Chapter - 6

Cognitive Weighted

Pointcut Per Aspect
CHAPTER - 6

COGNITIVE WEIGHTED POINTCUT PER ASPECT

6.1 Introduction

Software engineering is a challenging and multifaceted chore. Software metrics are one way of predicting quality within a system, pointing to problem areas which can be addressed before a software release. Metrics attempt to measure a particular aspect of a software system. Several approaches to estimate the complexity of software but none of them has been accepted as a true measure of the complexity of an Aspect [Ram, 03]. Aspect-oriented perspective is one of the most significant ways to quantify the reliability of software by controlling Aspect-oriented constructs.

Aspect Oriented Programming (AOP) is a new technology for separating crosscutting concerns that are usually hard to do in object-oriented programming [Chi, 94]. As AOP has better capability to handle crosscutting concerns than object-orientation, it helps to write more modularized and more maintainable code. AspectJ is a general-purpose, aspect-oriented extension to the Java programming language [Ana, 15]. Given that AspectJ is an extension to Java, every valid Java program is also a valid AspectJ program.

A pointcut is a program construct that selects joinpoints and collects context at those points. For example, a pointcut can select a joinpoint that is a call to a method, and it could also capture the method’s context, such as the target object on which the method was called and the method’s arguments. In AspectJ has CWPA metric to measure the different type of pointcut designator and joinpoint signature proposed by various researchers.
Cognitive complexity of a computer program is studied with respect to many cognitive processes. One of the most important cognitive processes involved in programming is program comprehension. In this chapter, a new metric CWPA is defined and validated against comprehension process.

6.2 Motivation

Several metrics have been proposed for AOP systems by researchers. Many AOP metrics proposed by Ceccato et al. [Cec, 04] and Kotrappa Sirbi et al. [Kot, 10]. Those metrics are closely interconnected to Weighted Pointcut per Aspect (WPA) metric.

WPA is calculated by adding the cognitive weight of the pointcut designator and cognitive weight of the joinpoint signature used in an aspect, proposed by Parthipan, Senthil Velan and Chitra Babu [Par, 14].

Pointcut designator describes that the advice was interlaced into the joinpoints. The joinpoint signature describes the functions that are related to the respective pointcut definitions. Pointcut decreases the complexity and increases reliability. In order to reap these benefits, it is important to measure the pointcut, of the software in order to raise the quality of the software and to reduce the cost of software production. This is the reason that calls for proposing better pointcut factor metric which can measure the cognitive complexity more accurately and comprehensively.

6.3 Formulation of the CWPA Metric

6.3.1 Existing Metric

Weighted Pointcut per Aspect (WPA) is calculated by adding the weight of the pointcut designator and cognitive weight of the joinpoint signature used in an aspect [Par, 14].
The formula to calculate WPA (A) is given in Equation 6.1.

\[ \text{WPA}(A) = \sum_{i=1}^{m} [\text{CW}(PD_i) + \text{CW}(JS_i)] \]  

... (6.1)

### 6.3.2 Proposed Metric

Several metrics have been proposed for AOP systems by researchers. One of the metric proposed by Parthipan, Senthil Velan, Chitra Babu [Par, 14] is WPA. It is calculated by adding the weight of the pointcut designator and cognitive weight of the joinpoint signature used in an aspect [San, 03].

The WPA metric uses the computation of pointcuts and joinpoints. Pointcuts are one of the major factors which will affect the complexity of the class and it is clear that the use of different data type of pointcuts increase the complexity of the programs. There is no specific measure exists to calculate the complexity due to pointcut. Hence, a new metric CWPA has been proposed for AOP system. The proposed metric called CWPA, which is adding Cognitive Weight of the Pointcut Designator (CWPD) and Cognitive Weight of the Method per Class (CWMC) used in an aspect.

### 6.4 Calibration of CW for WPA

This section discusses the CWPA metric, empirical data, collection statistics, analysis and its implication. WPA metric is selected for AO software. This metric is used to find the accurate cognitive weight value of pointcut designator using Cognitive Approach.
An experiment is conducted to assign cognitive weight to the various types of pointcut designator. A comprehension test has been conducted for a group of students to find out the time taken to understand the complexity of Aspect-Oriented program concerning different types of pointcut designator. The group of students selected had sufficient exposure in analysing the Aspect-oriented programs, as they had undergone courses in AspectJ language. 60 students were selected to participate in the comprehension test.

The time taken by students to comprehend the programs were recorded after the completion of each program. The time taken for comprehension of all these programs were noted and the Average Comprehension Time (ACT) was calculated. Five different programs have been administered in each case. Average time was calculated for each program from the individual time taken by students which are given in Table 6.1.

### Table 6.1 Categorized Average Comprehension Time

<table>
<thead>
<tr>
<th>Programs</th>
<th>Average Comprehension Time (ACT) (In Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Call</td>
</tr>
<tr>
<td>P1</td>
<td>14.33</td>
</tr>
<tr>
<td>P2</td>
<td>13.8</td>
</tr>
<tr>
<td>P3</td>
<td>13.97</td>
</tr>
<tr>
<td>P4</td>
<td>13.33</td>
</tr>
<tr>
<td>P5</td>
<td>13.28</td>
</tr>
</tbody>
</table>

For each pointcut designator, mean was selected as a measure of central tendency and the standard deviation as a measure of dispersion.
### Table 6.2 Statistical computation of different types of pointcut designator (In Hours)

<table>
<thead>
<tr>
<th>Programs</th>
<th>Call (CL)</th>
<th>Execution (EX)</th>
<th>Get (GT)</th>
<th>Set (ST)</th>
<th>Handler (HD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2388</td>
<td>0.3237</td>
<td>0.39</td>
<td>0.4808</td>
<td>0.5658</td>
</tr>
<tr>
<td>2</td>
<td>0.23</td>
<td>0.2912</td>
<td>0.4013</td>
<td>0.4803</td>
<td>0.5663</td>
</tr>
<tr>
<td>3</td>
<td>0.2328</td>
<td>0.3172</td>
<td>0.4052</td>
<td>0.4803</td>
<td>0.5655</td>
</tr>
<tr>
<td>4</td>
<td>0.2222</td>
<td>0.3038</td>
<td>0.3912</td>
<td>0.4803</td>
<td>0.5647</td>
</tr>
<tr>
<td>5</td>
<td>0.2213</td>
<td>0.2858</td>
<td>0.3955</td>
<td>0.4812</td>
<td>0.567</td>
</tr>
<tr>
<td>Mean</td>
<td>0.2291</td>
<td>0.3043</td>
<td>0.3966</td>
<td>0.4808</td>
<td>0.5659</td>
</tr>
<tr>
<td>Std.Dev.</td>
<td>0.9684</td>
<td>0.8153</td>
<td>0.7483</td>
<td>0.7048</td>
<td>0.7097</td>
</tr>
</tbody>
</table>

![Figure 6.1 Statistical computation of different types of pointcut designator](image)

In Table 6.2, the different types of pointcut designators and the statistical computation of mean and Standard Deviations (SDs) are calculated. The SDs for each
type of pointcuts are given to meet under the directions of call, execution, get, set and handler to bring out the group differences in comprehending the programs. The Figure 6.1 shows the pictorial representation of Table 6.2.

The mean and standard derivation values were normalized to get appropriate weight value. ACT value of each type of pointcut is divided by corresponding mean standard derivation. The final cognitive weight values are given as follows,

**Table 6.3 Cognitive Weight Value of each type of Joinpoint**

<table>
<thead>
<tr>
<th>Joinpoint</th>
<th>Cognitive Weight Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CW_{CL}$</td>
<td>0.7</td>
</tr>
<tr>
<td>$CW_{EX}$</td>
<td>1.1</td>
</tr>
<tr>
<td>$CW_{GT}$</td>
<td>1.6</td>
</tr>
<tr>
<td>$CW_{ST}$</td>
<td>2</td>
</tr>
<tr>
<td>$CW_{HD}$</td>
<td>2.4</td>
</tr>
</tbody>
</table>

The Cognitive Weight of each type of Pointcut Designator is calibrated in Table 6.3 using the method discussed in the Empirical Metric Data Collection and their corresponding chart view also given in Figure 6.1.

**6.5 Cognitive Weighted Pointcut per Aspect**

The proposed metric called CWPA, which considers the cognitive complexity of the different types of pointcut designator such as call, execution, get, set, and handler. The CWPA can be calculated using the equation 6.2.

$$CWPA = CWPD + CWMC \quad \ldots (6.2)$$

**Cognitive Weighted Pointcut Designator (CWPD)**

$$CWPD = ((EX\cdot CW_{EX}) + (CL\cdot CW_{CL}) + (ST\cdot CW_{ST}) + (GT\cdot CW_{GT}) + (HD\cdot CW_{HD})) \quad \ldots (6.3)$$
Cognitive Weighted Method per Class (CWMC)

\[
\text{CWMC} = ((BFA*\text{CW}_{\text{BFA}}) + (AFA*\text{CW}_{\text{AFA}}) + (ARA*\text{CW}_{\text{ARA}})) \quad \ldots \quad (6.4)
\]

where,

- \( \text{EX} \) – Execution
- \( \text{CL} \) – Call
- \( \text{ST} \) – Set
- \( \text{GT} \) – Get
- \( \text{HD} \) – Handler

\( \text{CW}_{\text{EX}} \) – Cognitive Weight of Execution

\( \text{CW}_{\text{CL}} \) – Cognitive Weight of Call

\( \text{CW}_{\text{ST}} \) – Cognitive Weight of Set

\( \text{CW}_{\text{GT}} \) – Cognitive Weight of Get

\( \text{CW}_{\text{HD}} \) – Cognitive Weight of Handler

The following section explains how CWPA is calculated using a case study.

6.6 Illustration

The proposed CWPA metric given by Eq. 6.2 is evaluated with the AspectJ program given in appendix B. From the program, the existing and proposed metric value are calculated as,

\[
\text{WPA} = \sum_{\text{PD}} \left( \text{CW}(PD) + \text{CW}(JS) \right)
\]

\[
\text{WPA} (A) = 1.5 + 0.4 = 2.1
\]
CWPA

CWPA = CWPD + CWMC

\[
\text{CWPD} = ((\text{EX} \cdot \text{CW}_{\text{EX}}) + (\text{CL} \cdot \text{CW}_{\text{CL}}) + (\text{ST} \cdot \text{CW}_{\text{ST}}) + (\text{GT} \cdot \text{CW}_{\text{GT}}) + (\text{HD} \cdot \text{CW}_{\text{HD}}))
\]

\[
\text{CWPD} = 0.7 + 1.1 + 1.6 + 2 + 2.4 = 7.8
\]

\[
\text{CWMC} = ((\text{BFA} \cdot \text{CW}_{\text{BFA}}) + (\text{AFA} \cdot \text{CW}_{\text{AFA}}) + (\text{ARA} \cdot \text{CW}_{\text{ARA}}))
\]

\[
\text{CWMC} = 1 + 1.33 + 1.66 = 3.99
\]

\[
\text{CWPA} = 7.8 + 3.99 = 12.79
\]

<table>
<thead>
<tr>
<th>Program#</th>
<th>Existing Metric Value (WPA)</th>
<th>Proposed Metric Value (CWPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.1</td>
<td>12.79</td>
</tr>
</tbody>
</table>

6.7 Comparative Study

A comparative study has been made with most widely accepted metric called WPA. The current CWPA metric is one step ahead of existing WPA metric; because it takes cognitive weights into consideration and data collection satisfies the Fenton et al. [Fen, 97] properties. To compare the proposed metric, a comprehension test was conducted to degree students. There were sixty students who participated in the test; the students were given five different programs in AspectJ for the comprehension test. The test was to find out the output of the given programs. The time taken to complete the test in minutes is recorded. The average time taken by all the students is calculated. In the following Table 6.5, a comparison has been made with WPA, CWPA and the comprehension test result and their corresponding graph are also shown in Figure 6.2.
Table 6.5 Complexity Metric Values and Mean Comprehension Time

<table>
<thead>
<tr>
<th>Program#</th>
<th>Existing Metric Value (WPA)</th>
<th>Proposed Metric Value (CWPA)</th>
<th>Mean Comprehension Time (in Mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.1</td>
<td>12.79</td>
<td>37</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>6.06</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>1.4</td>
<td>9.39</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
<td>9.99</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>12.8</td>
<td>42</td>
</tr>
</tbody>
</table>

CWPA calculated by adding the cognitive weight of the pointcut designator (CWPD) and cognitive weight of the joinpoint signature (CWMC) [Edu, 12] used in an aspect. This is a better indicator than the existing WPA. The weight of each type of pointcut is calculated by using cognitive weights and weight factor similar to which is suggested by Wang et al. [Wan, 03]. It is found that the resulting value of CWPA is larger than the WPA. Cognitive weights for calculation of the CWPA is more realistic because it considers different types of pointcut designator and advice and data satisfies the Fenton et al. [Fen, 97] properties. The results are shown in Table 6.5. A
correlation analysis was performed between WPA and Comprehension Time with 
\[ r = 0.900334 \] and CWPA Vs. Comprehension time with \[ r = 0.932175 \]. CWPA has 
more positive correlation than WPA. From the Table 6.5, it is observed that CWPA 
value is larger than WPA value which concludes that CWPA is a better indicator of 
the complexity of the aspect with a pointcut.

6.8 Theoretical Validation

Fenton et al. [Fen, 97] defined some properties which are used for the data 
collection process and are described as follows:

a. **Accuracy** - The higher the difference between the actual data and measured data 
and the lower is the accuracy and vice-versa. The difference between CWPA and 
WPA is lower, so the accuracy is higher.

b. **Replicability** - Means that the analysis can be done at different times by different 
people using the same setting. Data are taken from rural and urban PG students at 
a different time.

c. **Correctness** - According to the metrics definition data was collected. The value of 
CWPA is collected and calculated through the WPA metric.

d. **Precision** - Data is expressed by a number of decimal places. Less number of 
decimal places shows a lower accuracy. The decimal place of the data is high. So 
it shows a higher accuracy.

e. **Consistency** - It counts the differences in the metric values when collected using 
different tools by different people. Accordingly, we found the difference between 
existing metric - WPA and proposed metric – CWPA by giving different programs 
by different students.
6.9 Conclusion

A CWPA metric for measuring the aspect level complexity has been formulated. The Pointcut complexity of the aspect includes the Advice Execution complexity and Joinpoint complexity. CWPA has proven that complexity of the class getting affected, is based on the cognitive weights of the various types of Joinpoint. The metric is evaluated through statistical analysis, case study and a comparative study, and proved to be a better indicator of the aspect level complexity. The following chapter attempts to define and validate the proposed Cognitive Weighted Coupling on Attribute Reference (CWCoAR) metric.