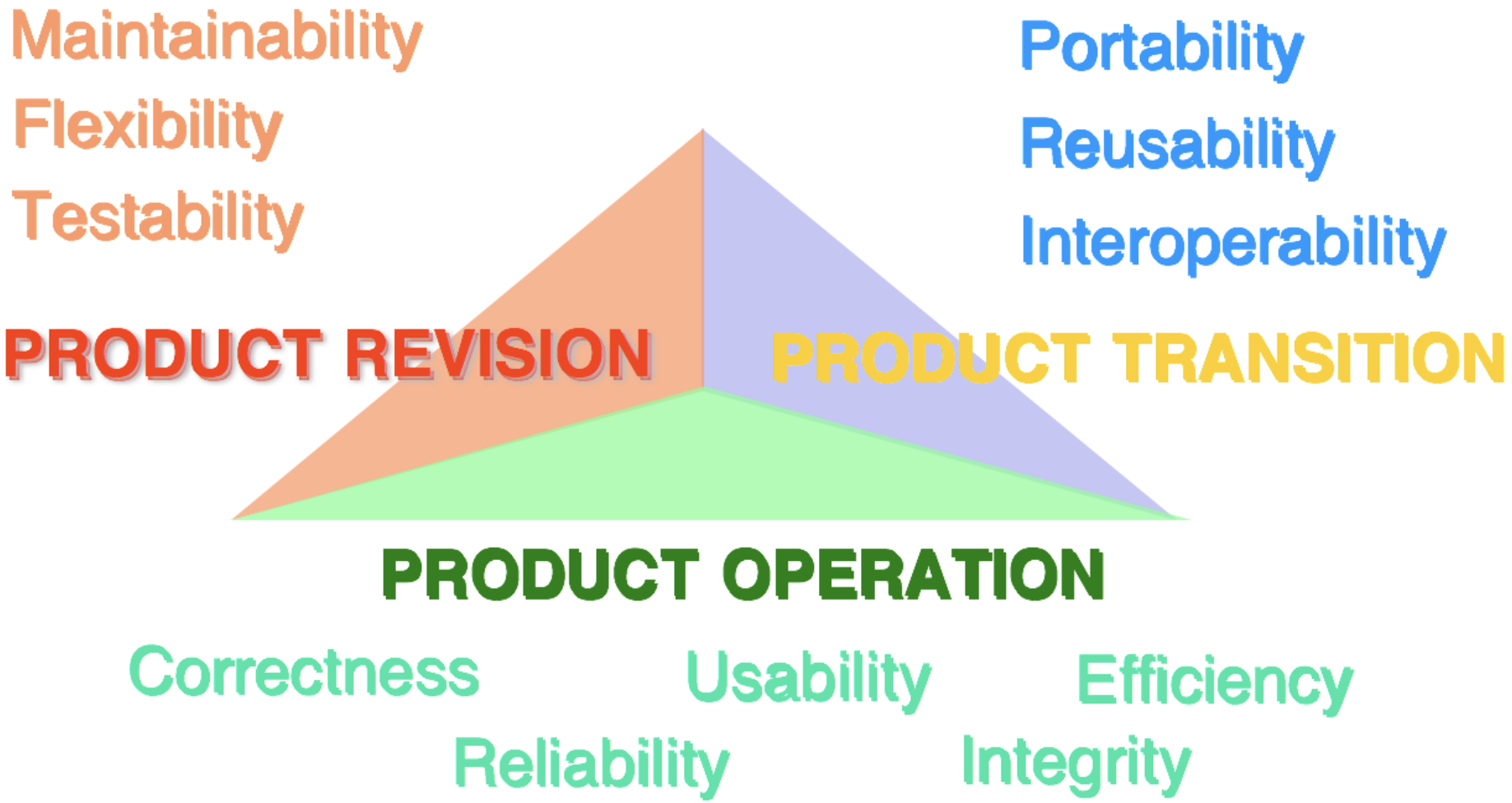
- Feature points
  - To deal also with engineering and real time applications
  - Not much used, however...
- Software Backfiring
  - to link function points to LOC on the average, since there are (poor) techniques to estimate the duration of a software project, given the predicted lines of code (COCOMO2, Putnam model)

Quality Metrics

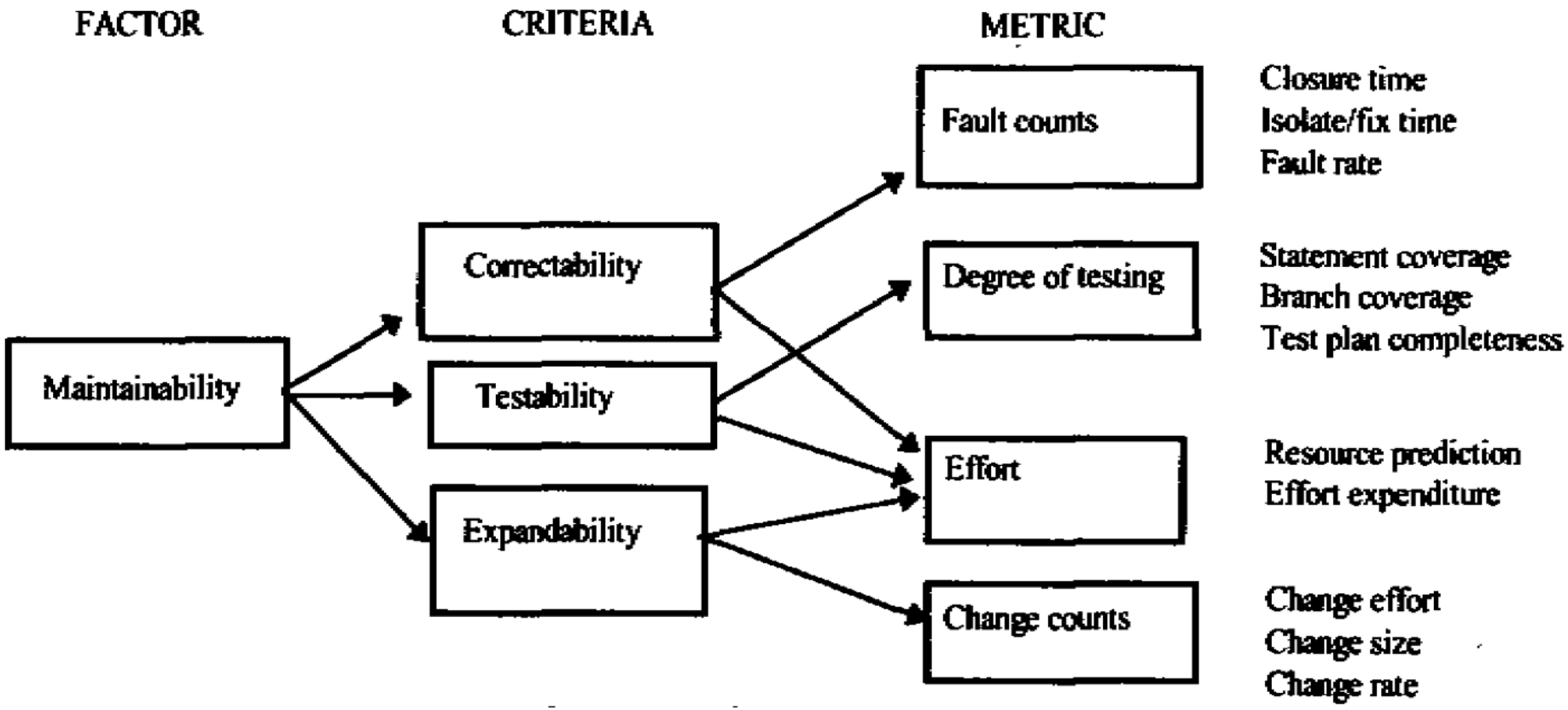
McCall's Triangle of Quality



McCall Software Quality Model



McCall's Metrics for Maintainability



A Comment

McCall's quality factors were proposed in the early 1970s. They are as valid today as they were in that time. It's likely that software built to conform to these factors will exhibit high quality well into the 21st century, even if there are dramatic changes in technology.

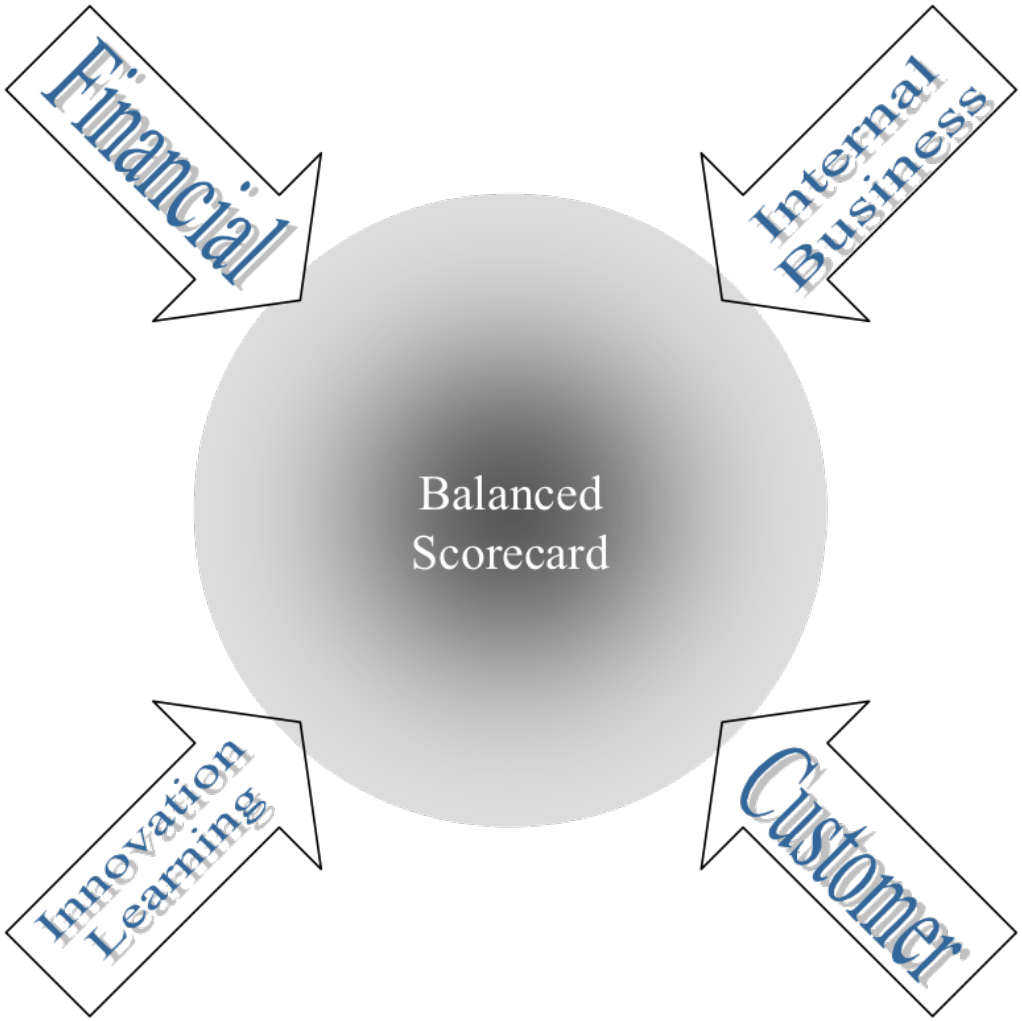
Product Quality - ISO 9126

- A means to specify the features of a software product and to verify them
- ISO 9126 identifies 6 characteristics and 21 sub-characteristics
- Each characteristic is defined by a ***disjoint subset*** of sub-characteristics that are then used to its evaluation

ISO 9126 Characteristics

- Functionality
- Reliability
- Usability
- Efficiency
- Maintainability
- Portability

Balanced Scorecard



Other Kinds of Metrics

Other Kinds of Metrics

There are MANY other kinds of metrics:

- Metrics for requirements
- Metrics for analysis
- Metrics for design
- Metrics for testing
- Object oriented metrics
- ...

The CK Metrics suite

- The CK metrics suite is a set of metrics for object oriented systems
- It tries to capture different kind of properties of OO
- It attempts to compromise between providing a careful description and a the principle of parsimony

Metrics in the CK suite

- Weighted Methods per Class (WMC)
- Depth of Inheritance Tree (DIT)
- Number of Children (NoC)
- Coupling between Objects (CBO)
- Response for a Class (RFC)
- Lack of COhesion in Methods (LCOM)

WMC

Let C be a class with methods M_1, M_2, M_n
with complexity c_1, c_2, c_n
$WMC(C) = \sum c_i$
If all methods are considered to be of complexity one:
$WMC(C) = NoM(C)$

DIT

- The Depth of the Inheritance Tree of a class is the longest path in the inheritance hierarchy from the class to its most remote ancestor
- In case of multiple inheritance, DIT is the largest number among the different most remote ancestors

NoC

- The Number of Children of a class is the number of immediate subclasses of that class

CBO

- Coupling between objects of a class C is the number of other classes to which C is related through association, aggregation, or composition

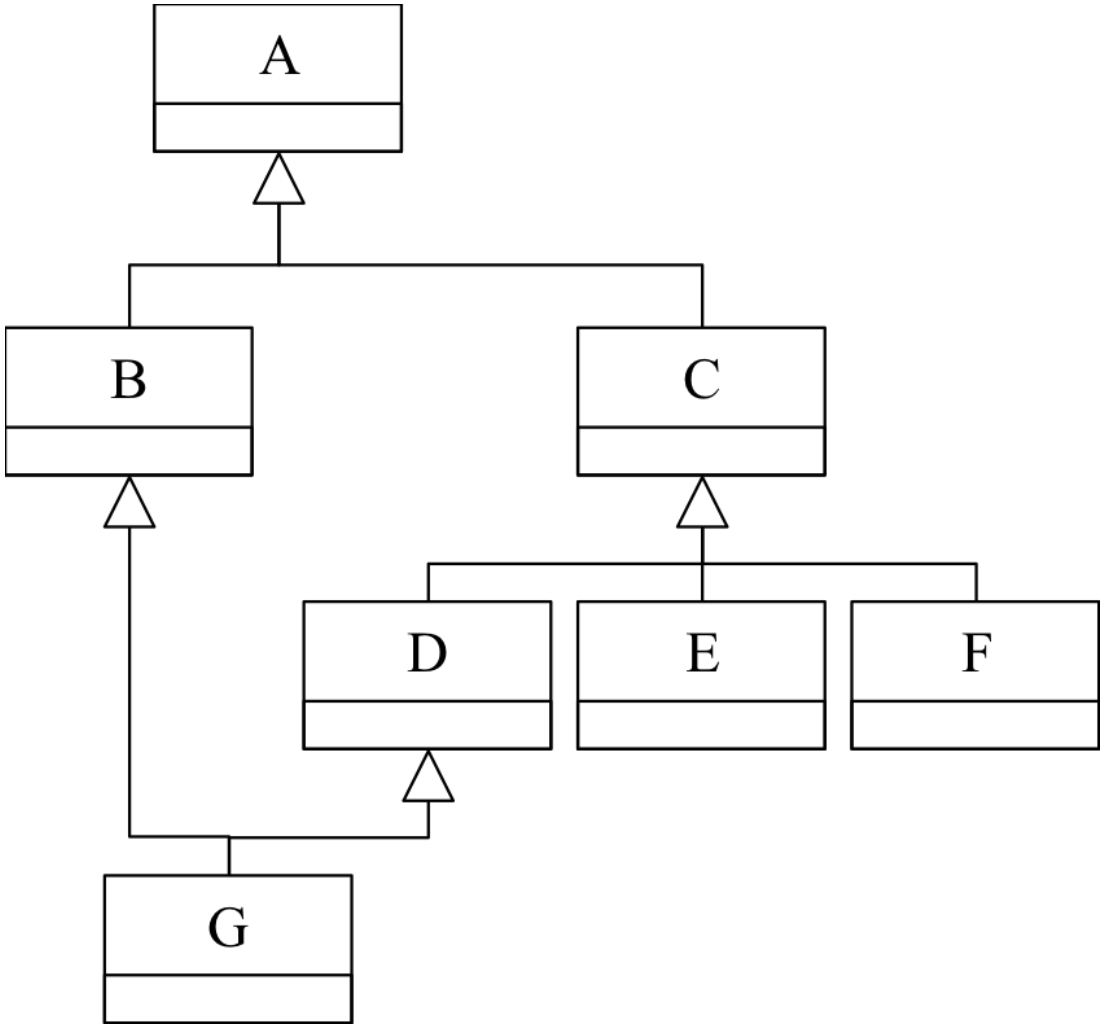
RFC

- Response For a Class is the number of methods (of that class or of other classes) that can be invoked from within the class in response to a call to a method of the class

LCOM

- Let C be a class with methods M_1, M_2, M_n using each using set of attributes UA_1, UA_2, UA_n
- Consider the sets of Non Cohesive Methods and of Cohesive Methods of C:
  - $NCM(C) = \{< M_i, M_j >: UM_i \cap UM_j = \varnothing, i < j\}$
  - $C(C) = \{< M_i, M_j >: UM_i \cap UM_j \neq \varnothing, i < j\}$
- LCOM(C) = |NCM(C) |– |C(C) |

Example (1/4)



Example (2/4)

```
class A {
public: A(){}
   void aMethod(){}
   void aMethod(int i){}
   void anotherMethod();
   ~A(){}
private: int attr;
};

class B : public A{ public: void f(){}};

class C : public A{ public: int aValue;};

class D : public C{ public: int g(){}};
```

Example (3/4)

```
class E {
private: int a, b, c, d, e, x, y, z;
public:
  void M1() { a = b = c = d = e;}
  void M2() { a = b = e; }
  void M3() { x = y = z; }
};

class F : public C {};

class G : public B, public D {};

void A::anotherMethod() {
  B b; C c; D d; b.f();
  attr = c.someValue + d.g();
}
```

Example (4/4)

```
WMC(A)= |{A(), aMethod(), aMethod(int), anotherMethod(), ~A()}|=5

DIT(G)= max{|{B,A}|,|{D,C,A}|,|{E,C,A}|,|{F,C,A}| = 3

NOC(C)= |{D,E,F}| = 3

CBO(A)= |{B, C, D}| = 3

RFC(A)= |{A(),aMethod(),aMethod(int), anotherMethod(),~A()}| +
    |{B::f(),D::g()}| = 7

LCOM(E)= | {<M1,M3>,<M2,M3>}| - | { <M1,M2> } | = 2 - 1 = 1
```