Computer Algebra System (CAS) As a Mathematical Kernel for Web-based Physics Educational Symbolic Package

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Abstract: Computer Algebra System (CAS) is a mathematical tool used in many fields including engineering, medicine, biotechnology, physics, robotics, education, and more to help solve problems from simple to complex. This paper discussed the capabilities of the Computer Algebra System (CAS) software as a mathematical kernel (engine) and at the same time can be implemented as a visual interface in the web-based physics educational package. The Computer Algebra System (CAS) software discussed in this paper is Mathematica as a back-end kernel while webMathematica is a front-end implemented in the web environment through Java web technologies (Java Servlets and Java Server Pages). This paper also illustrates how CAS programming language is implemented in the physics educational symbolic package.

Keywords: Computer Algebra System, Mathematical Kernel, Mathematica, webMathematica, Physics Symbolic Package

1.0 Introduction

Physics is one of the most critical disciplines in science. Most students consider it is a difficult subject [1] to understand. Problems of misconceptions in physics often occur among students. Students cannot distinguish between scientific concepts and actual experiences [2], [3]. The study of physics education shows that most students consider science to be just words and facts[2]. The learning environment should provide students with the experiment and direct observation of the authentic objects to help students understand abstract and complex concepts[3]–[5]. Current learning requires the use of the latest technologies that require more visuals and teaching aids that can reduce verbal learning[6]. Problem-solving in the visual graphic is expected to solve student problems in understanding physics concepts. Various programming languages are integrated to produce educational software that can solve physics problems [7]–[9]. The programming languages are Java, Mathematica, and webMathematica. This paper represents an important topic related to the emergence of technology Computer Algebra System (CAS). CAS is not only beneficial in the mathematical kernel, but it is also used as a graphical user interface in physics educational package. Computer Algebra System (CAS) is a software package capable of manipulating numerical and symbolic mathematical formulas. Mathematica is a high-performance Computer Algebra System (CAS) software in computer
calculation systems and technical applications [10]. Whereas the global technology that mathematicians are talking about is webMathematica technology. This dynamic web technology was developed by Wolfram Research Group. This technology allows users to interact directly over the internet. User can perform computational activities and obtain output in various visual forms.

2.0 Computer Algebra System (CAS) Technology

For this particular study, Computer Algebra System (CAS) software is used to build up the Physics package. The software is Mathematica and webMathematica. Mathematica [11] is functioned as a Mathematical Kernel (Mathematical Engine) while webMathematica provides scientific calculations and interactive web interface. webMathematica is being executed in the website using Java server technology, which is Java Servlets and Java Server Pages (JSP).

Computer Algebra System (CAS) can integrate with other supported software applications via web [12]. Figure 1 shows the relations of technical structure in server-side in developing web-based software.

![Figure 1](image)

**Figure 1.** Server Side for developing web-based symbolic package using a Computer Algebra System (CAS).

The relations of technical structure in server-side for developing web-based symbolic package consists of four components that include; mathematical kernel, client-server, web server, and java server.

- **Mathematical Kernel**
  Mathematical Kernel is also known as mathematical engine and visualization. The Mathematical kernel in this technical structure is Mathematica. Mathematica is one of the Computer Algebra System (CAS) software that works as front-end and back-end [1].

- **Client-Server**
  The Client-Server in the technical structure of an educational package is webMathematica. webMathematica allows dynamic websites that include interactive calculations and graphical visualization integrated with Mathematica as a mathematical kernel using the client-server. The scripting language for webMathematica is Mathematica Server Pages (MSP).

- **Web Server**
Web Server receives HTTP requests from the client and responds as a website in HTML document or other web applications. Web Server in developing the technical structure for the educational package is known as servlets container or servlets engine. Servlets Container that is being used is Apache Tomcat[13].

- **Java Server**
  
  Java Servlets and Java Server Pages (JSP) are the Java Server technologies used in building up this software. JSP is the scripting for server-side to produce dynamic and interactive websites. It needs the Apache Tomcat web-server to run the JSP scripting.

### 3.0 Mathematica Technology

*Mathematica* is a dynamic computer software of computing systems and technical applications. It was developed by Wolfram Research Inc. in 1988. Its founder was Stephen Wolfram [14]. Mathematica is also design software that can perform complex calculations, as well as being an interactive media tool and capable of communicating with various programming languages such as C and Java. It is also capable of interacting with database software such as MySql. Mathematica is widely used in scientific studies from pre-school to doctoral studies[15]. Mathematica is the essential mathematical software for computer science, especially software development, prototype, and interface environment. Mathematica consists of two parts that function as a kernel and a front end (see Figure 2.). The kernel acts as the back end of the calculation engine. It interprets the Mathematica code (performs the calculation) to produce the desired output. In education, it is often used as a teaching tool in classroom teaching and learning. The front end provides the environment in the form of the Graphical User Interface. Mathematica has a Notebook application that acts as an interface in its environment. The front end is using webMathematica integrated with Java technology namely java servlets and java server pages. Examples of using Mathematica as a kernel and front-end can be referenced in Figure 3. (Source: http://www.wolfram.com/mathematica).

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**Figure 2. Mathematica Environment as Front-End and Back-End**
Figure 3. Mathematica Notebook Interface as Kernel and Front-End

4.0 WebMathematica Technology

The global technology that mathematical thinkers are talking about is webMathematica technology. This dynamic web technology was developed by Wolfram Research Group. This technology allows users to interact directly over the internet. Consumers can perform computational activities and obtain output in various visual forms[16]. Figure 4. illustrates a web-based interface using webMathematica technology. WebMathematica functions as a front-end while Mathematica acts as a computation kernel. Users do not need to know about the Computer Algebra System (CAS) and the installation of Mathematica and webMathematica software. Most importantly, users only have to browse educational software through Internet Explorer or Netscape web browser.

Figure 4. WebMathematica visual output interface (Source: WebMathematica is implemented in the web environment through Java web technologies namely Java Servlets and Java Server Pages (JSP)[17]. Java Servlets is a Java program that runs on a web server. The web server that supports this program is a servlet container or also known as a servlet engine. Servlets engine used is Apache Tomcat. Apache Tomcat will translate from javascript (JSP)
and webMathematica script (Mathematica Server Pages; MSP) to web browser (Internet Explorer, Google Chrome, etc.).

Java Server Pages (JSP) is a scripting language for server-side web programmings such as PHP and ASP. JSP can integrate with HTML directories, applets, JavaScript, and functions from the JSP itself to create a more dynamic and interactive website. Java Server Pages (JSP) uses tags for a library in Mathematica called TagSP MSP. Like other server-side scripts, JSP also requires a web server. ASP scripts require IIS as a web server, PHP requires IIS or Apache while JSP uses Apache Tomcat as a web server whereas MSP is the scripting language for webMathematica (front-end). The back-end kernel is Mathematica. Figure 5.0 depicts the Mathematica web environment and the Mathematica computation kernel in operation.

![Mathematica web environment and the Mathematica computation kernel in operation.](image)

**Figure 5.** Mathematica web environment and the Mathematica computation kernel in operation.

### 5.0 Technical Structure Computer Algebra System (CAS) in Web-Based Education Packages

The technical structure of the Computer Algebra System (CAS) application works an essential role in implementing the educational package. The process of how it works is graphically depicted in Figure 6.

![Technical Structure of CAS Applications in Educational Software Development](image)

**Figure 6.** Technical Structure of CAS Applications in Educational Software Development

The learning environment for this package is web-based. The package involves three components: end-user, webMathematica server architecture, and database design.
• **End-User**
  The intended users of this package are students or respondents of the study. In the web-based learning process, a browser is required to browse dynamic educational packages. The dynamic web-based package here means that users can not only browse and access learning information, but users can interact interactively with data, manipulate motion graphs in either 2D or 3D[18] and control the movement of simulation objects through the use of sliders.

• **WebMathematica Technology Architecture**
  WebMathematica technology developed by Wolfram Research. WebMathematica 3.0 software that functions as a client-server. webMathematica is based on a Java web technology [19] known as Java Servlets. Java Servlets is a java program implemented in a web server. Servlets Container (Servlets Engine) is a web server known as Apache Tomcat [13], [17], [20]. Development study of this educational package using Apache Tomcat 6.0 web server. The calculation engine (kernel) for webMathematica is Mathematica. The scripting language used is Java Server Pages (JSP). This JSP has integrated with Mathematica Server Pages (MSP) technology. MSP runs webMathematica, which also allows HTML commands, JSP commands, and Mathematica commands. The latest Mathematica software is Mathematica 8.0. Mathematica is a kernel of numerical computations, symbols, visual integers, programming, and interrelated with various computer programming languages such as C ++ and Java.

• **Database**
  Databases play an essential role in storing information in a learning system. The database software used is MySql. In web-based education packages, usually, the main table in the database is the user log-in table. This log-in interface allows users to enter their login id and password before using the software entirely. The purpose of this table is for the storage of registered user information. There are other tables, quiz mark tables, forums, email feedback, and so on. It is up to the developer to design the database for the educational package.

### 6.0 Results and Discussion

**i. Graphical User Interface of Graph Visualization**

webMathematica 3.0.1 is used to help physics problem-solving techniques visualize motion graphs. While Mathematica 8.0.1 is used as a back end to translate numerically and symbolically into graphics.

Figure 7(a) shows the user interface for training questions related to linear motion. The user is asked to enter a value in the input box based on the given question. After entering a value in the input box, the user clicks the graph plot button, and the calculation kernel will automatically translate the mathematical calculation. Programming through MSP and HTML scripts will visualize the desired motion graph, as shown in Figure 7(b).
Figure 7 (a). Linear Motion Selftest Questions Interface
Figure 7 (b). Linear Motion Graphical User Interface Through Motion Graph Visualization

ii. Mathematica Server Pages (MSP) Script
MSP Technology is the foundation of webMathematica. The scripting language of webMathematica is the Mathematica Server Pages (MSP). MSP is based on Java technology known as servlets. Servlets is a Java program that runs on a web server. MSPs that handle webMathematica allow HTML commands, JSP commands, and Mathematica commands. An example MSP tag is <msp: tag>. Mathematica is a kernel of numerical computation, symbolism, visual imagery, and programming. The example Scripts for visualization of motion graphs in Figure 7 are as shown in Figure 8.
Figure 8. MSP Programming Visualizing Motion Graph Problem Solving

7.0 Conclusion
In conclusion, we have shown how Computer Algebra System (CAS) as a Mathematical Kernel for Web-based Physics Educational Symbolic Package can overcome the student’s misconception in
physics especially, in understanding the motion graphs. This study is an example of the visualization process of numerical and symbolic data interpreted in graphical information. This study is a contribution to the technique of solving physics problems in interpreting numerical data into visual graphs of motion graphs through the webMathematica technology algorithm. The programming language in using MSP scripts is practical and useful for visualizing motion graphs.

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