TOPICS

Overview

Metrics

Estimation

Planning

SOFTWARE METRICS

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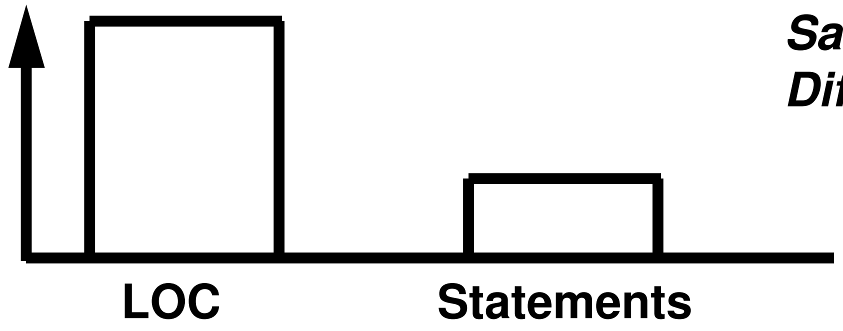
Measuring Software

- Objectively measuring software is difficult.
  - Most projects use only "lines of code" (LOC) for metrics.
  - Much disagreement exists on what and how much to measure.

but

- Accurately measuring software is vitally important to tracking and controlling software development.



Same Project
Different Metrics

Why Measure Software?

To --

1. identify quality of the software product
2. assess productivity of the software developers
3. assess benefits of using development processes and tools
4. form a baseline for estimation
5. justify requests for tools and training

Two Types of Measurements

- **Direct**
  - -- cost
  - -- LOC
  - -- execution speed
  - -- binary code size
  - -- memory used
  - easy to make

- **Indirect**
  - -- functionality
  - -- quality
  - -- "-ilities"
  - not easy to make

Categories of Metrics

	Productivity	Quality	Technical
Size-Oriented			
Function-Oriented			
Human-Oriented			

Size-Oriented Metrics

Let *KLOC* = "thousand lines of code"

Then we can define

- *productivity = KLOC / person-months*
- *quality = defects in code / KLOC*
- *cost = dollars / KLOC*
- *documentation = pages of documents / KLOC*

Efforts and costs include all elements of software development (analysis, design, code, test, *etc.*).

Size-Oriented Metrics - Examples

Project	Person-Months	Cost	KLOC	Pages of Doc	Errors
A	24	$168,000	12.1	365	29
B	62	$440,000	27.2	1224	86
C	43	$314,000	20.2	1050	64

Project	Productivity (KLOC/p-months)	Quality (errors/KLOC)	Cost ($/LOC)	Documents (pages/KLOC)
A	0.504	2.40	$13.88	30.17
B	0.439	3.55	$16.18	45.00
C	0.470	3.67	$15.54	51.98

Problems with Size-Oriented Metrics

- Definition of "lines of code"
  - Programming language dependent
  - Penalize well-designed shorter programs
  - Cannot easily accommodate non-procedural languages
  - Difficult to assess LOC before a program is written
- Only known errors can be counted
- Types, skill levels, and productivity of personnel varies

Function Points - Fi Values

0	1	2	3	4
No Influence	**Incidental**	**Moderate**	**Average**	**Significant**

1. Does the system require reliable backup?
2. Are data communications required?
3. Are there distributed processing functions?
4. Is performance critical?
5. Will the system run in an existing environment?
6. Does the system require on-line data entry?
7. Does the on-line data entry require the input transaction to be built over multiple screens or operations?
8. Are the master files updated on-line?
9. Are the inputs, outputs, files, or inquiries complex?
10. Is the internal processing complex?
11. Is the code designed to be reusable?
12. Are conversion and installation included in design?
13. Is the system designed for multiple installations in different organizations?
14. Is the application designed to facilitate change and ease of use?

Function Points - Computation

Measurement Parameter	Count		Weighting Simple	Average	Factor Complex		Product
Number of user inputs		x	3	4	6	=	
Number of user outputs		x	4	5	7	=	
Number of user inquiries		x	3	4	6	=	
Number of files		x	7	10	15	=	
Number of external interfaces		x	5	7	10	=	

Count - Total →

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

Feature Points

Function Point Extensions for Technical Software

- Function points were originally designed for business information systems applications.
- Extensions called *feature points* apply to technical software applications.
- Algorithms are a bounded computational problem that is included within a specific computer program.

Feature Points - Computation

Measurement Parameter	Count	Weight		Product
Number of user inputs		x 4	=	
Number of user outputs		x 5	=	
Number of user inquiries		x 4	=	
Number of files		x 7	=	
Number of external interfaces		x 7	=	
Algorithms		x 3	=	

Count - Total →

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

Problems with Function Points and Feature Points

1. These metrics are based on subjective data.
2. Parameters can be difficult to obtain after-the-fact.
3. Function and Feature Points have no direct physical meaning.

Function-Oriented Metrics

- Focus is on "functionality" or "utility"
- Both Function Points and Feature Points support the derivation of potentially useful data for the comparison of one project to another:

  - Productivity = FP / person-month
  - Quality = defects / FP
  - Cost = $ / FP
  - Documentation = pages / FP

Measuring Software Quality

Before Delivery

- **Program complexity**
- **Effective modularity**
- **Program size**

After Delivery (most widely used)

- **Number of defects uncovered in the field**
- **Maintainability of the system**

“After Delivery” Quality Metrics

- *Correctness* - defects/KLOC or defects/FP over a one-year period
- *Maintainability* - mean-time-to-change (MTTC), which is the time required to:
  - analyze the change request,
  - design a modification to the software,
  - implement the change,
  - test the changed software and the system as a whole, and
  - distribute the changed system to the users

"After Delivery" Quality Metrics, Continued

- *Integrity* - based on threats and security
  - *Threat* - probability that a specific attack will take place within a given period of time
  - *Security* - probability that the attack of a specific type will be repelled

$$\text{Integrity} = \sum_{\text{allthreats}} (1 - \text{threat}\,(1 - \text{security}\,))$$

- *Useability* - based on several perceptions of the users:
  - skill required to use the program
  - time required to learn the use of the program
  - the increase in productivity from using the program
  - the user's attitude towards the program

Relationship of LOC to FP

- **The relationship of lines of code to feature points is a function of the programming language used and the quality of the design.**
- **Rough estimates of the number of lines of code to create on feature point are:**

Language	***LOC/FP***
Assembly	**300**
COBOL	**100**
FORTRAN	**100**
Pascal	**90**
Ada	**70**
Object-Oriented Languages	**30**
Fourth Generation Languages	**20**
Automatic Code Generators	**15**

Use of Software Productivity Data

- Do not use LOC/person-month or FP/person-month to:
  - Compare one group of developers to another
  - Rate the performance of an individual
- Many factors affect productivity:

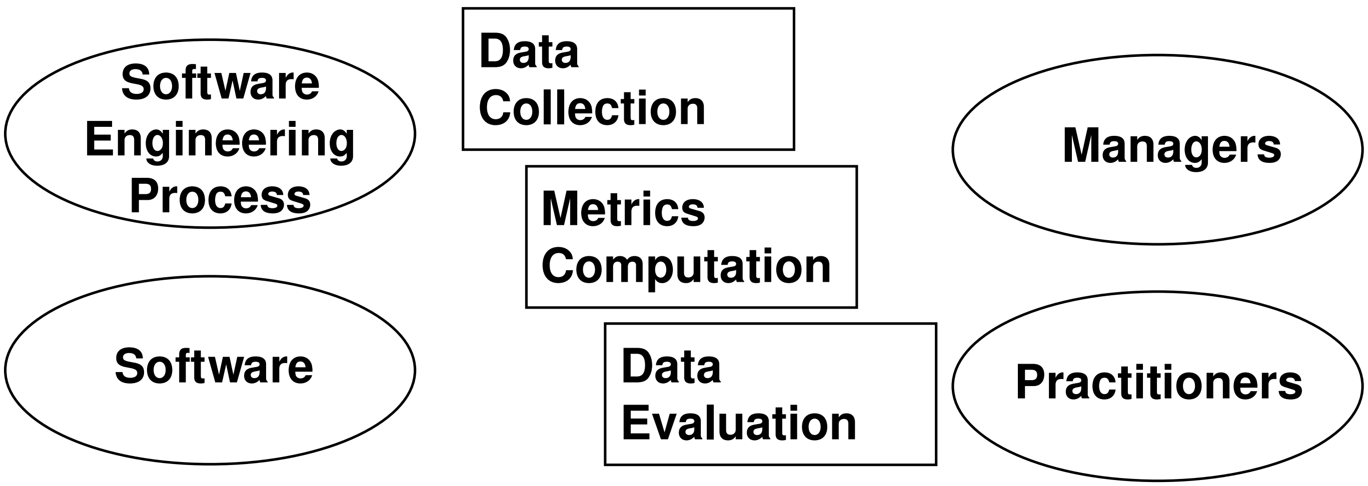
Factor	*Approximate % Variation in Productivity*
People (number, experience)	90%
Problem (complexity, number of changes)	40%
Process (language, CASE)	50%
Product (reliability, environment)	140%
Resources (CASE, hardware, software)	40%

Integrating Metrics into the Software Engineering Process

- A historical baseline of metrics data is needed:
  - Company, department, or unit should be identified in the scope of this data.
  - Resistance to data collection should be expected in many corporate cultures.
- At least three years of accurate, standardized metric data collection is needed to produce accurate planning estimates.

Collecting Software Metrics

- The process of collecting and using software metrics includes the following steps:
  1. data collection
  2. metrics computation
  3. data evaluation
- The following slides show a spreadsheet model for the collection and computation of historical software baseline data.



Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
• Cost Data Input		
Labor cost	$/person-month	$7,744
Labor year	hours/year	1560
• Data for Metrics Computation		
Release type	alphanumeric	maintenance
Number of staff members	people	3
Effort	person-hours	4800
Elapsed time to complete	hours	2000
Source code	KLOC	
Newly developed		11.5
Modified		0.4
Reused		0.8
Delivered		33.4

Spreadsheet Data Collection Model

Description	Units	Sample Data
• Data for Metrics Computation, Continued		
Documentation	pages	
Technical		265
User		122
Number of errors to date	numeric	
Critical errors		0
Level 1 errors		12
Level 2 errors		14
Documentation errors		40
Maintenance to date	person-hours	
Modifications		3550
Error correction		1970

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
• Project Data	% of total	
Analysis and specification		18%
Design		20%
Coding		23%
Testing		25%
Other - Describe		14%

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
Function-Oriented Data		
Information Domain		
1. No. of user inputs	inputs	24
2. No. of user outputs	outputs	46
3. No. of user inquiries	inquiries	8
4. No. of files	files	4
5. No. of ext. interfaces	interfaces	2
Weights		
1. No. of user inputs	3, 4, 6	4
2. No. of user outputs	4, 5, 7	4
3. No. of user inquiries	3, 4, 6	6
4. No. of files	7, 10, 15	10
5. No. of ext. interfaces	5, 7, 10	5

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
• **Function-Oriented Data, Continued**		
Processing Complexity Factors	**0-5**	
1. backup and recovery required		4
2. data communication required		1
3. distributed processing function		0
4. performance critical		3
5. heavily utilized operating environment		3
6. online data entry		5
7. input transaction with multiple screens		4
8. master files updated online		4
9. input, output, files, queries complex		3
10. internal processing complex		3
11. code designed to be reusable		2
12. conversion/installation included in design		2
13. system design for multiple installation		4
14. maintainability/ease of use		5

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
• Size-Oriented Metrics		
Productivity and Cost		
Output	KLOC/p-month	0.905
Cost - all code	$/KLOC	$22,514
Cost - exclude reuse	$/KLOC	$24,028
Elapsed time	months/KLOC	1.0
Documentation	pages/KLOC	30
Documentation	pages/p-month	10
Documentation	$/page	$739
Quality		
Defects	errors/KLOC	2.0
Cost of errors	$/error	$376

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
• Function-Oriented Metrics		
Productivity and Cost		
Output	**FP/p-month**	**378**
Cost - all code	**$/FP**	**$700**
Elapsed time	**FP/month**	**31.4**
Documentation	**pages/FP**	**0.9**
Quality		
Defects	**errors/FP**	**0.064**