Selecting software design based on birthmark

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Abstract- A good software design is the backbone of any software system that leads to the successful development of a usable and useful software system. Selection and decision about the most appropriate design based on property of birthmark is very crucial, and at the same time a strenuous task. Software birthmark is a promising technique which helps in detecting software piracy. Software industry is facing a severe issue of copying, stealing and misusing software without proper permissions as mentioned in the desired license agreement. This paper presents the technique of multi-criteria decision making (analytic hierarchy process) as a tool for selection of software design based on the property of birthmark. The proposed technique makes use of credibility attribute and resilience attribute of birthmark. The paper also presents a step by step application of the proposed analytic hierarchy process, with the help of an example, which validates its usefulness and helpfulness in situations where decision making is hard and critical. While detecting software theft may be the main concern of selection of the software design based on the property of birthmark there can be many other scenarios for which this selection can be beneficial.
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1. Introduction

Software birthmark is a promising technique which helps to identify the originality of a software system. It is different from the concept of software watermark which embeds additional information (code) to the software to establish the ownership of the software system. On the other hand, in software birthmark there is no extra information (or code) added to the existing system. While software watermark can be destroyed by using some advanced techniques [1] [2], software birthmark will still be there to show the originality of the software [3]. A lot of research has been presented on different aspects of software birthmark, which includes analyzing effectiveness of a software birthmark [2], software birthmark selection [4], using birthmark to detect theft of Java code [5], etc. Due to uniqueness of birthmark for software, a software birthmark can be effectively used for making decisions regarding different aspects in software engineering process. As a birthmark is a collection of some attributes that are embedded in the design and code of the software [3], it can be used to make many important decisions regarding software design.

A software design defines the basic skeleton of the software upon which the whole processing and communication structure of the software relies, within the system and with its external environment. Selecting a good software design is an ultimate objective of software engineering. Making selection decisions for software design can be critical in many situations.

This research proposes a multi criteria decision making process named as Analytic Hierarchy Process (AHP) [6] for the selection of software design based on birthmark. AHP is chosen as the supporting multi criteria decision making technique. AHP provides support for solving complex problems by helping to choose the best option from among numerous alternatives. Prioritization of requirements [7] assigning resources in software projects [8] and decision making in project management [9] are some of the applications of AHP. AHP achieves this by structuring a given problem as a hierarchy of goals, criteria, and alternatives. Generally, AHP is defined by the following properties;1) it is based on mathematical and logical reasoning, 2) it structures the problem in a hierarchy, and 3) it has a defined process for decision making. AHP has its application in a variety of fields including healthcare, economics, social science, project planning, and project management. Due to this versatility AHP has become famous as a tool for decision making.

The paper is organized as follows. Section 2 provides details about the methodology used to define the proposed technique. Section 3 shows the analysis and discussion of the proposed methodology, and section 4 concludes the paper.

2. Methodology

Software birthmark is the inherent characteristic of software to detect originality of software system. It is an intrinsic characteristic of a program which is then used to spot out software theft. Comparing the birthmarks of software tells us whether software is a copy of any other software or not. A software birthmark is defined as follows [10].

Let p, q be programs and f be a technique for take out a set of features from a program. Then f (p) is a birthmark of p if and only if:

1. f (p) is obtained only from p itself, and
2. q is a copy of p $\Rightarrow$f (p) = f (q).

A good software birthmark is defined having the properties of credibility and resilience. According to Tamada et al. [10] software birthmark should satisfy the following two properties which indicates that the two independently implemented programs should be different.

Property 1. Let P; Q, P be two independently written programs which achieve the same task, then f is credible if f (P) $\neq$ f (Q).

Property 2. Let P` be the program obtained from P by applying semantic preserving transformation T. f is resilient to T if f (P) = f (P`).

Both properties are very important to ensure the originality of software based on birthmark. A birthmark is actually properties of software code that is why it is known to be embedded into the design of the software.

The proposed methodology for selecting and deciding over an appropriate software design based on software birthmark is explained in the following section.

2.1 AHP for selection of software design based on birthmark

Analytic Hierarchy Process (AHP) is a multi criteria decision making process developed by Thomas L. Saaty [6]. It structures the problem in a hierarchy of goal, criteria, sub criteria and alternatives. AHP takes ratio scale from the paired comparisons of criteria and lets for small inconsistencies in judgments. The input weights (gathered from experts) can be entered in the pair-wise comparison matrix. It can be qualitative (for example, equal to or extremely strong) or quantitative (for example, 1, 2, 3,..9) in scale. Priorities and a consistency ratio are calculated based on these weights .AHP is a supporting tool for decision making process which helps to achieve an improved insight in complex problems and to make decisions in a more comprehensible manner.

The proposed method incorporates AHP for making a decision about software design based on software birthmark. The following diagram shows the structure of AHP method.

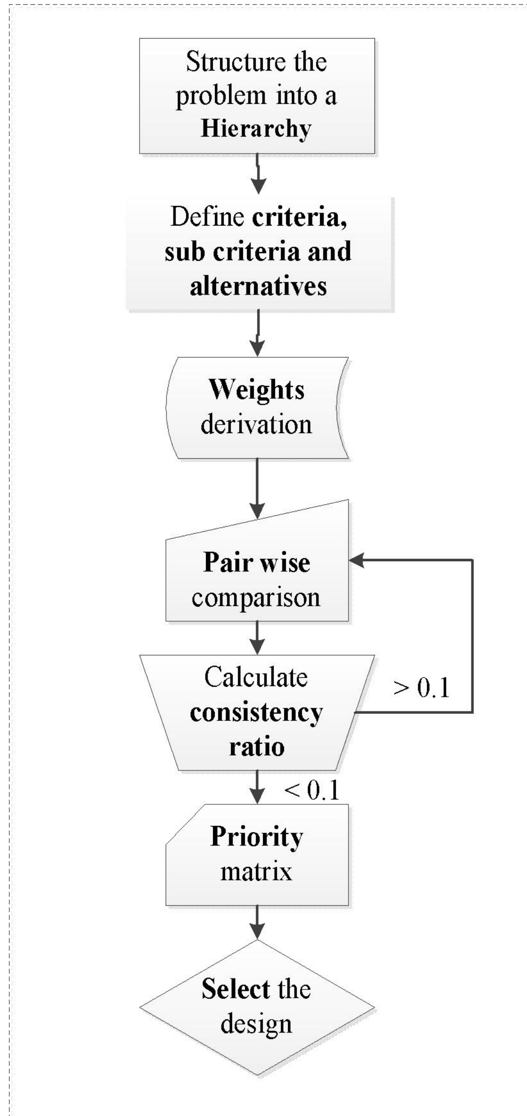

Figure 1. AHP structure (adapted from [6])

Further details of figure 1 are given below.

Step 1and 2. Structure the problem into hierarchy of goal, criteria and alternatives. The goal (first level) of the process is to select software design based on birthmark. Criteria and their sub criteria represent second level of the hierarchal structure. Criteria selected for the process are credibility and resilience. Alternatives (third level) are the available design options (that is, design 1, design 2, design 3, and design 4). Figure 2 represents the proposed AHP structure for the selection of software design based on birthmark.

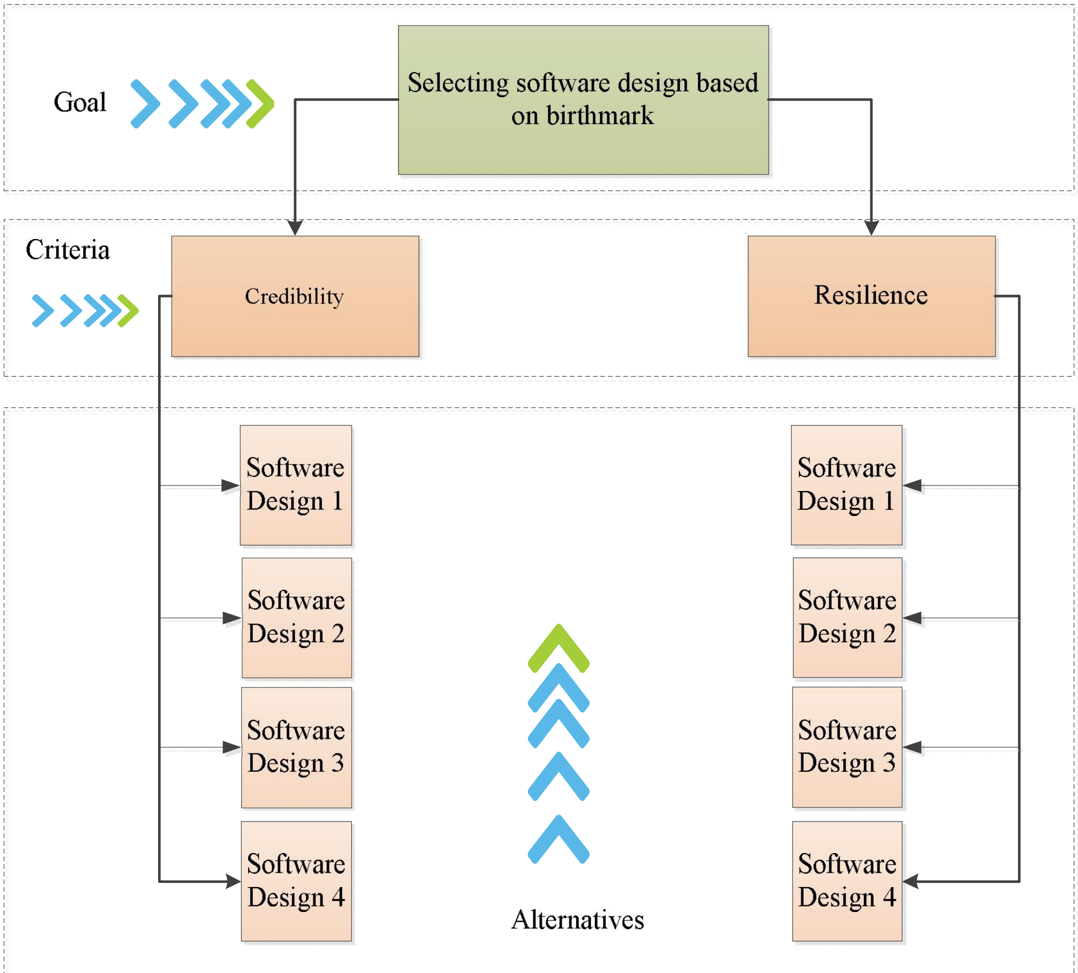

Figure 2. Analytic Hierarchy Process for software design based on birthmark

Step 3. Weights are derived based on the qualitative scale of equal, slightly strong, strong or exceptionally strong and converted into quantitative numbers of scale extremely strong (9), very strong (7), strong (5), moderate (3), equal (1) and other (reciprocal values of these)[6].

Step 4. In this step pair wise comparison of criteria, sub criteria and alternatives is performed. Weights derived in step 2 are assigned to the criteria, sub criteria and alternatives. In pair wise comparisons, the comparative importance of one criterion over another is obtained**.** Pair wise comparisons are done in $m \times m$ matrix,

For example, m is the number of criteria multiplied by the same number of criteria as shown in table 1.

Table1.pair wise comparison

	Criteria	Criteria
Criteria	(ii)	(ij)
Criteria	1/(ij)	(jj)

In a comparison matrix, a_{ij} represent the importance of the *i*th criteria relative to the *j*th criteria. If $a_{ij} > 1$, the *i*th criteria is more important than *j*th criteria, and if $a_{ij} < 1$, the *i*th criteria is less important than the *j*th criteria. If two criteria have the same importance, then the entry a_{ij} is 1.

Step 5. The next step is to find the consistency of the comparison matrix. To do so, row sums are calculated and the matrix is normalized (pair wise comparison). The process of normalization is repeated until the consistency of the matrix is less than 0.1. A Random consistency table (RI) is given by Saaty [11] which is shown in table 2. It is calculated as: CI= λ_{max}-n/(n-1), CR=CI/RI, where λ_{max} is the maximum Eigen value of the comparison matrix. The CI can be compared with that of a random matrix RI. The value of CR must be less than 0.1.

Table 2.Consistency ratio [11]

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.6	0.9	1.1	1.2	1.3	1.4	1.5	1.5

The following matrix 1 shows the comparison among criteria.

$$\begin{pmatrix} & \text{Credibility} & \text{Resilience} & \text{E.V} \\ \text{Credibility} & 1 & 3 & 0.75 \\ \text{Resilience} & 1/3 & 1 & 0.25 \\ \text{CR}=0.00 & & & \end{pmatrix} -----(1)$$

Matrix 2 shows the comparison of available designs with respect to attribute of credibility.

$$\begin{pmatrix} & D1 & D2 & D3 & D4 \\ D1 & 1 & 4 & 2 & 1/3 \\ D2 & 1/4 & 1 & 2 & 1/4 \\ D3 & 1/2 & 1/2 & 1 & 1/3 \\ D4 & 3 & 4 & 3 & 1 \end{pmatrix} -----(2)$$

The normalization process of matrix 2 is explained below, in which the original matrix is multiplied by itself, and then the values of the rows are added, resulting in a priority weight matrix. The next step is to add the values of the priority matrix and then divide each value by the sum of the total. The next obtained values are the Eigen value of the matrix.

AHP normalization process for the proposed criteria and alternatives is given in A.

$$\begin{pmatrix} & D1 & D2 & D3 & D4 \\ D1 & 1.00 & 4.00 & 2.00 & 0.33 \\ D2 & 0.25 & 1.00 & 2.00 & 0.25 \\ D3 & 0.50 & 0.50 & 1.00 & 0.33 \\ D4 & 3.00 & 4.00 & 3.00 & 1.00 \end{pmatrix} * \begin{pmatrix} & D1 & D2 & D3 & D4 \\ D1 & 1.00 & 4.00 & 2.00 & 0.33 \\ D2 & 0.25 & 1.00 & 2.00 & 0.25 \\ D3 & 0.50 & 0.50 & 1.00 & 0.33 \\ D4 & 3.00 & 4.00 & 3.00 & 1.00 \end{pmatrix} = \begin{pmatrix} 4.000 & 10.333 & 13.000 & 2.333 \\ 2.250 & 4.000 & 5.2500 & 1.250 \\ 2.125 & 4.333 & 4.0000 & 0.958 \\ 8.500 & 21.500 & 20.000 & 4.000 \end{pmatrix}$$

$$\begin{pmatrix} 4.000+10.333+13.000+2.333 \\ 2.250+4.000+5.2500+1.250 \\ 2.125+4.333+4.0000+0.958 \\ 8.500+21.500+20.000+4.000 \end{pmatrix} \begin{matrix} = \\ = \\ = \\ = \end{matrix} \begin{pmatrix} 29.667 \\ 12.750 \\ 11.417 \\ 54.000 \\ 107.833 \end{pmatrix} \begin{matrix} = \\ = \\ = \\ = \end{matrix} \begin{pmatrix} 0.27 \\ 0.12 \\ 0.10 \\ 0.50 \\ 1.00 \end{pmatrix} = \begin{pmatrix} & D1 & D2 & D3 & D4 & E.V. \\ D1 & 1 & 4 & 2 & 1/3 & 0.27 \\ D2 & 1/4 & 1 & 2 & 1/4 & 0.12 \\ D3 & 1/2 & 1/2 & 1 & 1/3 & 0.10 \\ D4 & 3 & 4 & 3 & 1 & 0.50 \end{pmatrix}$$

-A-

The same process of pair wise comparison can be repeated for the remaining matrix. The following matrix 3 shows the resulting comparison of design with respect to resilience.

$$\begin{pmatrix} & D1 & D2 & D3 & D4 & E.V. \\ D1 & 1 & 3 & 4 & 1/2 & 0.31 \\ D2 & 1/3 & 1 & 3 & 1/4 & 0.15 \\ D3 & 1/4 & 1/3 & 1 & 1/3 & 0.09 \\ D4 & 2 & 4 & 3 & 1 & 0.45 \\ \text{CR}=0.07 & & & & & \end{pmatrix} -----(3)$$

Step 7. In this step the overall status of the alternatives and the criteria is multiplied which produces a priority matrix. This priority matrix shows the final weights of the available alternatives, and helps in making final decision about the design alternative to be selected.

The calculation of priority matrix (criteria * alternatives) is given in matrix 4.

$$\begin{pmatrix} 0.27 & 0.31 \\ 0.12 & 0.15 \\ 0.10 & 0.09 \\ 0.50 & 0.45 \end{pmatrix} * \begin{pmatrix} 0.75 \\ 0.25 \end{pmatrix} = \begin{pmatrix} 0.28 \\ 0.13 \\ 0.10 \\ 0.49 \end{pmatrix} -----(4)$$

3. Analysis and discussion

So far, many techniques are being used for selection, prioritization and decision making in different environments. The multi criteria decision making processes such as analytic hierarchy process [6], analytic network process [12], fuzzy analytic network process [13], fuzzy logic [14] are some to mention. These techniques are used when there are dependencies and complex structures among the elements. For example S. Shahzad et al. used FANP for component project evaluation [15]. Here in the context of this research AHP technique has been used for the purpose of software design selection which is based on birthmark. AHP is known to give best results when there are fewer factors (elements) involved as selection criteria. As in the proposed method two factors that is credibility and resilience are used for the selection of software design based on birthmark, so here AHP is one of the most efficient and suitable technique which can be used. This selection of design based on birthmark can be used for different purposes, that is, for investigating software design theft, design piracy, understanding similarities among design of different software's, and so on.

The results of the process shown in section 2 (in matrix 4) show that design 4 which has the weight 0.49 is the most relevant design based on the property of birthmark, then design 1, then 2 and design 3 is the last one. The simplicity and efficiency of the AHP process shows that the proposed method is helpful in the selection of software design based on birthmark.

$$\begin{pmatrix} \text{Design 1} = 0.28 \\ \text{Design 2} \quad 0.13 \\ \text{Design 3} = 0.10 \\ \text{Design 4} = 0.49 \end{pmatrix} ------(5)$$

4. Conclusion

The selection of software design based on birthmark is one of the most important decisions to be made for a software development project. A software design is the basic skeleton of any software system. Selection of a good and relevant design is a very critical decision which is to be made in certain situations in software engineering. This can be either selecting a software design for investigating software theft, or it can be selection of software design by the owners for further development. This paper proposed a technique to efficiently contribute toward the selection of software design based on birthmarks. The technique has been evaluated based on the two properties of software birthmark that are credibility and resilience. The results of the proposed method clearly show that it is an effective method for the selection of software design.

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