Software Reengineering Toolkit with Tangible Interface by Haptics

Makoto Yoshida[1], Shinnta Okumura[1] and Noriyuki Iwane[2]
[1]*Department of Information & Computer Engineering, Okayama University of Science, Okayama, Japan*
[2]*Department of Information & Computer Science Hiroshima City University, Hiroshima, Japan*

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Abstract: Software reengineering is an important task for software maintenance and improvement. Several metrics are proposed for evaluating software programs, and the toolkits which evaluate the software using the metrics are developed. The tool should be easy to understand, easy to modify the programs, enjoyable to use, and must be effective. We developed the 3D visualized toolkit for software reengineering providing various tangible user interfaces with haptics. The toolkit decomposes the java source program into small classes, and integrates them into the harmonized program using haptic device. The decomposed classes can be given the sound, colour and vibration attributes that can be touched and perceived, and can be merged into another classes by moving the arm of the haptic device. This paper describes the toolkit which uses the haptic device for program reorganization providing various tangible user interfaces. Software reengineering methodology is proposed, and some experiments are performed and the results are presented.

1 INTRODUCTION

Most of the programs are not newly written; they are reused, and the systems are maintained. The objective of reengineering is to produce a new maintainable system with least efforts (Stephen, 2007). The programs must be reorganized, and many tools are developed (Serge, 2013). Metrics analysis and visualization help to reorganize the programs (Serge, 2000; Lanza, 2006). The reorganized program must have adequate modularity; modules with high cohesion and low coupling must be maintained (Kionel, 1999; Fernando, 2000). M. Lanza, et al, express the metrics of the program by 3D visualization and by the metaphor of cities (Werrel, 2011; Greevy, 2006). Unharmonized programs that may have intensive coupling, shotgun surgery, dispersed coupling, god class, et al (Lanza, 2006), are recognized by visualizing the structure of the program on metrics.

Looking at the tool interfaces, the user interface has changed from CUI to GUI, namely from 1D metrics values to 2D to 3D visualization, and now is changing from GUI to TUI, the tangible user interface. The TUI was first proposed by Ishii (Ishii, 1997), and now is used for as the next generation interface. Ishii tried to operate the computer on manipulating the virtual objects by touching and moving the objects, connecting the body movement with the computer operations (Ishii, 1997).

We developed the software reengineering toolkit with tangible user interface by using hapatic device. Two types of user interface: the active user interface that the user can touch any objects and the passive user interface that the arm of the haptic device moves among objects automatically based on the execution log of the program, are developed. As the active user interface, the perceptual user interface which can touch the program modules, which can hear the sounds of program modules by hitting, which can feel the vibration of program modules by executing the program, are supported. As the passive user interface, the movements of the arm of the haptic device which follow the execution of the program modules are supported. The program modules are visualized as 3D objects like spheres and cubes; each objects has its tangible attributes mapped from the program metrics. The program module structure is reorganized by decomposing and coupling modules by using the tangible user interface.

This paper describes the system framework and the user interface of the toolkit for software reengineering with some experiments. The methodology using tangible user interface by haptics is proposed and examined.

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2 TOOLKIT

Figure 1 shows the haptic device, FALCON, the physical device which provides the tangible user interface to the toolkit. Through touching an object displayed on the screen by the arm (catching Part A in Figure 1), it can perceive the object. Recognizing the object perception, it can couple the object putting one onto another object. It integrates the objects into one object.

Figure 2 shows the system framework of the toolkit. It consists of three parts: the program analysis part, the object perception part, and the code generation part. The program analysis part analyses the Java source program, and produces the metrics of the program. Numbers of classes, lines, methods, fields, dependency of classes, et al, are analysed. It can also decompose the program into smaller components. A class can be decomposed into more small classes. Decomposed classes are represented as the objects in the object perception part given the device attributes mapped from the metrics analysed. In object perception part, haptic device shown in Figure 1 is used to manipulate the object operations. In the code generation part, the java source code is automatically generated from the results of object integration operated either in the object perception part or in the analysis part.

Figure 2 also shows the way that the program is reengineered using the tangible user interface. There exists three cycles in Figure 2. The first cycle is depicted by the arrows ① and ②. This cycle uses metrics to reorganize the program. In this cycle, the metrics such as overviewPyramid, complexity, hotspots and blueprint (Lanza, 2006) can be 2D visualised, and used to reorganize the program. The second cycle is depicted by the arrows ③,⑤ and ⑦. The analyzed metrics are passed to the object perception part, and those data are mapped to the attributes of the haptic objects. As the user active perception using the haptic device, the operations of coupling and decomposing objects by sound hearing, looking at the colours and feeling the vibration of the objects, are provided. The third cycle is depicted by the arrows ④,⑥ and ⑦. It is the user passive perceptive operation using the haptic device. The arm of the haptic device chases the program execution. In addition to the above mentioned mapping, it is possible to map the metrics into any attributes of the haptic device. Any cycles can be repeated any times; if n times cycles were repeated, then 3^n ways of the program reorganization can be possible.

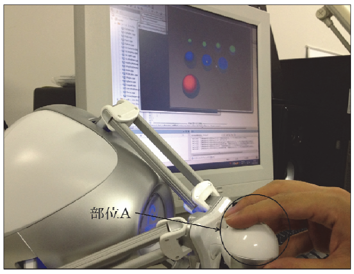


Figure 1: Haptic device.

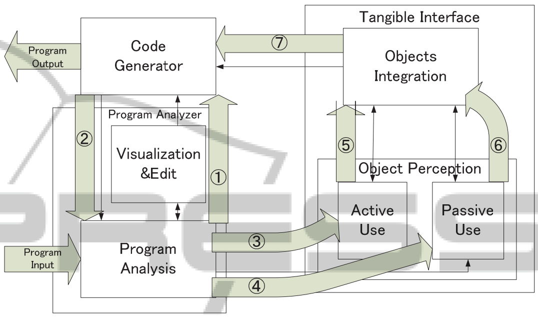


Figure 2: Toolkit framework.

2.1 Program Analysis

Program analysis consists of two parts: the program analysis part and the visualization & edit part. The former analyses the program and produces the metrics, and the latter visualizes and edits the program and decomposes the program into smaller elements such as subclasses and modules. One class can be decomposed into several subclasses, or integrated into one large class. This is shown in Figure 3. Figure 3 shows that class 0 is decomposed into two classes: class 1 and class 2, as the method A and B only access the field a, and method C only accesses the field b and c. Figure 3 also shows the integration possibility of two classes, class 1 and class 2, into a class 0. The basic policy for program decomposition is the fact that the program can be decomposed into the smaller unit if there exists no dependency among units, namely if no units interaction occurs.

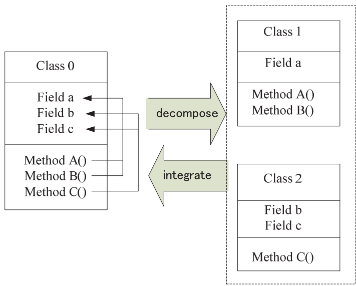


Figure 3: Class decomposition & ntegration.

2.2 Object Perception

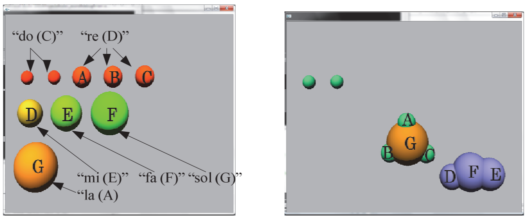
This section describes the object perception part in the toolkit framework. The metrics of the programs analyzed are passed to the object perception part, and mapped to the haptic objects with appearance. Haptic objects are displayed in the screen and touched by using the arm of the haptic device. Two types of tangible interface, active and passive interface, are provided. As the active user interface, object sounding, colouring, and vibrating are introduced. As the passive user interface, automatic arm chasing of the haptic device with program execution is introduced.

Figure 4 shows the example of the sound objects. Touching and moving the objects, object A, B, C and G are merged into one large object and the new sound is assigned. In Figure 4(b), the sound 'mi' is assigned, as the average sound of the objects merged.

The object can be given the colour. Figure 5(a) indicates 9 objects, and each object is given the colour. Touching and moving the objects, object A, B, C and G are merged into one large object and the colour 'orange' is assigned, as the average colour of the objects merged.

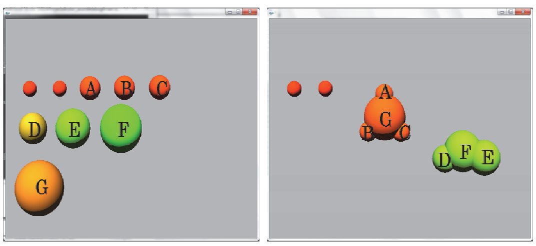
Figure 6 shows an example of the vibrating objects. It is based on the execution log of the program. The execution of the program can be recognized by vibrating and touching the objects.

Figure 7 shows the passive user interface. The arm of the haptic device chases automatically with the execution log of the program. Figure 7(b) shows that the object 1, 5 and 15 are integrated into one object.



(a) Sound Object (b) Sound Integration

Figure 4: Object sounding.



(a) Coloured Object (b) Colour Integration

Figure 5: Object colouring.

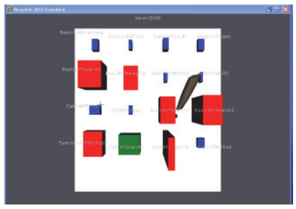


Figure 6: Object vibration.

(a) Arm Movement (b) Object Integration

Figure 7: Passive use interface.

3 HAPTICS OPERATION EXAMINED

This section shows various haptic operations performed for reengineering the program by using tangible user interface. Table 1 shows the metrics mapped to the object in this experiments. Two metrics, metrics 1 and metrics 2, are used. The metrics 1 is the number of lines per method, and the metrics 2 is the number of methods per class (Lanza, 2006). The metrics 1 is used for decomposing the program, and method 2 is used for measuring the integration goodness of the program. In this section, the left side of each Figures shows the program structure of before the coupling, and the right side shows the program structure of after the coupling.

Table 1: Metrics mapping example.

Metrics	Sound Representation	ColourRepresentation
# of classes	# of objects	# of objects
# of lines	size of the object	size of the object
# of lines/method	sound of the object	colour of the object

3.1 Sound Coupling

Figure 8 shows an example of sound coupling. Sixty six sounds, ranging from 110Hz to 4693Hz, are arranged, and the metrics 1 is mapped to the sound of object. The objects which have high difference on sound are coupled. In the example, object A, which has the sound 293Hz, and object B, which has the sound 123Hz, are coupled together into one object AB, and the integrated sound became 165Hz. Figure 9 shows another example of sound coupling with different coupling method. Several objects are merged into one object to have the adequate object sound after couplings. The adequate sound, whose Hz is set to the average Hz of the whole objects, is represented by the square in Figure 9. The sound of the square object is preliminary settled, and user can ascertain the sound of the object by hitting the square object by haptic hand. Figure 9 shows the object A ,whose sound is 'so' and its height is784Hz, and the object B whose sound is 'do' and the height is 1046Hz, are merged into the object AB, and the sound 'ra' is assigned, and the height became 932Hz.

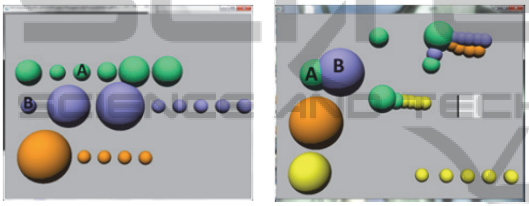


Figure 8: Example of sound coupling 1.

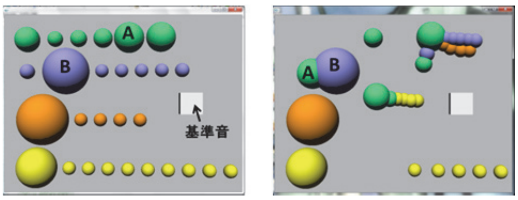


Figure 9: Example of sound coupling 2.

3.2 Colour Coupling

Figure 10 shows an example of colour coupling. Sixty six colours, ranging from red to green, are arranged. Metrics 1 is mapped to the colour of an object. The experiments that couple the objects which have similar colours are examined. In the left of figure 10, the object A and B, both of which has the colour green, and the object C which has the colour yellow green, are merged, and produced the object ABC coloured green.

3.3 Undo Coupling

Module should be in high cohesion and low coupling. The execution log of the program, which is the history of the objects executed, is collected. The operation UNDO, which undoes the coupling when the objects coupled have no access relationship among them in the execution log, is provided.

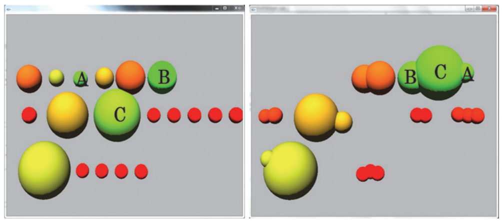


Figure 10: Example of colour coupling.

In the left figure of Figure 11, the object A and B are coupled into one object. However, as the abject A and B have no access relationship in the execution log, its integration was denied by the toolkit, and the colour of the coupled object changed to the black, as is shown in the right figure of Figure 11. In this case, the coupling operation must be undone.

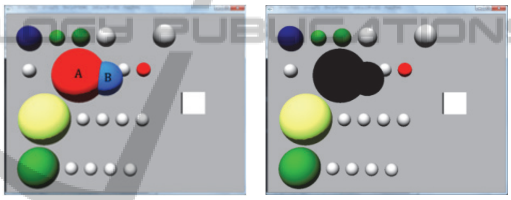


Figure 11: Example of undone coupling.

4 METHODOLOGY

4.1 Coupling Schema

Several experiments were performed, and the coupling schema was examined. Figure 12 shows the coupling schema that the metrics must satisfy. A dotted rectangle in the Figure 12 shows the appropriate domain of the program, and it shows that two metrics of the program are converging into the rectangular. The right figure of Figure 12 is the general schema. Two metrics, metrics 1(M1) and metrics 2(M2), are adopted. M1 is the number of methods in a class, and M2 is the lines of code in a method [1]. The schema adapted for object integration is as follows;

Operation1. First, decompose the program, and map the metrics M1 to the object. The toolkit we developed decomposes a class into smaller units of module, and creates the corresponding objects. This operation always decreases the value of M1, and it is repeated until the M1's value of the program becomes lower than the lower bound predefined (see the right figure of Figure12).

Operation2. Use the metrics M2 to integrate the objects. The coupling operations provided should be performed to lead the M2's value to converge into the dotted rectangular area.

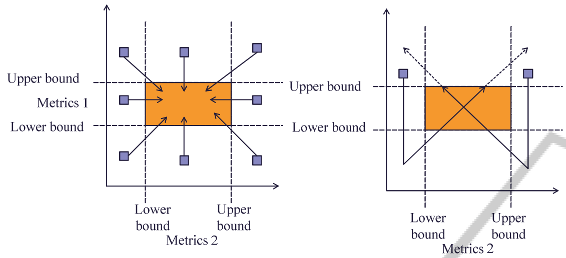


Figure 12: Object integration schema.

4.2 Discussions

Reengineering programs using the toolkit by haptics was examined. In the Appendix, the metrics of the program experimented are depicted. The original program was reorganized using several coupling methods following the methodology described in section 4.1, and the reorganized metrics were collected.

Table 2 shows five experimental results. The transition of metrics 1 and 2 of the programs followed by the coupling schema is shown in Figure 13. In Figure 13, the original program is denoted as O1, and the succeeding reorganization of the program is described as arrows. Three programs, O1, O2 and O3, are reengineered. S stands for Sound, and objects are integrated by sound coupling, C stands for Colour, and objects are integrated by colour coupling. M1(Y1) and M1(Y2) are the boundaries of metrics 1, and the program had better be in this boundary when reorganized. M2(X1) and M2(X2) are the boundary of metrics 2; M2(X3) and M2(X4) are the other boundary of metrics 2. These boundaries are predefined and the integration of objects was performed to be converged in these boundaries.

Michele Lanza (Lanza, 2006) computed the methods per class (M1) and the lines per method (M2) by analyzing 45 java projects, and showed that the average of M1 is 7 ranging from 4 to 10, and the average of M2 is 10 ranging from 7 to 13. The suitable metrics area of the program by the reference (Lanza, 2006) is between M2(X1) and M2(X2) for metrics 2 and between M1 (x 1) and M1 (x 2) for metrics 1.

In Figure 13, it can be seen that the metrics M1 for the program O1 was decomposed, and changed the metrics M1 to B1 and B2, and then changed to C1 and S1 after integration. The program O3 is decomposed, and changed to B3, and then integrated to S1. If we follow the reference (Lanza, 2006), only an object O2 had the appropriate metrics, and O3's reengineering was performed well, but O1's reengineering was not appropriate.

5 CONCLUSIONS

This paper described the software reengineering toolkit with tangible user interface by using haptic device. The system framework of the toolkit, the program decomposition method and several coupling methods of the objects are described. Two types of the tangible user interface by haptics, the active user interface and the passive user interface, are introduced. Several object coupling methods are described and discussed. The methodology of the program integration by using haptic device is proposed. Two metrics, methods per class and lines per method, are adopted, and some experiments for software program reengineering were performed. The discussion of the results examined the usefulness of the toolkit.

Software visualization is changing from 2D to 3D, and the user interface is changing from GUI to TUI (Ishii, 1997). The interface devices with body movement, and 3D visualization tools with more sophisticated metaphor are emerging (Wettel, 2011). This paper introduced the new tangible user interface by using the haptic device, and examined some experiments.

However, we need more efforts for practical use. Shaping up the toolkit, and validating the effectiveness of the toolkit with more experiments, we are going to use the toolkit to the first programming course to learn the style of the program, and also be going to provide to the people who is not familiar with the programming.

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APPENDIX

Table 2: Metrics of the experiments.

Metrics	Original	Decomposed	Integrated1	Integrated2	Integrated3	Integrated4	Integrated5
# of classes	10	19	7	11	8	5	5
# of fields	126	126	126	126	126	126	126
# of lines	2171	2186	2167	2175	2169	2153	2163
# of methods	76	76	76	76	76	76	76
lines/method	38.5	31.7	28.3	28.1	24.8	35.7	27.6
methods/class	7.6	4.0	10.9	6.9	9.5	15.2	15.2

*Original: The metrics of the original program. O1 in Figure 13.
Decomposed: The metrics of the decomposed program. Denoted by B1 in Figure 13.
Integrated1: Integrated by using ① and ② in Figure2. TUI is not used.
Integrated2: Integrated by sound coupling. TUI is used. The metrics of Figure 9. Denoted by S1 in Figure 13.
Integrated3: Integrated by colour coupling. TUI is used. The metrics of Figure 10. Denoted by C1 in Figure 13.
Integrated4: Integrated by sound and colour coupling. Sound coupling followed by colour coupling.
Integrated5: Integrated by two times of colour couplings. Denoted by C2 in Figure 13.

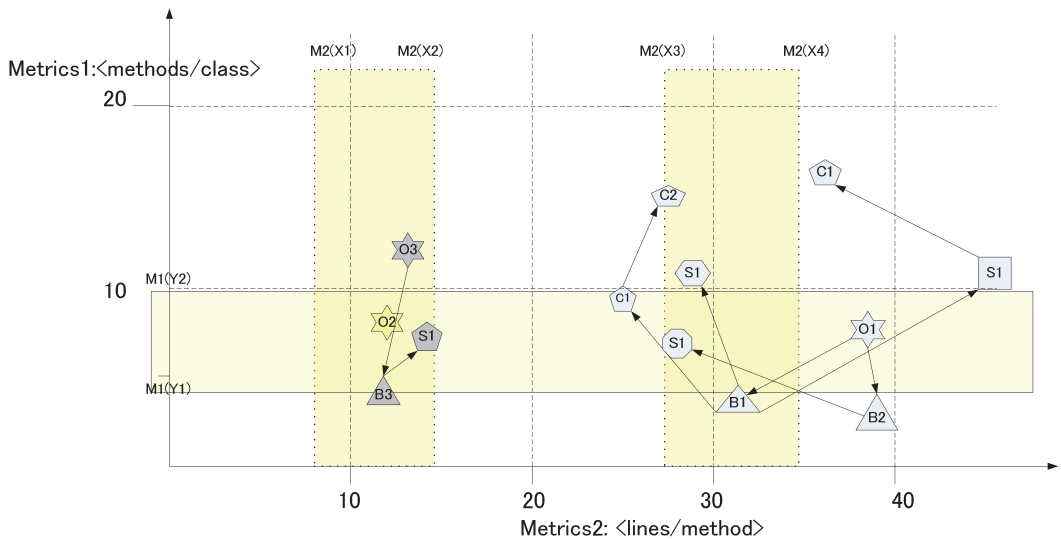

Figure 13: Metrics of the experiments.