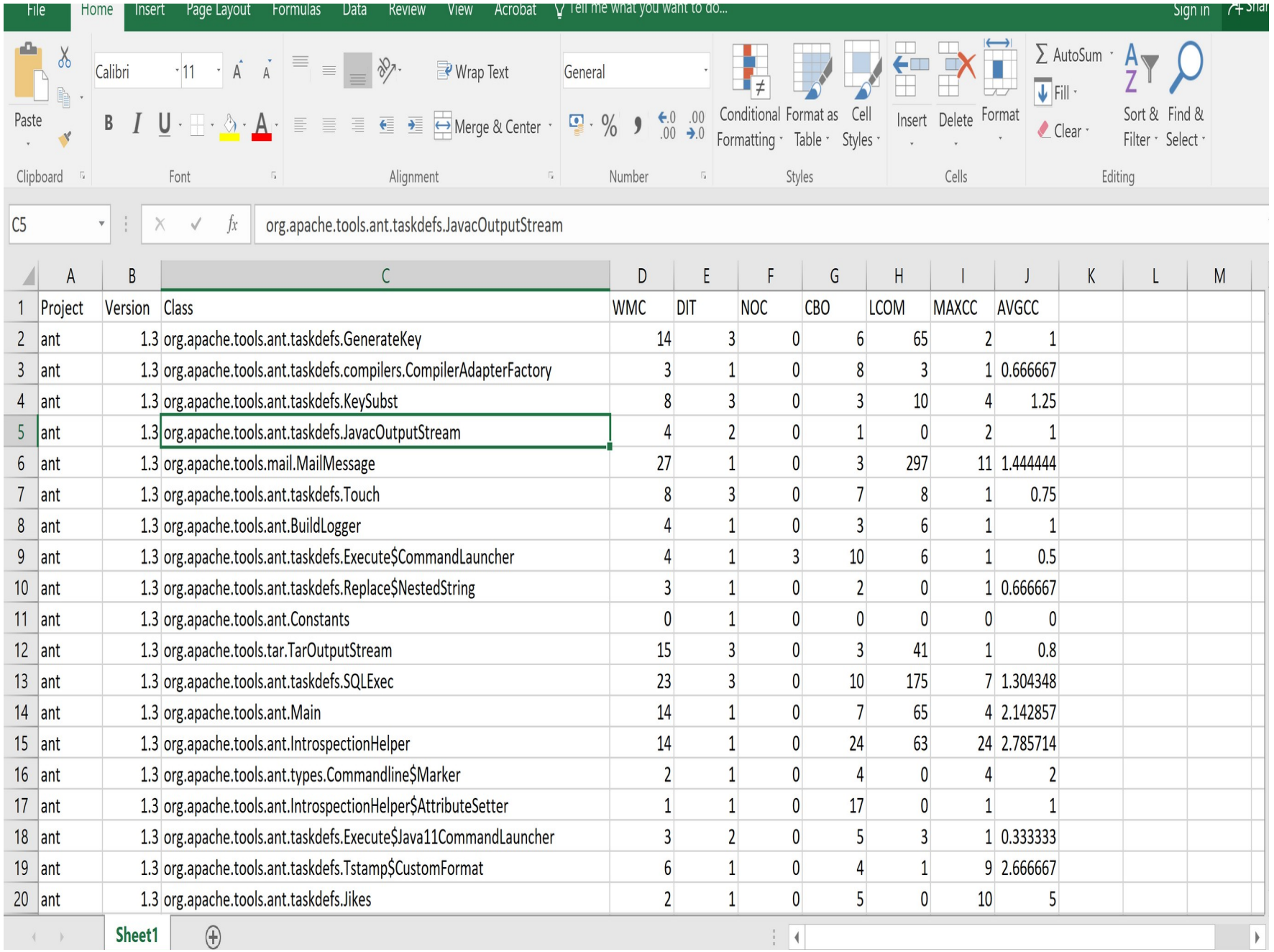
Software Engineering CS3003

Lecture 3: Software Metrics



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C5 org.apache.tools.ant.taskdefs.JavacOutputStream

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Project	Version	Class	WMC	DIT	NOC	CBO	LCOM	MAXCC	AVGCC			
2	ant	1.3	org.apache.tools.ant.taskdefs.GenerateKey	14	3	0	6	65	2	1			
3	ant	1.3	org.apache.tools.ant.taskdefs.compilers.CompilerAdapterFactory	3	1	0	8	3	1	0.666667			
4	ant	1.3	org.apache.tools.ant.taskdefs.KeySubst	8	3	0	3	10	4	1.25			
5	ant	1.3	org.apache.tools.ant.taskdefs.JavacOutputStream	4	2	0	1	0	2	1			
6	ant	1.3	org.apache.tools.mail.MailMessage	27	1	0	3	297	11	1.444444			
7	ant	1.3	org.apache.tools.ant.taskdefs.Touch	8	3	0	7	8	1	0.75			
8	ant	1.3	org.apache.tools.ant.BuildLogger	4	1	0	3	6	1	1			
9	ant	1.3	org.apache.tools.ant.taskdefs.Execute$CommandLauncher	4	1	3	10	6	1	0.5			
10	ant	1.3	org.apache.tools.ant.taskdefs.Replace$NestedString	3	1	0	2	0	1	0.666667			
11	ant	1.3	org.apache.tools.ant.Constants	0	1	0	0	0	0	0			
12	ant	1.3	org.apache.tools.tar.TarOutputStream	15	3	0	3	41	1	0.8			
13	ant	1.3	org.apache.tools.ant.taskdefs.SQLExec	23	3	0	10	175	7	1.304348			
14	ant	1.3	org.apache.tools.ant.Main	14	1	0	7	65	4	2.142857			
15	ant	1.3	org.apache.tools.ant.IntrospectionHelper	14	1	0	24	63	24	2.785714			
16	ant	1.3	org.apache.tools.ant.types.Commandline$Marker	2	1	0	4	0	4	2			
17	ant	1.3	org.apache.tools.ant.IntrospectionHelper$AttributeSetter	1	1	0	17	0	1	1			
18	ant	1.3	org.apache.tools.ant.taskdefs.Execute$Java11CommandLauncher	3	2	0	5	3	1	0.333333			
19	ant	1.3	org.apache.tools.ant.taskdefs.Tstamp$CustomFormat	6	1	0	4	1	9	2.666667			
20	ant	1.3	org.apache.tools.ant.taskdefs.Jikes	2	1	0	5	0	10	5			

Sheet1

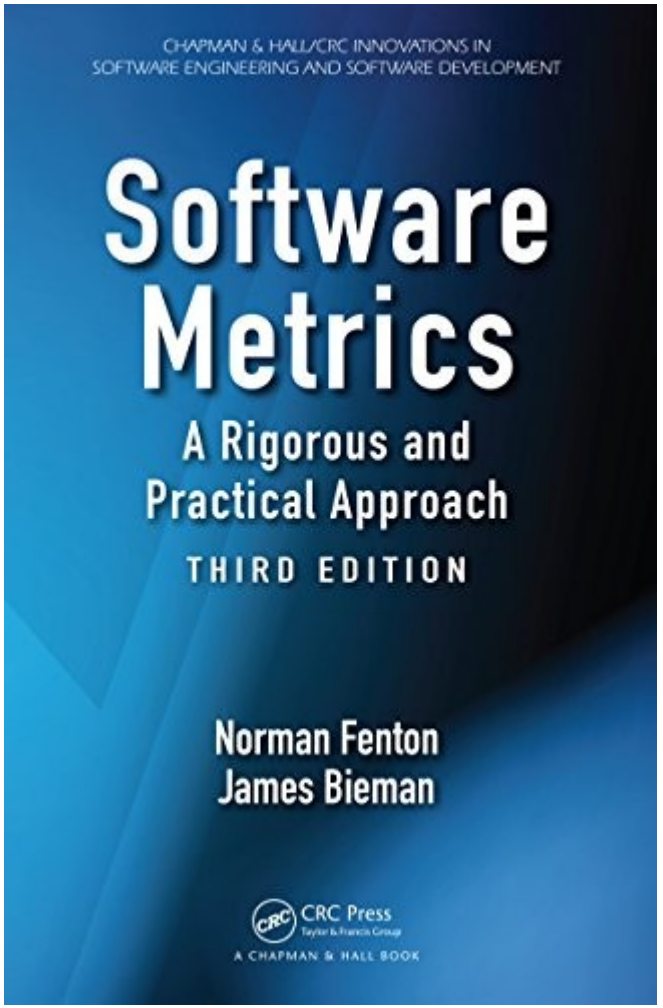
Lecture schedule

Week	Lecture Topic	Lecturer	Week Commencing
1	Introducing the module and Software Engineering	Steve Counsell	20th Sept.
2	Software maintenance and Evolution	Steve Counsell	27th Sept.
3	Software metrics	Steve Counsell	4th Oct.
4	Software structure, refactoring and code smells	Steve Counsell	11th Oct.
5	Test-driven development	Giuseppe Destefanis	18th Oct.
6	Software complexity **Coursework released Tues 26th Oct.**	Steve Counsell	25th Oct.
7	**ASK week**	**N/A**	**1st Nov**
8	Software fault-proneness	Steve Counsell	8th Nov.
9	Clean code	Steve Counsell	15th Nov.
10	Human factors in software engineering	Giuseppe Destefanis	22th Nov.
11	SE techniques applied in action	Steve Counsell	29th Dec.
12	Guest Lecture (tba) **Coursework hand-in 6th December**	Guest Lecture	6th Dec.

Lab schedule

Week	Labs	Week Commencing
1	**No labs**	20th Sept.
2	Lab (Introduction)	27th Sept.
3	Lab	4th Oct.
4	Lab	11th Oct.
5	Lab	18th Oct.
6	**No lab**	25th Oct.
7	**ASK week**	**1st Nov.**
8	Lab	8th Nov.
9	Catch-up Lab	15th Nov.
10	Work on coursework (no Lab)	22nd Nov.
11	Work on coursework (no Lab)	29th Nov.
12	**No lab**	6th Dec.

Norman Fenton



Structure of this lecture

This lecture will try to answer the following questions:

- How can software size be measured?
- How can software structure be measured?
- How can objected oriented code be measured?
- .....What is the link to the previous lecture on Maintenance and Evolution?

Uses of measurement

- Measurement helps us to “understand”
  - Makes the current activity visible
  - Measures can establish guidelines
    - Methods too long, classes too long etc.
- Measurement allows us to “control”
  - Predict outcomes and change processes
- Measurement encourages us to “improve”
  - When we measure our product we can establish quality targets and aim to improve

How can software size be measured?

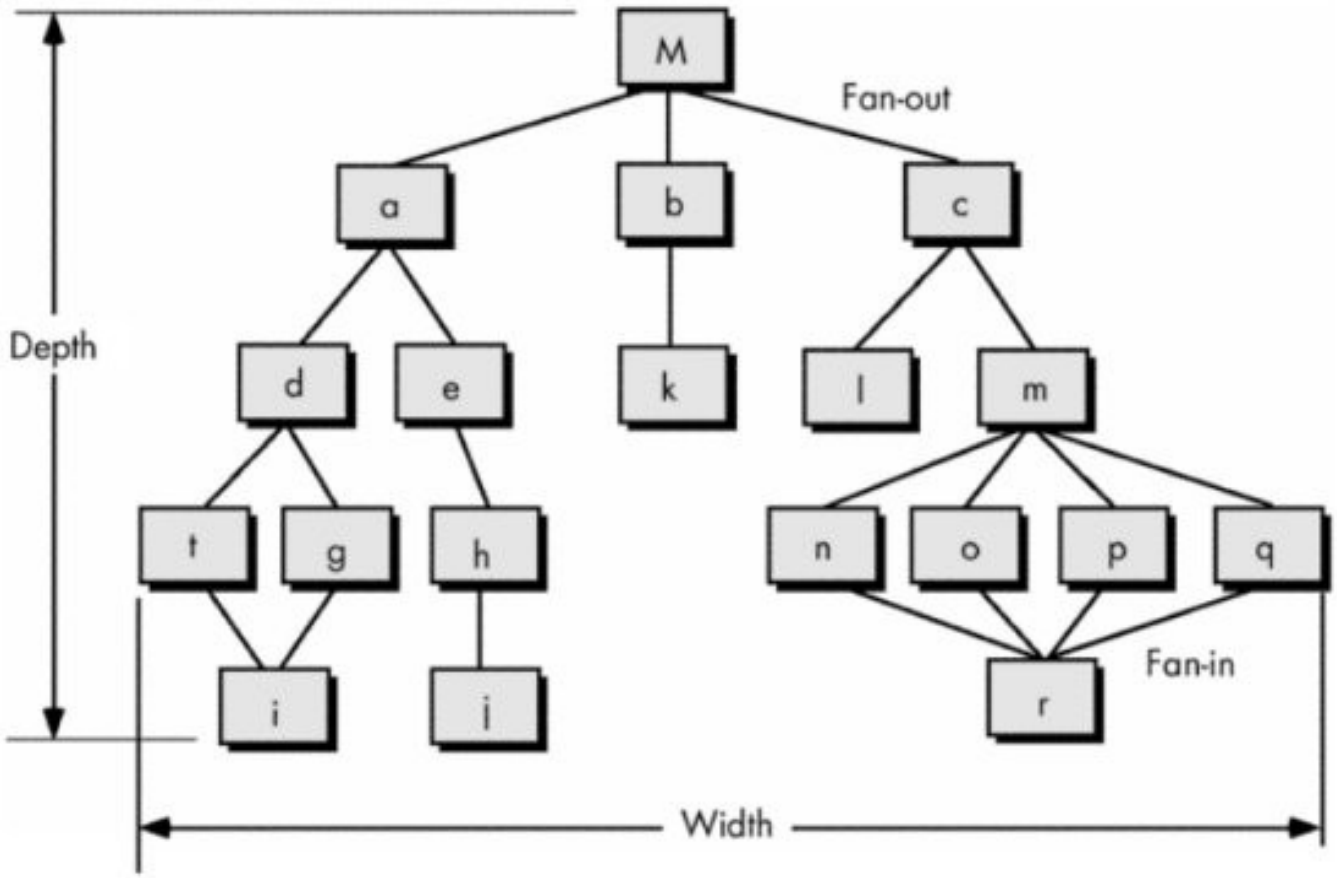
- Why is software size important?
  - Related to effort and cost
- Lines of code (LOC) is a common measure of size:
  - …but not very useful?
  - What about comment lines, blank space, "}"?
    - Are they all counted?
- Many companies measure functionality rather than code length

How can software structure be measured?

Information flow within the system

- Indicator of maintainability and “coupling”
- Identifies critical stress parts of the system and design problems
- Based on:
  - Fan-in: number of modules calling a module
  - Fan-out: number of modules called by a module

Fan-in and fan-out



Henry & Kafura's Complexity Metric:

- A module X is 10 lines long
- It has fan-in of 3 and fan-out of 2
- Complexity of a module = module length * $(\text{fan-in} * \text{fan-out})^2$

Complexity of X = $10 * (3 * 2)^2$

= 360

A complexity measure

- McCabe's Cyclometric Complexity measure
  - Commonly used by industry
  - In lots of tools
  - Based on control flow graph
  - Very useful for identifying white box test cases
- Attributed to Tom McCabe who worked for IBM in the 1970's

Cyclomatic Complexity (CC)

- CC(P) =
  #edges - #nodes +2

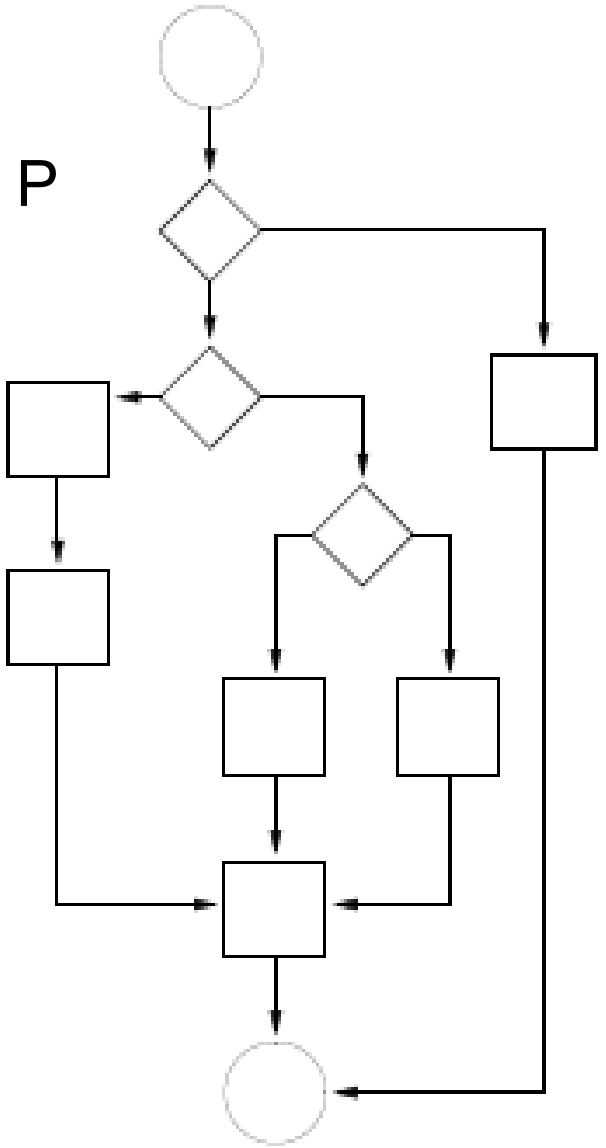
#edges = 11

#nodes = 9

CC = 4

(note: we exclude the start and end nodes and edges – although some sources don't)

Program P



```
stcode getlist(char *lin, int *i, stcode *status)
/*  1 */ {
/*  1 */   int num, done;
/*  1 */   line2 = 0;
/*  1 */   nlines = 0;
/*  1 */   done = (getone(lin,i,&num,status)!=OK);
/*  2 */   while (!done)
/*  3 */   {
/*  3 */     line1 = line2;
/*  3 */     line2 = num;
/*  3 */     nlines++;
/*  3 */     if (lin[*i]==SEMICOL)
/*  4 */       curln = num;
/*  5 */     if ((lin[*i]==COMMA)||(lin[*i]==SEMICOL))
/*  6 */     {
/*  6 */       *i = *i + 1;
/*  6 */       done = (getone(lin,i,&num,status)!=OK);
/*  6 */     }
/*  7 */      else
/*  7 */        done = 1;
/*  8 */   }
/*  9 */   nlines = min(nlines,2);
/*  9 */   if (nlines == 0)
/* 10 */     line2 = curln;
/* 11 */   if (nlines <= 1)
/* 12 */     line1 = line2;
/* 13 */   if (*status != ERR)
/* 14 */     *status = OK;
/* 15 */   return(*status);
/* 16 */ }
```

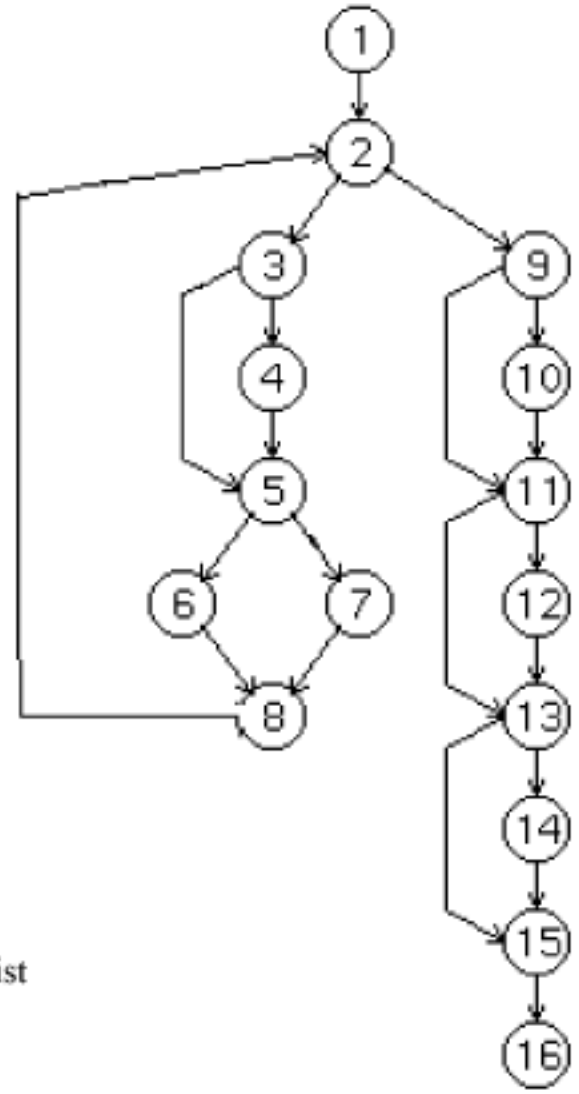


Figure 1. Program Getlist

Complexity Metrics

- Why use complexity metrics like CC?
  - They can be used to identify:
    - Candidate modules for code inspections
    - Areas where redesign may be appropriate
    - Areas where additional documentation is required
    - Areas where additional testing may be required
    - Areas for refactoring

Chidamber and Kemerer’s work has been referenced over 8000 times

IEEE TRANSACTIONS ON

SOFTWARE ENGINEERING

FEBRUARY 1985 VOLUME SE-11 NUMBER 2 (ISSN 0098-5589)

A PUBLICATION OF THE IEEE COMPUTER SOCIETY

How can OO code be measured?

- We'll look at 5 of the 6 metrics of Chidamber and Kemerer (C&K)
- Developed in 1991
  - Weighted methods per class (WMC)
    - A simple count of the number of methods in a class
  - Depth in the inheritance tree of a class (DIT)
    - The level in the inheritance tree of a class
  - Number of children (NOC)
    - The number of immediate sub-classes a class has

C&K metrics (cont.)

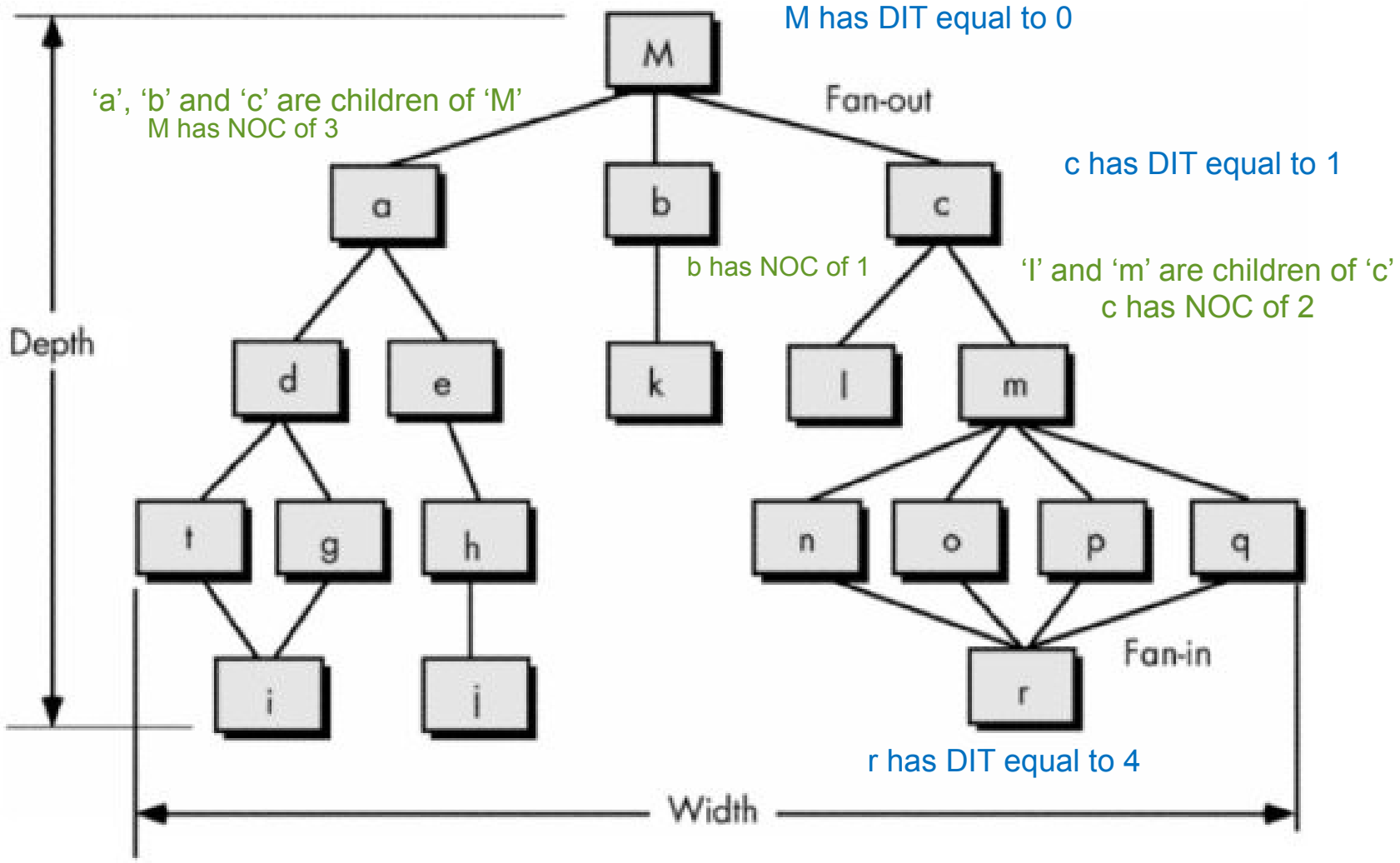
- Coupling between objects (CBO)
  - Number of other classes coupled to a class
- Lack of cohesion of methods in a class (LCOM)
  - Measure of how “well intra-connected” the fields and methods of a class are
  - The missing metric is called The Response for a Class
    - But nobody really understands what it is trying to measure

Weighted Methods per Class (WMC)

WMC

- The “weighted” part can be ignored
- Simply the number of methods in a class
- The number of methods is a predictor of how much time and effort is required to maintain the class
- Classes with large numbers of methods are likely to be more application specific, limiting the possibility of reuse

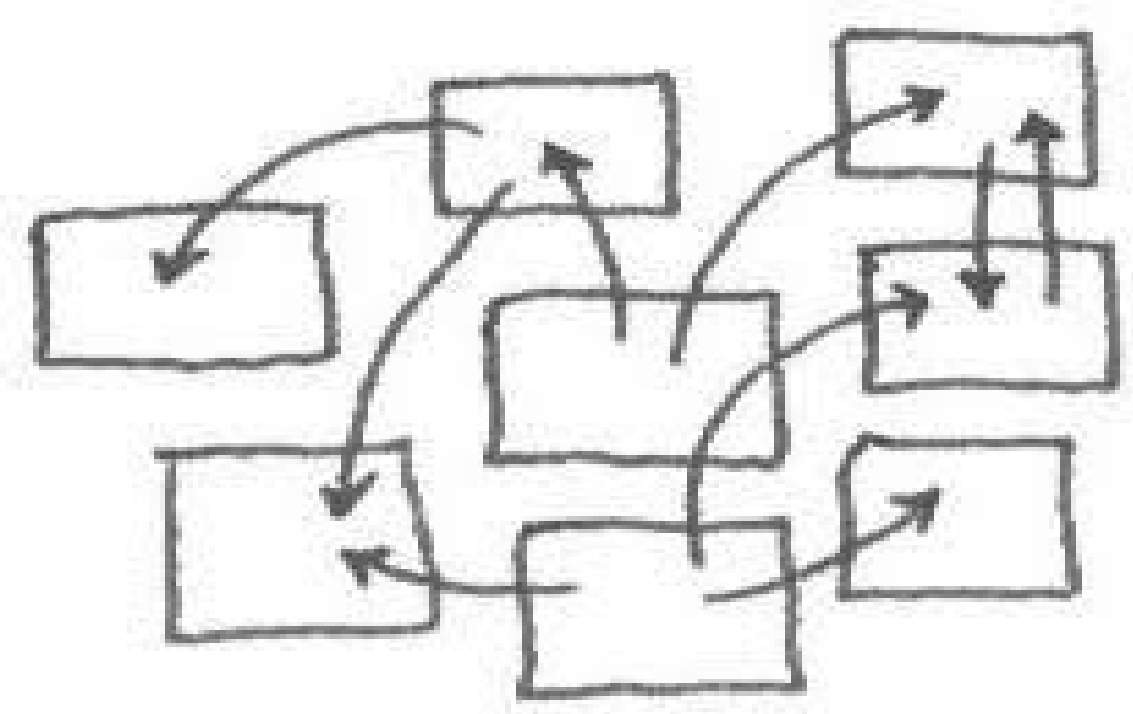
Depth in the Inheritance Tree of a Class (DIT) and Number of Children (NOC)



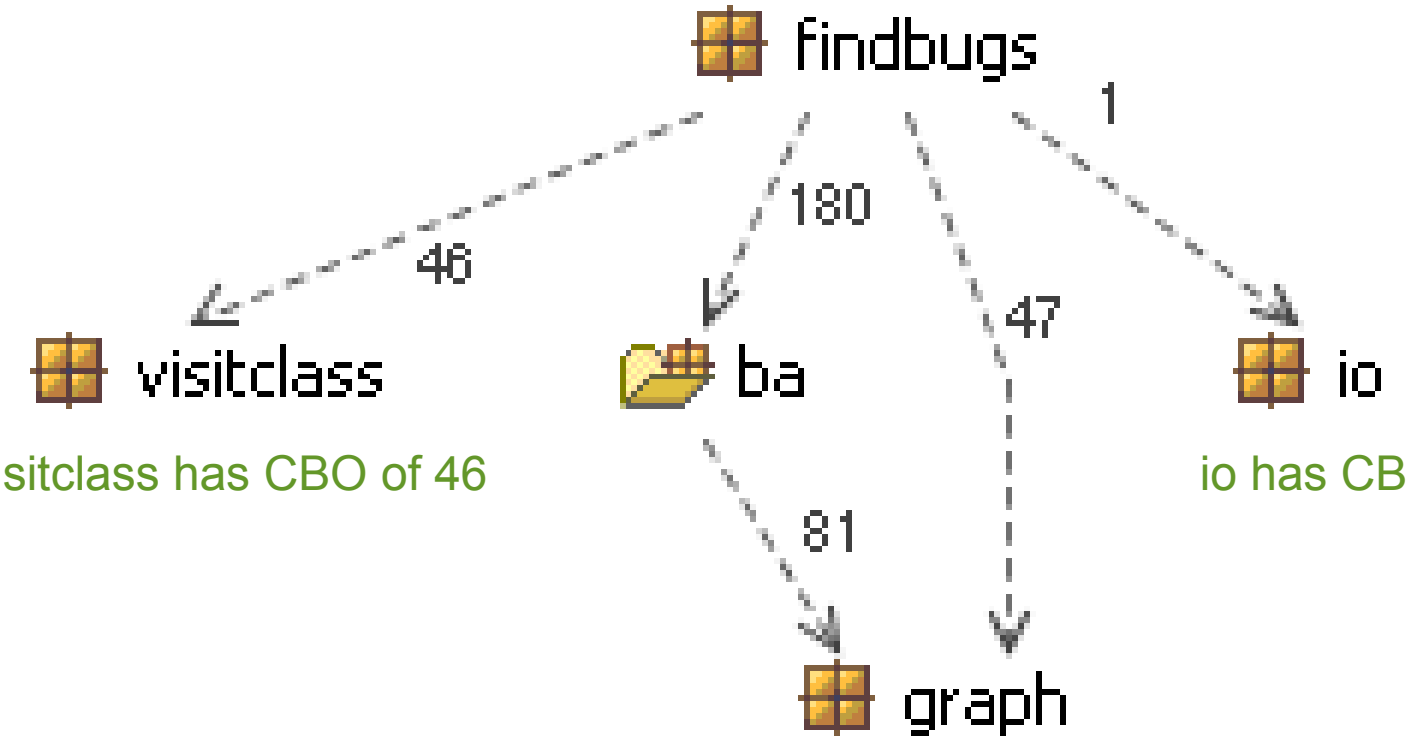
Ref: Marchese, PACE University

Coupling Between Objects (CBO)

CBO



Class coupling (ravioli code); here, boxes represent classes and arrows represent links (i.e., coupling) between classes



visitclass has CBO of 46

io has CBO of 1

graph has CBO of 81 + 47 = 128

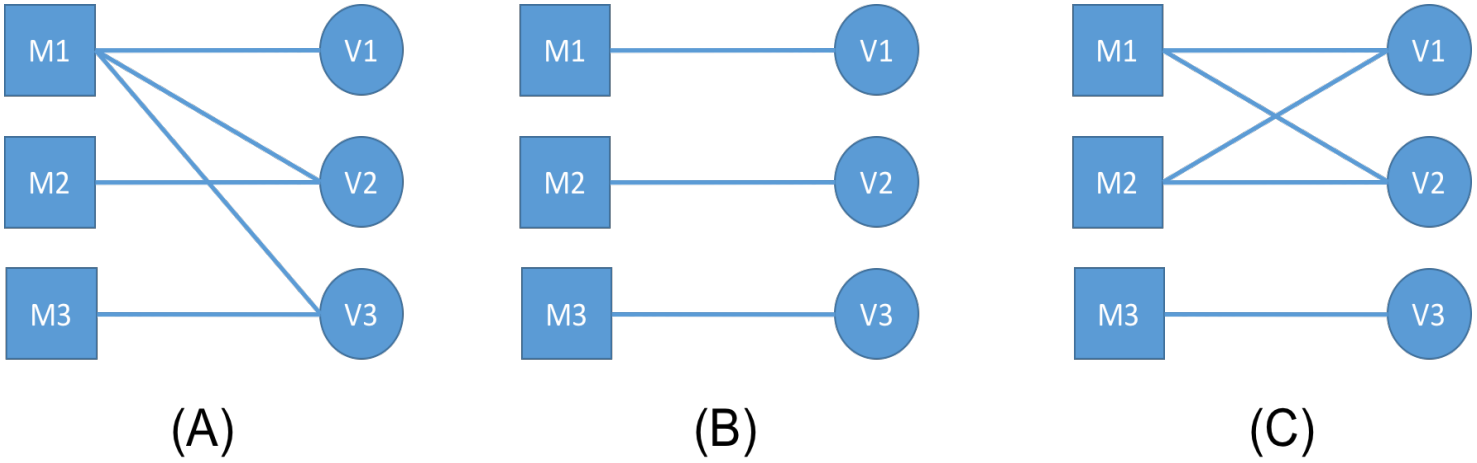
https://structure101.com/2008/11/27/software-erosion-findbugs/

Lack of cohesion of methods in a class (LCOM)

LCOM

- Cohesiveness of methods within a class is desirable, since it promotes encapsulation
- Lack of cohesion implies classes should probably be split into two or more subclasses
- Low cohesion increases complexity, thereby increasing the likelihood of errors during the development process
- (source: virtualmachinery.com/sidebar3.htm)

LCOM Example



Methods (M1-M3) and the variables those methods use (V1—V3)

http://www.tusharma.in/technical/revisiting-lcom/

Problems with metrics

- There is a tendency for professionals to display over-optimism and over-confidence in metrics
- Metrics may cause more harm then good
  - Data is shown because its easy to gather and display
- Metrics may have a negative effect on developer productivity and well-being
- Academic/industry divide
  - Industry may be interested in specific aspects of their code
    - For example, code churn, level of technical debt

Software Metric Usage

- Use common sense and organizational sensitivity when interpreting metrics data
- Provide regular feedback to the individuals and teams who have worked to collect measures and metrics
- Don’t use metrics to appraise individuals
- Never use metrics to threaten individuals or teams
- Metrics data that indicates a problem area should not be considered “negative”.
  - These data are merely an indicator for process improvement

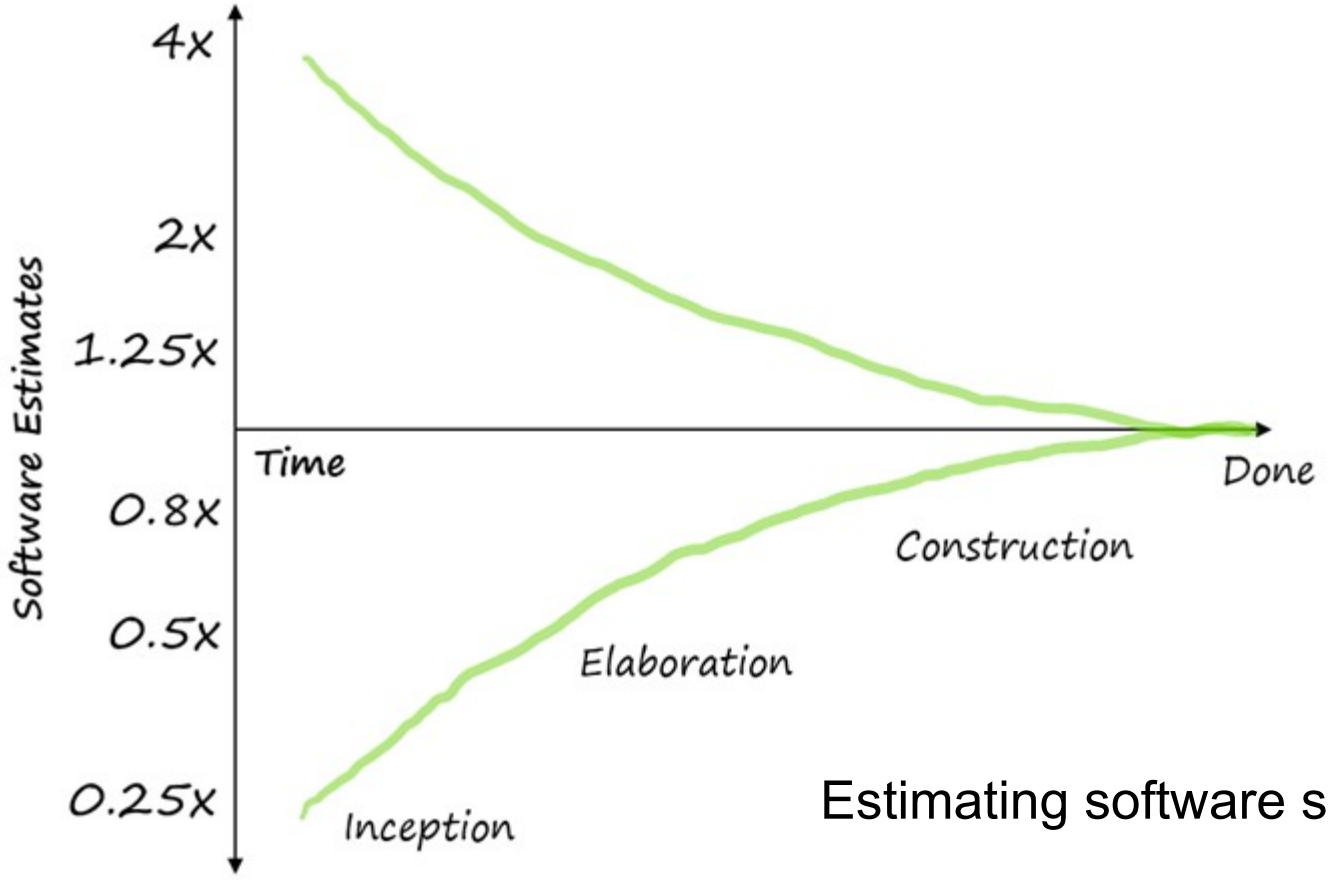
NASA's use of metrics

- What do NASA use on their code?
  - Cyclomatic Complexity
  - Lines of Code
  - Number of comments
  - Number of blank lines
  - Branch count
- NASA has one of the best metrics collection programmes that I know of:
  - The reason is simple

NASA metrics

Metrics	Description
BRANCH_COUNT	Branch count metric
LOC_TOTAL	Total number of source code lines
LOC_EXECUTABLE	Number of lines of executable code
LOC_COMMENTS	Number of lines of comments
LOC_BLANK	Number of blank lines
NUM_OPERATORS	Total number of operators
NUM_OPERANDS	Total number of operands
NUM_UNIQUE_OPERATORS	Number of unique operators
NUM_UNIQUE_OPERANDS	Number of unique operands
CYCLOMATIC_COMPLEXITY	Cyclomatic complexity of a module.
ESSENTIAL_COMPLEXITY	Essential complexity of a module.
DESIGN_COMPLEXITY	Design complexity of a module.
LOC_CODE_AND_COMMENT	Number of lines with both code and comments

Cone of uncertainty (McConnell)

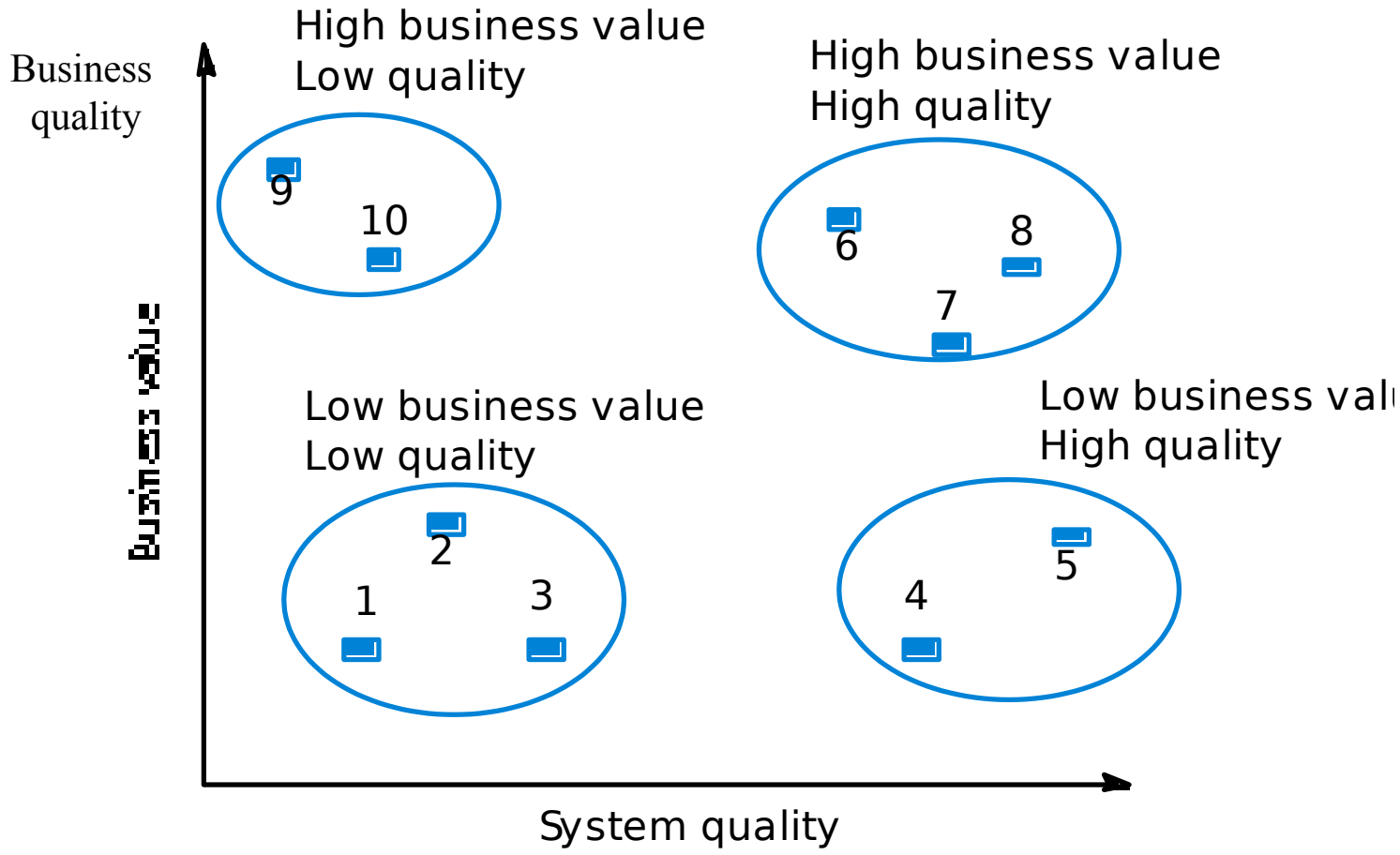


Estimating software size

What does the cone show?

- At the beginning of a software project:
  - Estimates are subject to large uncertainty
- As we progress, we learn more about the system and uncertainty decreases (estimates become more accurate)
- When we start writing code, that uncertainty decreases even more
  - The more features we complete, the more that uncertainty decreases
- Eventually, the uncertainty reaches 0% (at the project release)

How metrics can help us make decisions (an "audit grid")



Test-based metrics

- How many test cases have been designed per requirement?
- How many test cases have still to be designed?
- How many test cases have been executed?
- How many test cases passed or failed?
- How many bugs were identified and what were their severities?

Questions

- **Question 1:** What do you think is the value of using software metrics to measure code?
- **Question 2:** Discuss one disadvantage of any four of C&K's metrics of your choice.
- **Question 3:** "Small classes are less likely to be fault-prone than larger ones." To what extent do you agree with this statement?
- **Question 4:** Why are test-based metrics important?

Reading

- Sommerville – Ch. 24 in both editions 9 and 10
- Norman Fenton, James Bieman Software Metrics: A Rigorous and Practical Approach, Third Edition, CRC Press, 2014
- **Lines of Code (LOC)**
  - Why LOC is not good as a measure see: http://www.inf.u-szeged.hu/~beszedes/research/SED-TR2014-001-LOC.pdf

Reading (cont.)

- **Cyclomatic Complexity**
  - geeksforgeeks.org/cyclomatic-complexity/
- **C&K metrics**
- slideshare.net/skmetz/oo-metrics
- http://people.scs.carleton.ca/~jeanpier/sharedF14/T1/extra%20stuff/about%20metrics/Chidamber%20&%20Kemerer%20object-oriented%20metrics%20suite.pdf
- virtualmachinery.com/sidebar3.htm