A JAVA-PLATFORM SOFTWARE FOR THE EVALUATION OF MASS ATTENUATION AND MASS-ABSORPTION COEFFICIENTS FOR BODY TISSUES AND SUBSTITUTES

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ABSTRACT

A computer software was written for the evaluation of mass attenuation coefficient (μ/ϱ) and mass energy-absorption coefficient (μ_{en}/ϱ) for body tissues and substitutes of arbitrary elemental composition and percentage-by-weight of elemental constituents using the Java development platform which could run on any operating system (Windows, Linux, Unix etc.) that ports Java Runtime Environment (JRE). Results obtained from the program for values of μ/ϱ and μ_{en}/ϱ were in agreement with those reported in literature.

Keywords: Mass Attenuation Coefficient, Mass Energy-absorption Coefficient, Body Tissues Substitutes, Computer Software.

INTRODUCTION

It is becoming a common practice to parameterize and develop user-friendly software for the evaluation of large volume of data that are required in scientific computations. A specific example is the data on mass attenuation and mass energy-absorption coefficients (μ/ϱ and μ_{en}/ϱ) that are required in the extensive study of interaction of photons with matter (Loi *et al.*, 1977; Hawkes and Jackson, 1980; Massaro *et al.,* 1982; Tucker *et al.,* 1991a, 1991b; Ouellet and Schrener, 1991; Assiamah *et al.*, 2003; Midgley, 2004; Williamson *et al.*, 2006). A sizable number of software programs such as XCOM(Berger and Hubbell,1987;1999), WinXCOM (Gerward*et al.,* 2001), XMuDat (Nowotny, 1998), and MUA_T and MUEN_T (Okunade, 2007) have been reported for obtaining interaction data for photons. WinXCOM is a window version of XCOM that was written in FORTRAN language. The log-log and cubic spline interpolation methods used in XCOM (and invariably in WinXCOM) require more computer memory and runtime. XMuDat limits the choice of elemental constituents of compounds and mixtures (absorber materials) to a maximum of six. MUA_T and MUEN_T were written in FORTRAN language which operates in DOS environment that is not object-oriented.

In this work, to provide easy-to-use software for the evaluation of mass attenuation and mass energy-absorption coefficients for body tissues and substitutes, MUA_T and MUEN_T have been re-engineered into an object-oriented program using Java programming. The re-engineered program given the acronym, MUAT_MUENT can run in any operation system (WINDOWS, LINUS, UNIX etc.) that ports Java Runtime Environment (JRE).

METHODOLOGY AND PROGRAM DEVELOPMENT

Input data and algorithms

The values of mass attenuation coefficient μ/ϱ and mass energy-absorption coefficient μ_{en}/ϱ reported by Hubbell and Seltzer, (1995) for 17 elements which are majorly found in body tissues (namely H, C, O, N, F, Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca, Mn, and Fe) were incorporated into the Java program. Algorithms (least-square curve fits) incorporated were those earlier reported in literature (Okunade, 2007). The calculations of the interaction data for biological materials (body tissues and substitutes) of known elemental composition and percentage-by-weight of these elements are carried out using the mixture rule. The program is designed to evaluate the interaction data for energy of photons in the range used in diagnostic and orthovoltage therapeutic procedures (1 keV or k-edge – 400 keV). The validation of the results obtained by using the algorithms that were incorporated in this program and those obtained by Berger and Hubbell (1987) has been reported in an earlier work (Okunade, 2007).

Java Swing Classes.

The swing controls and containers of the Java programming language used in the design of the software are as follows:

- JPanel: This is a generic lightweight container.
- JLabel: This is a display area for a short text string or an image, or both. A label does not react to input events. As a result, it cannot get the keyboard focus. A label can, however, display a keyboard alternative as a convenience for a nearby component that has a keyboard alternative but can't display it. Its object can display text, an image, or both.
- JTextField: This is a lightweight component that allows the editing of a single line of text.
- JList: This is a component that displays a list of objects and allows the user to select one or more items.
- JButton: This is an implementation of a "push" button.
- JTextArea: This is a multi-line area that displays plain text.
- JRadioButton: This implements such that an item that can be selected or deselected and it displays its state to the user. It is used with a ButtonGroup object to create a group of buttons in which only one button at a time can be selected.
- ButtonGroup: This class is used to create a multiple-exclusion scope for a set of buttons.

Program design and implementation

The swing classes were used to implement a set of components for the building of graphical user interfaces (GUIs) and adding rich graphics functionality and interactivity. The swing components used in the implementation of this work were entirely in Java programming language. The software developed in this work consists of five classes. These include:

1. Screen.java: This class displays a picture containing the title of the program at the first launching of the application. It consists of a JPanel that encloses the picture and a JButton (labeled "Next>"), which when clicked launches the next page (LiabilityPage.java) of the application.
2. LiabilityPage.java: This class contains JTextArea, JLabel, JButton, JRadioButton all enclosed in a JPanel. It displays only when the JButton (nextButton) in the Screen.java class is clicked. The JRadioButton is used with the ButtonGroup class so that any two JRadioButton cannot be selected at the same time (i.e. the selection of the acceptButton deselects the rejectButton) in the application. The selection of the acceptButton activates the nextButton such that the next page (i.e. IntroPage.java) is displayed only when the acceptButton is selected and the nextButton clicked.
3. IntroPage.java: The functionality of this class is similar to that of LiabilityPage.java but differs as a result of the page that is launched when either MUA_T or MUEN_T RadioButton is selected and the enterButton is clicked.
4. MAU_T.java: This class computes the mass attenuation coefficients for body tissues and substitutes ranging between 1 keV or k-edge – 400 keV and saves the output in a file with name specified by the user (Fig. 1).
5. MUEN_T.java: This class computes the mass energy-absorption coefficients for body tissues and substitutes ranging between 1 keV or k-edge – 400 keV and saves the output in a file with name specified by the user.

The flow scheme for the execution of the program is shown in Figure 2.

RESULTS AND DISCUSSIONS

The results of the implementations of the classes that constitute the computer program developed in this work are typified in Figure 1. Figure 3 shows a typical result of the mass attenuation and mass energy-absorption coefficients for Bone, Cortical using the software, MUAT_MUENT. The values of mass attenuation and mass-energy absorption coefficients obtained from MUAT_MUENT and those of Berger and Hubbell (1987) are in good agreement.

MUAT_MUENT provides means for the evaluation of radiation interaction data that are not tabulated in literature for varieties of body tissues or substitutes with arbitrary elemental constituents and percentage-by-weight elemental composition. These body tissues or substitutes include those for different age, gender and conditions of health which are practically impossible to tabulate in literature. There is a wide spread of elemental compositions and percentage-by-weight of elemental constituents for body tissues for different age, gender and state of health. Each of these is with unique interaction data. For example, the variations in the values of mass attenuation and mass-absorption coefficients are maximally as high as 50% for skeletal-cortical bone for different ages in the energy range (1 keV–100 keV) used for medical diagnostic procedures (Okunade, 2007). The elemental compositions in body tissues cannot be given a standing of physical constant; their expected variability due to age, gender and state of health must always be taken into consideration (ICRU, 1992).

The use of inappropriate values of radiation interaction data for a particular age, gender and health condition can significantly affect the result of optimization studies in medical x-ray diagnostic and therapeutic work. The computer tomography (CT) scanning relies extensively

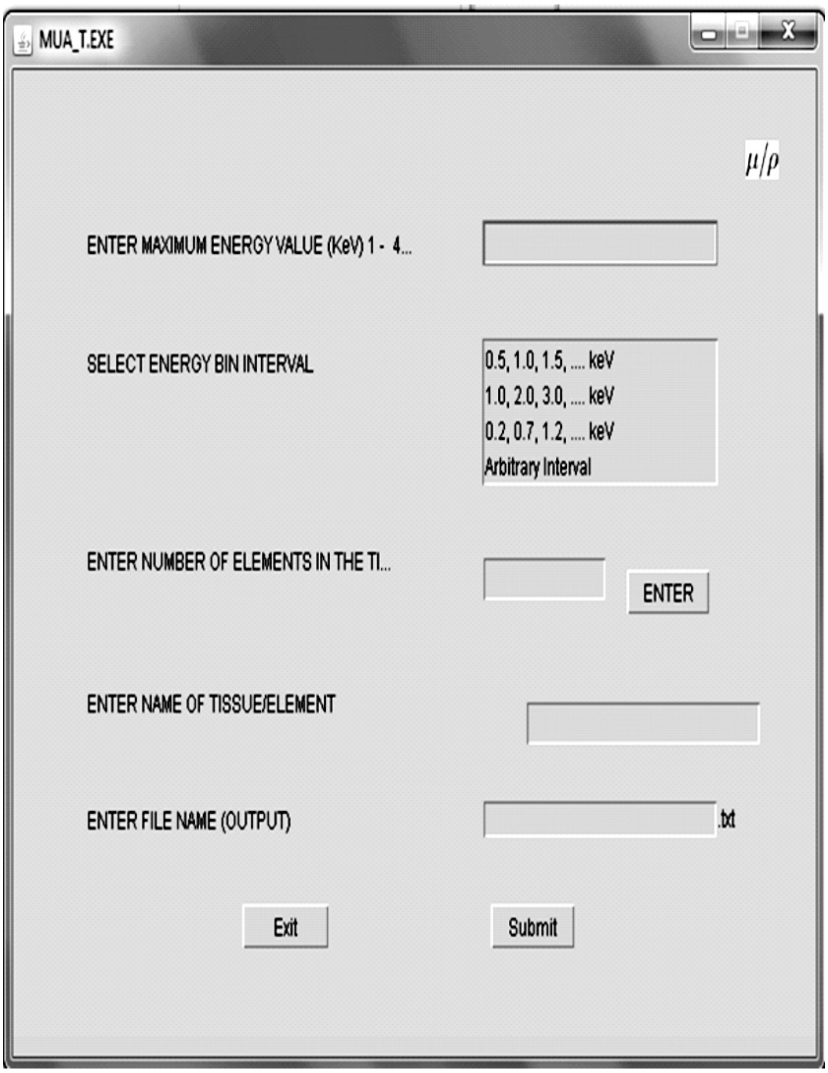


Figure 1: Interface Showing the Result of the Launching of the Class MAU_T.java.

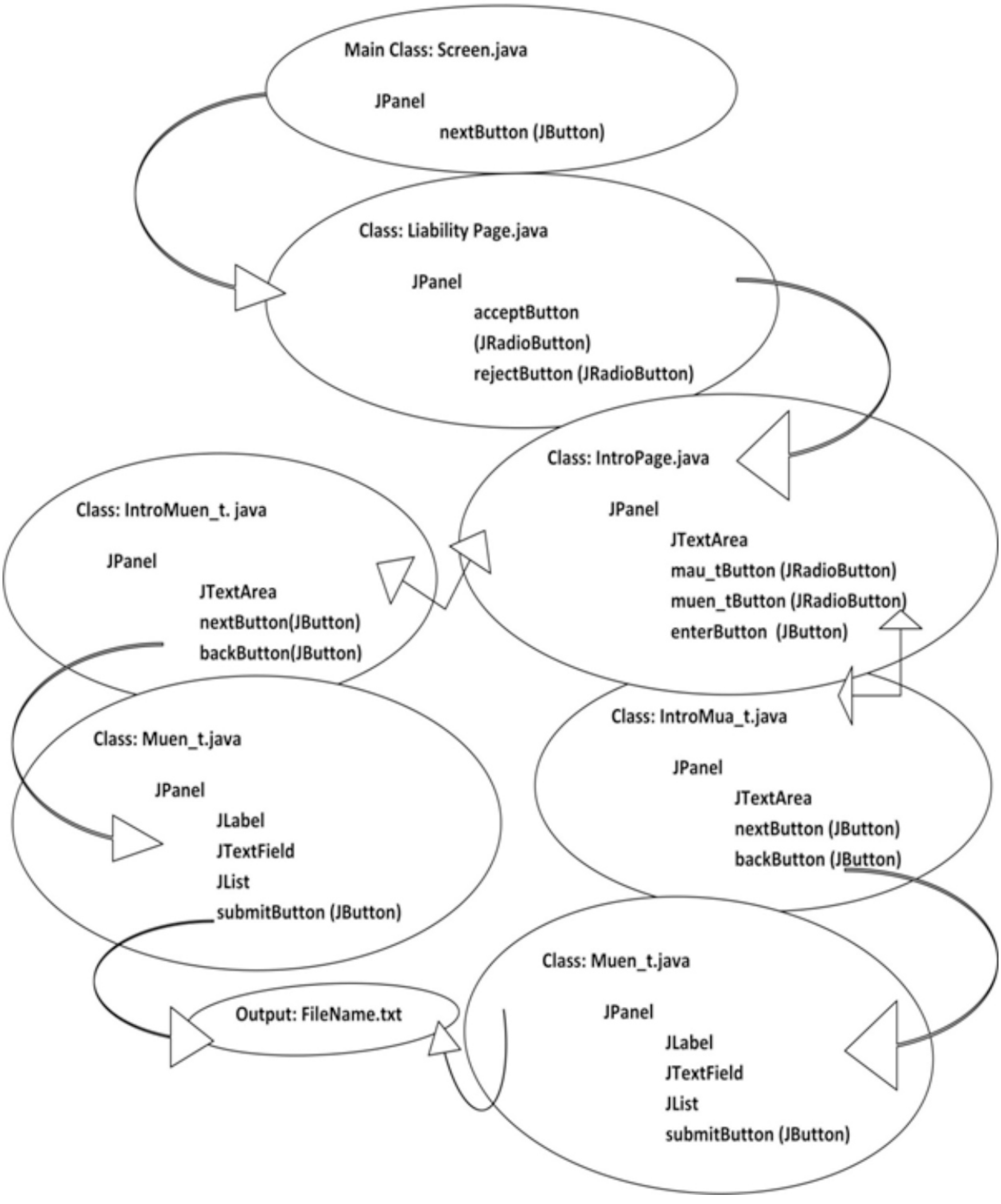
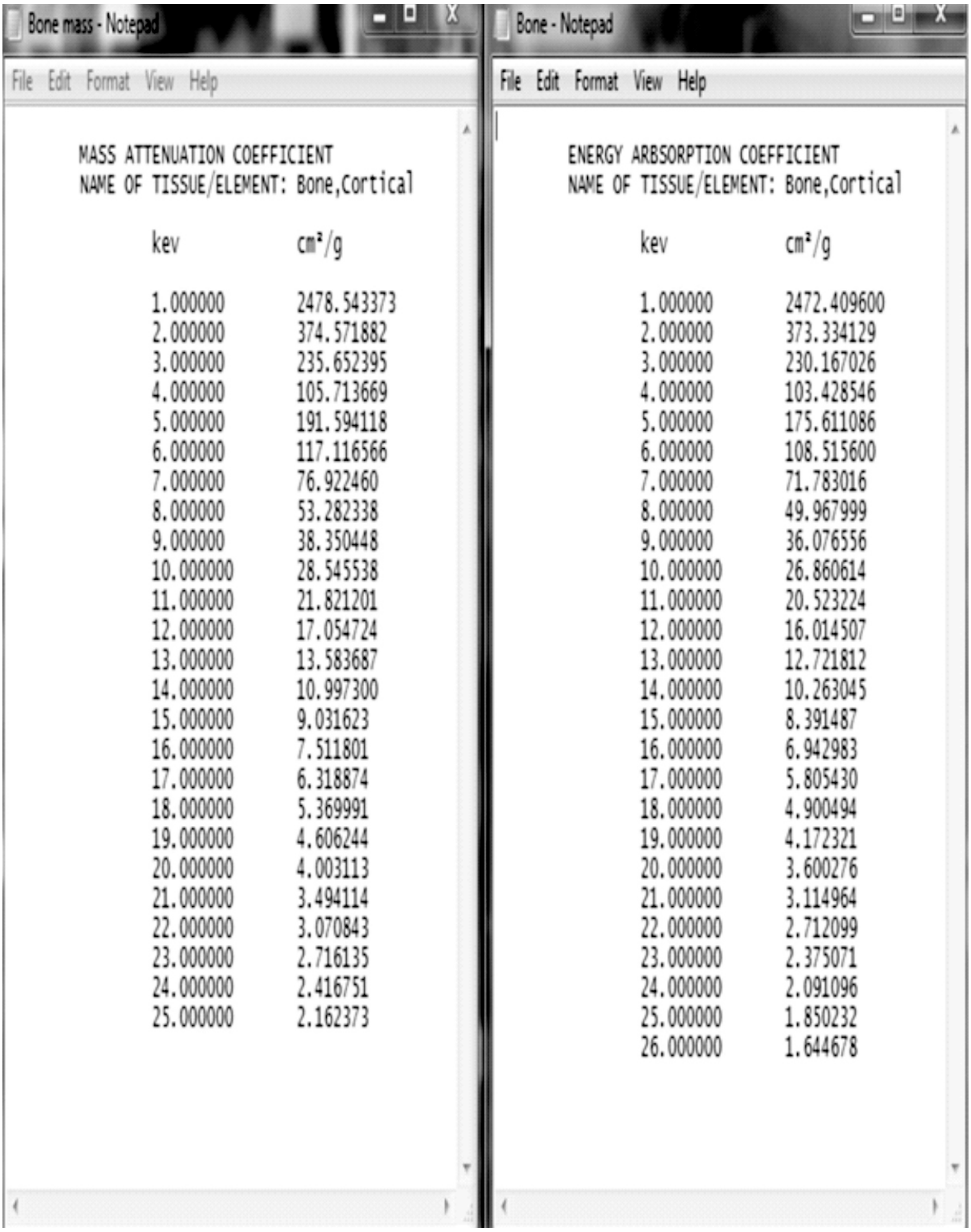


Figure 2: The Flow Scheme for the Execution of the Software Program



Bone mass - Notepad

File Edit Format View Help

MASS ATTENUATION COEFFICIENT
NAME OF TISSUE/ELEMENT: Bone,Cortical

kev	cm²/g
1.000000	2478.543373
2.000000	374.571882
3.000000	235.652395
4.000000	105.713669
5.000000	191.594118
6.000000	117.116566
7.000000	76.922460
8.000000	53.282338
9.000000	38.350448
10.000000	28.545538
11.000000	21.821201
12.000000	17.054724
13.000000	13.583687
14.000000	10.997300
15.000000	9.031623
16.000000	7.511801
17.000000	6.318874
18.000000	5.369991
19.000000	4.606244
20.000000	4.003113
21.000000	3.494114
22.000000	3.070843
23.000000	2.716135
24.000000	2.416751
25.000000	2.162373

Bone - Notepad

File Edit Format View Help

ENERGY ARBSORPTION COEFFICIENT
NAME OF TISSUE/ELEMENT: Bone,Cortical

kev	cm²/g
1.000000	2472.409600
2.000000	373.334129
3.000000	230.167026
4.000000	103.428546
5.000000	175.611086
6.000000	108.515600
7.000000	71.783016
8.000000	49.967999
9.000000	36.076556
10.000000	26.860614
11.000000	20.523224
12.000000	16.014507
13.000000	12.721812
14.000000	10.263045
15.000000	8.391487
16.000000	6.942983
17.000000	5.805430
18.000000	4.900494
19.000000	4.172321
20.000000	3.600276
21.000000	3.114964
22.000000	2.712099
23.000000	2.375071
24.000000	2.091096
25.000000	1.850232
26.000000	1.644678

Figure 3: Typical Results of the Mass Attenuation and Mass Energy-absorption Coefficients for Bone, Cortical using the software, MUAT_MUENT.

on numerical reconstruction of values of x-ray attenuation (determined by interaction data) obtained for tissues within the patient. Researchers in search of tissue-like materials have had to vary elemental compositions in order to arrive at best alternative to body tissues. Monte Carlo simulation techniques make use of interaction data for the evaluation of the transport of photons through body tissues for obtaining radiation dose parameters such as tissue weighting factors and effective dose. Accuracy of results from techniques for the evaluation of these radiation dose parameters which are vital for the assessment of risk associated with the use of radiation rely on the use of interaction data that are appropriate for body tissues for particular age, gender and state of health. In recent works reported in literature, organ and effective dose conversion factors are obtained based on size, gender, age and human race (ICRU, 1992; Khursheed, 2002; Petoussi-Henn *et al.,* 2006; Choonsik*et al.,* 2007). A significant level of precision in values of interaction data based on realism is important in the simulation of transport of radiation through classified individuals with different body constituents. The user-friendly computer software, MUAT_MUENT reported in this work provides easy means of evaluation of values of μ/ϱ and μ_{en}/ϱ for body tissues and substitutes of arbitrary elemental composition and percentage-by-weight of elemental constituents. This makes it adaptable to being used for obtaining μ/ϱ and μ_{en}/ϱ (which are not tabulated in literature) for body tissues and substitutes for different size, gender, age and race of individual as may be required.

CONCLUSION

The computer program developed in this work provides a user-friendly means of obtaining values of mass attenuation and mass-energy absorption coefficients for body tissues orsubstitutes. This can serve as technical tools in the optimization studies involving dose evaluation, shielding and formulation of phantoms for body tissues in low-energy diagnostic radiology and orthovoltage therapeutic applications. This program is written using the Java development platform which can run on any operating system (Windows, Linux, Unix etc.) that port Java Runtime Environment (JRE). The functional expressions incorporated into the computer program provide for reduction in data storage requirements and computation time.

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