Software Engineering | Halstead’s Software Metrics

A computer program is an implementation of **an algorithm** considered to be a collection of **tokens** which can be classified as either **operators or operands**.

Halstead’s metrics are included in a number of current commercial tools that **count software lines of code**. By **counting the tokens and determining which are operators and which are operands**,

the following base measures can be collected :

n1 = Number of distinct operators.
n2 = Number of distinct operands.
N1 = Total number of occurrences of operators.
N2 = Total number of occurrences of operands.

In addition to the above, Halstead defines the following :

n1* = Minimum Possible Number of potential operators.
n2* = Minimum Possible Number of potential operands.

Halstead refers to n1* and n2* as the **minimum possible number of operators and operands for a module and a**

program respectively. This minimum number would be embodied in the programming language itself, in which the required operation would already exist

(for example, in C language, any program must contain at least the definition of the function main()), possibly as a function or as a procedure:

n1* = 2, since at least 2 operators must appear for any function or procedure :

1 for the name of the function and 1 to serve as an assignment or grouping symbol, and n2* represents the number of parameters, without repetition, which would need to be passed on to the function or the procedure.

Halstead metrics –

Halstead metrics are :

- **Halstead Program Length –** The total number of operator occurrences and the total number of operand occurrences.

  N = N1 + N2

- **Halstead Vocabulary –** The total number of unique operator and unique operand occurrences.

  n = n1 + n2

- **Program Volume (V) –** Proportional to program size, represents the size, in bits, of space necessary for storing the program. This parameter is dependent on specific algorithm implementation.

- **Potential Minimum Volume –** The potential minimum volume V* is defined as the volume of the program in which **a problem can be coded**.

  $$V^* = (2 + n2^*) * \log_2(2 + n2^*)$$

  Here, n2* is the count of unique input and output parameters

- **Program Level –** To rank the programming languages, the level of abstraction provided by the programming language, Program Level (L) is considered. The higher the level of a language, the less effort it takes to develop a program using that language.

  $$L = V^* / V$$

  The value of L ranges between zero and one, with L=1 representing a program written at the highest possible level (i.e., with minimum size).

- **Program Difficulty –** This parameter shows how difficult to handle the program is.
  $$D = (n1 / 2) * (N2 / n2)$$
  $$D = 1 / L$$

- **Programming Effort –** Measures the amount of **mental activity** needed to translate the existing algorithm into

implementation in the specified program language.
$E = V / L = D * V$

E= Difficulty * Volume

- **Language Level –** Shows the algorithm implementation program language level. The same algorithm demands additional effort if it is written in a low-level program language. **For example, it is easier to program in Pascal than in Assembler**.

  L' = V / D / D
  lambda = L * V* = L^2 * V

- **Intelligence Content –** Determines the amount of **intelligence** presented (stated) in the program This parameter provides a measurement of program complexity, independently of the program language in which it was implemented.

  I = V / D

- **Programming Time –** Shows time (in minutes) needed to translate the existing algorithm into implementation in the specified program language.

  T = E / (f * S)

  5 <= S <= 20. Halstead uses 18. The value of S has been empirically developed from psychological reasoning, and its recommended value for programming applications is 18.

  number S = 18 moments / second

  seconds-to-minutes factor f = 60

McCabe Cyclomatic Complexity

(Alias: McCabe number)

> *Fools ignore complexity. Pragmatists suffer it. Some can avoid it. Geniuses remove it.*
>
> *- Alan Perlis, American Scientist*

McCabe's cyclomatic complexity is a software quality metric that quantifies the complexity of a software program. Complexity is inferred by measuring the number of linearly independent paths through the program. The higher the number the more complex the code.

The Significance of the McCabe Number

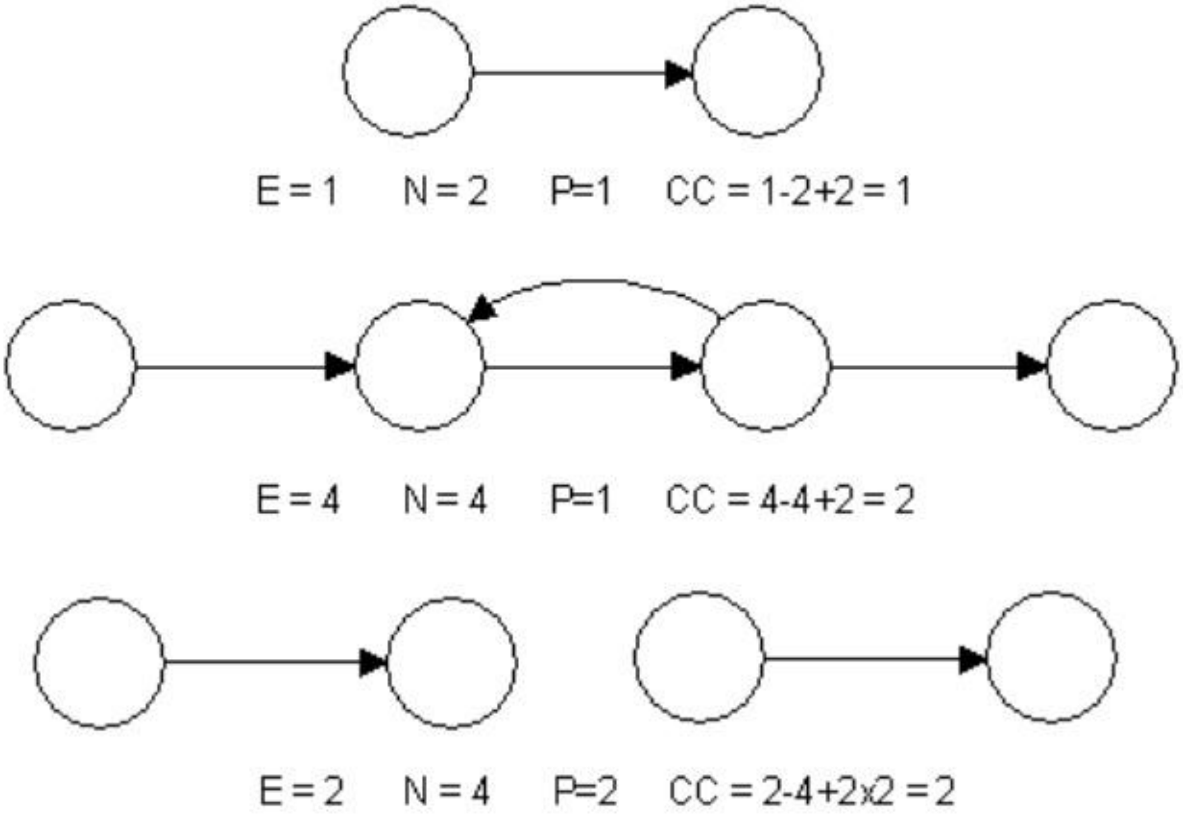
Measurement of McCabe's cyclomatic complexity metric ensures that developers are sensitive to the fact that programs with high McCabe numbers (e.g. > 10) are likely to be difficult to understand and therefore have a higher probability of containing defects. The cyclomatic complexity number also indicates the number of test cases that would have to be written to execute all paths in a program.

Calculating the McCabe Number

Cyclomatic complexity is derived from the control flow graph of a program as follows:

Cyclomatic complexity (CC) = E - N + 2P
Where:
P = number of disconnected parts of the flow graph (e.g. a calling program and a subroutine)
E = number of edges (transfers of control)
N = number of nodes (sequential group of statements containing only one transfer of control)

Examples of McCabe Number Calculations


E = 1 N = 2 P=1 CC = 1-2+2 = 1
E = 4 N = 4 P=1 CC = 4-4+2 = 2
E = 2 N = 4 P=2 CC = 2-4+2x2 = 2