Applying NASA Technology to Education, a Case Study Using Amphion

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Abstract: Amphion is a generic Knowledge Based Software Engineering (KBSE) system that targets scientific subroutine libraries. It was developed at NASA Ames' Computational Sciences Division. Amphion has proven useful for experts in the space science domain. One of the current challenges is to apply the system to different domains, educational settings, and the Internet. In order to assess the applicability of Amphion for educational settings, educators have been invited to try the system and to collaborate with the Amphion team. This paper describes the results of one such collaboration, which involved the development of educational web sites supported by Amphion-generated materials.

1. Introduction

The current implementation of Amphion (e.g. Amphion/NAIF) allows users to specify problems in the domain of solar system kinematics. These problems are specified using high-level terms that are relevant to the user, such as planet, ray, spacecraft, etc. The user-specified problems are then translated into programs that are composed of calls to the target library subroutines, in this case the FORTRAN libraries called SPICE developed by NASA JPL's NAIF group (see http://naif.jpl.nasa.gov/naif.html).

The translation is performed in two steps. First, a theorem prover, guided by a domain theory, solves the logical formula that represents the user-specified problem. The domain theory is a collection of rules and definitions that define how to convert a user-level formula into a low-level expression. Second, the resulting expression is converted by a translator into the final FORTRAN program. The execution of these programs may result in either an animation, or a calculation of specific pieces of information. The correctness of the resulting program, relative to the domain theory, is assured by the application of formal methods and artificial intelligence techniques. A description of the technical details can be found in (Lowry 1994).

Amphion (see http://ic-www.arc.nasa.gov/ic/projects/amphion/index.html) has proven useful for experts in the space science domain. One of the current challenges is to take the benefits of the system into different domains, to educational settings, and to the ever-growing audience of the Internet. In order to meet this challenge, a new version of Amphion, based on client-server technology has been recently developed. This new version allows access through WWW, supports different interfaces, and provides immediate execution of the programs generated by Amphion. A description of this architecture can be found in (Lazzeri 1998).

Different domain theories, such as computational fluid dynamics (CFD) are being developed for Amphion to operate on. Furthermore, in order to assess the applicability of Amphion for educational settings, educators have been invited to try the system. Dr. Jane Friedman was a NASA faculty fellow during the summers of `97 and `98. She is a faculty member in the mathematics and computer science department of the University of San Diego, with major teaching and research interests in mathematics education, particularly teacher training. Dr. Friedman worked with the Amphion group to develop materials for web based lessons on astronomy. This paper describes this collaborative experience and the web pages that were produced.

2. Motivation

There is quite a lot of excitement and even hype these days about the potential of the Internet and the World Wide Web to have a positive impact on education. There are an ever-increasing number of web sites which purport to be educational, and these vary greatly in quality and in their teacher-user friendliness. It is easy to create a web-site, but much harder to create one which will actually be useful to classroom teachers. As Cleborne Maddox notes "... the general state of the art in Web-based learning is in its infancy." (Maddox 1996). Another problem is how to best prepare prospective and practicing teachers to use the resources available on line effectively in their classrooms. New research is beginning to illuminate the substantial difficulties that exist in convincing teachers that the Web belongs in their classrooms, and then providing them with the necessary training (Wiesenmayer & Meadows 1997).

Thus there are two sides to the problem of how to ensure that the Internet realizes its potential as an educational tool, the problem of preparing appropriate Internet materials, and that of preparing teachers appropriately to use these materials. Both of these areas are poorly understood. Different kinds of expertise will be needed to create solutions to these problems, and this paper presents an example of the power of a synthesis between technological experts and educational experts. Amphion was developed by researchers at NASA for the use of other NASA scientists. It is not a toy program developed for the use of children, but a serious tool that has been used fruitfully by scientists. This can be a powerful motivating force for children. Even the most uneducated and deprived children can be turned on to space science. (See (Fierro 1997) for a moving account of the response of homeless Mexican children to presentations about Astronomy). It is exciting for children to know that they are working with the same tool that NASA scientists, real Astronomers, use in their work.

Amphion, as an educational tool, is under development. This means that the possibility exists of modifying Amphion in order to improve its usefulness to educators as well as to scientists. This is best accomplished by collaborative efforts between Amphion researchers, and educators including classroom teachers. The work described in this paper represents a first stage in developing such a collaboration. Each web page created was developed in response to published papers in educational journals. Thus, each is connected to work of educators and is responsive to their concerns. This is the power of such collaborative efforts.

3. Topic Selection

The Web is not necessarily the best teaching tool in all situations. There are many topics that may be taught just as well or better with books, other traditional teaching methods or manipulatives. The topics selected for use with Amphion, the causes of phases of heavenly bodies, and the causes of seasons, were ones which have proved resistant to teaching with traditional methods. Both topics are difficult for children and adults to understand. (See for example, (Atwood & Atwood 1996), (Kikas 1998), (Parker & Heywood 1998), (Sharp 1996)). In each case Amphion had a feature which could potentially aid in understanding.

The first web page developed was based on a paper by John Lamb (Lamb 1990), in which he posed the question of whether or not a crescent Mars could ever be seen from earth. In this paper he analyzed the problem geometrically and then presented a computer program which could be used to calculate the portion of Mars which would be seen at any given time. The difficulty in understanding the phases of Mars, or any heavenly body, is in understanding how the phases depend on the relative positions of the body viewed, the body from which the viewing is done and the sun. Using models and light bulbs can be helpful, but then the inaccuracies of scale can create misleading impressions. With Amphion we were able to create a pair of dynamically linked windows, which were displayed side by side to present animations that showed how the view of Mars from the Earth changes with the changing relative positions of the Earth, the Sun and Mars.

The causes of the seasons is difficult even for many prospective and practicing teachers to understand. (Atwood & Atwood 1997) showed that while physical models were completely effective in enabling prospective teachers to understand the causes of day and night, they were much less effective in helping these same teachers to understand the causes of the seasons. Atwood and Atwood suggest that the models might usefully be supplemented by a computer simulation. This again seemed a useful role for Amphion. The seasons are caused by the tilt of the Earth on its axis. The areas of the Earth which are tilted away from the Sun at any given time, receive less direct sunlight, and therefore less warming. Amphion was used to create an animation which displays the solar incidence angle as it changes with the changing seasons. This could be used to supplement other teaching methods to help K-12 students and their current and future teachers understand this complex phenomenon. Curriculum in K-12 is guided by various levels of educational standards, which are used by teachers to look for relevant materials. The topics selected for this project are identified as important in the National Science Education Standards: http://www.nap.edu/readingroom/books/nses/html/.

4. Lesson 1: "The Phases of the Heavenly Bodies"

4.1 Original Explanation

(Lamb 1990) asks the question "Can a crescent Mars ever be seen from Earth?". He was primarily interested in the mathematics used in answering this question. A full half of Mars will always be illuminated by the Sun, but the portion of Mars which is seen from the Earth will depend on the relative positions of the Earth, the Sun, and Mars. Let SME be the angle between the Sun, Mars and the Earth, and let SEM be the angle between the Sun, Earth and Mars; then the portion of Mars which appears dark will be directly proportional to SME. The larger SME is, the larger the dark portion of Mars and the smaller the illuminated portion. If we were to see a crescent Mars, the dark portion would be most of the visible portion of the planet. We can find the maximum value of SME by using traditional methods of the calculus (differentiating an expression involving trigonometric functions).

Lamb's paper is aimed at college level teachers. Yet in the National Science Standards, changes in objects in the sky, in particular the phases of the moon, are mentioned even in the K-4 content standards. These young children could not possibly understand the mathematics involved in Lamb's paper, but they can understand some of the basic science. In particular they can understand that the phases are caused by the light of the Sun shining on the bodies and the effect of relative position on the appearance of the illuminated body.

4.2 Amphion's Explanation

Amphion can be used to supplement traditional teaching methods involving the use of light bulbs and physical models. Lamb suggests using a computer as a computational aid. We use Amphion as a computational and a visualization tool. We not only calculate angles, but we create two dynamically linked animations; one which shows the relative positions of the bodies and another that shows how the planet would appear viewed from earth.

One of the benefits of using Amphion for this explanation is that once a given animation is generated, it is very easy to get similar animations for other configurations. For example, it would be easy to modify the program to observe the phases of the moon as seen from Earth, or the phases of Pluto as seen from Neptune. This ability allows the student to make several observations to support the generalization of a concept. In fact, we have developed a template that allows the user to designate the observed planet, observing planet, and bright body for a given animation. This template is shown in (Fig. 1), which is a snapshot of the graphical editor, one of the specification editors that can be used to input problems for Amphion.

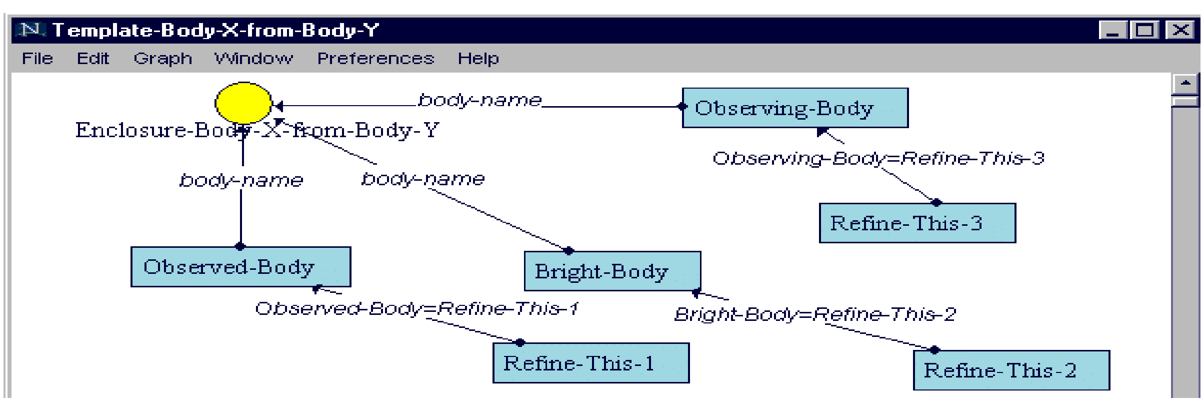

Figure 1: Sample Amphion Editor Screen.

All the user has to do is to replace the “refine-this-X” items by actual values and then to call the automated software engineering engine to produce an animation. Templates like the one in (Fig. 1) will allow students to easily create their own animations and formulate and solve their own problems, such as: As we move further away from the Earth, what happens to the maximum shadowed area of the planet as seen from Earth?

(Fig. 2) illustrates Amphion’s generated view of Mars as seen from Earth. The left side of the figure shows a view of Mars as seen from Earth on the date 11/12/94 at the time 17:35:17. The right side of the figure displays the relative position of the planets on the same specific date and time. The planets are not drawn to scale in order to better illustrate the different phases of Mars, otherwise, Earth and Mars wouldn’t be visible given the great size disparity as compared to the Sun. In that figure, the Sun is yellow, the Earth is cyan, and Mars is shaded so that it is possible to tell how much of its dark side is seen from Earth.

In a live animation, the positions of the planets in the right side change continuously, and the view of Mars from Earth in the left side change accordingly. Amphion generates automatically most of this image. However, the legends “Angle SME=40.9”, and “Maximum shadowed area of Mars visible from Earth”, as well as the lines that form the triangle and indicate the angles between the planets in the right side of the figure were manually added to enhance the expressive power of the picture for this particularly critical frame. Besides Amphion’s generated materials, the web site for this lesson contains background information about this concept.

The URL for this lesson is http://ic-www.arc.nasa.gov/ic/projects/amphion/MARS-PHASES/phases.html.

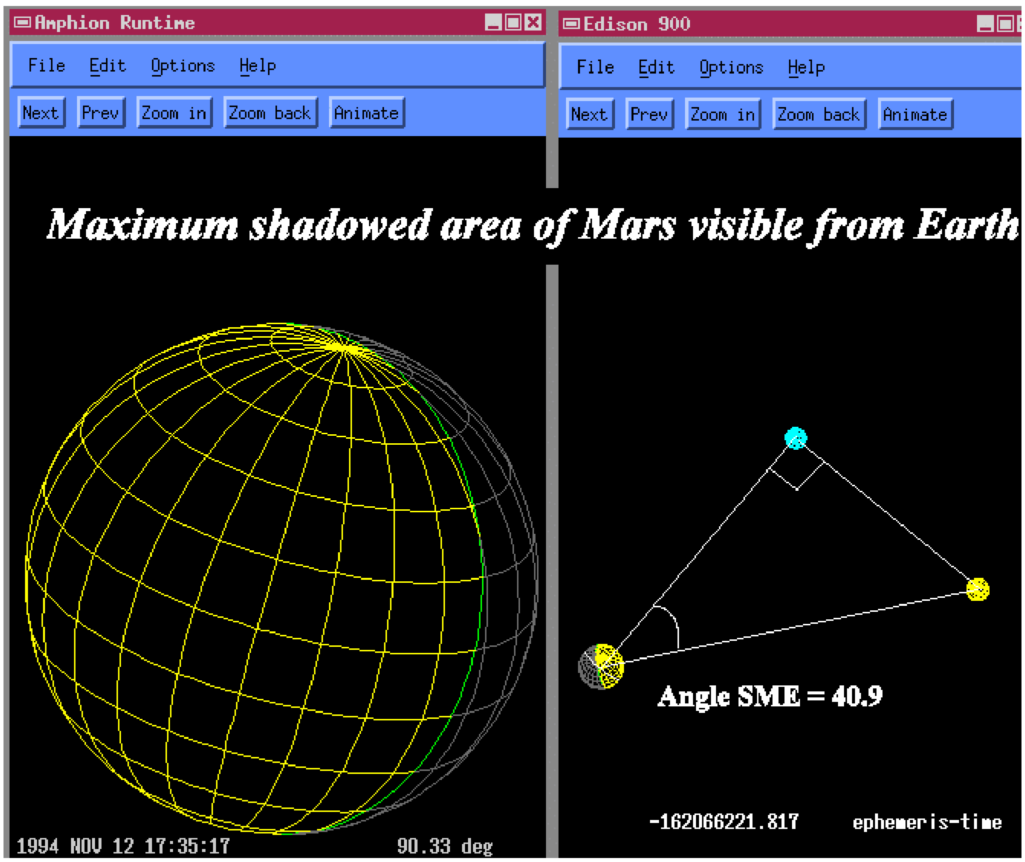

Figure 2: Still from Amphion-generated animation used to illustrate the phases of Mars as seen from Earth.

5. Lesson 2: “The Seasons”

5.1 Original Explanation

Children and adults alike have trouble understanding the causes of the seasons. Many will express the belief that the change in seasons is caused by the change in the distance between the Sun and the Earth. This explanation would imply that winter and summer occur simultaneously in the northern and southern hemisphere, which is not true. When it is winter in the northern hemisphere it is summer in the southern hemisphere and vice versa. Winter occurs in the northern hemisphere when the Sun is closer to the Earth. The seasons are caused by the tilt of the earth on its axis, and the effect this has on the angle with which the Sun's rays strike the Earth's surface. Now in fact this angle will not be constant over the course of the day. The Sun's rays will strike the earth most directly at noon. In winter, when the days are shorter, the Sun's rays strike less directly and over less time. To actually calculate the amount of energy absorbed by the earth would again require fairly sophisticated mathematics -- college level mathematics. But the National Science standards specifically mention the causes of the seasons as important content for grades 5-8. What these students need to understand is not the precise mathematical relationship, but the general relationship between the angle of the Sun's rays and the amount of warming energy which this transfers to the earth. Traditional teaching methods with physical models and lights are helpful for some students, but many still do not understand.

5.2 Amphion's Explanation

Amphion's capabilities are excellent for providing additional teaching tools that may help some learners understand this difficult but important concept. Amphion can produce an animation that shows how the angle of incidence of the Sun's rays changes over the course of a day, or at noon over the course of a year. This can show students the correlation between this angle and the seasons.

In order to explain the concept of seasons, an animation showing the view of the Earth from the Sun for a period of time is used. Two reference points are displayed in this animation, one of them is Canberra (Australia), and the other one is its mirror image in the Northern Hemisphere. The solar incidence angle computed from the Normal to the Earth's surface is displayed at each of these points. Then each point is color coded according to the corresponding season of the year. The incidence angle is computed at around 12:00 noon local Canberra time, which is the warmest time of the day. The smaller the angle, the closer the Sun's rays are to the perpendicular to the Earth's surface at that point.

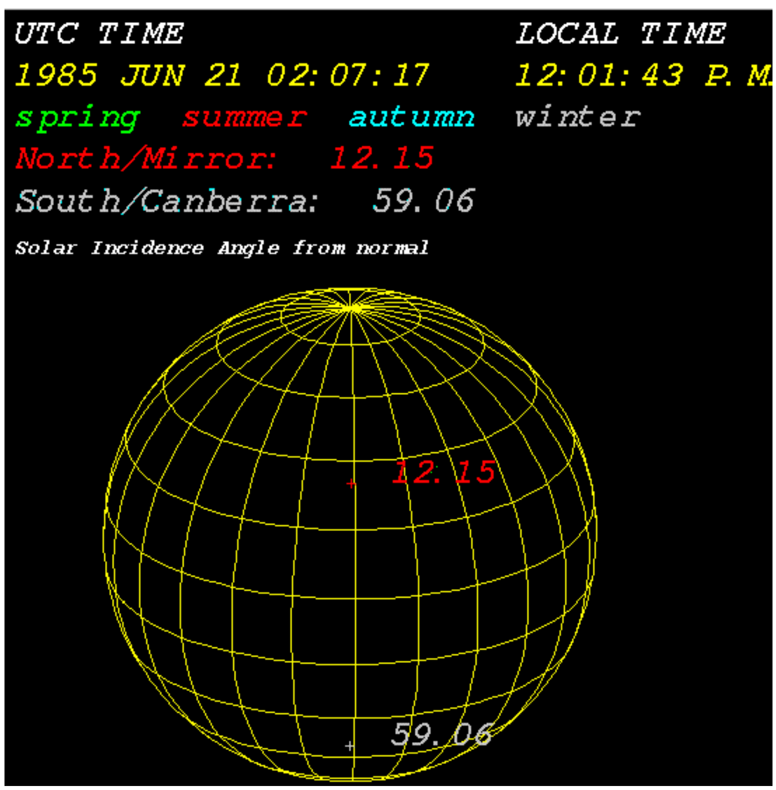

Figure 3: Still from Amphion-generated animation used to illustrate the seasons on Earth.

(Fig. 3) shows a snapshot of the live animation where we can see that the angle is smaller in the summer (i.e. when it is red in the animation). Likewise, the angle is much larger in the winter. Also, a summer point is visible longer than a winter point, indicating that summer days are longer than winter days. Several misconceptions, such as the belief that the seasons are due to the change in the distance between the Sun and the Earth, can be eliminated by experimenting with this animation.

The URL for this lesson is http://ic-www.arc.nasa.gov/ic/projects/amphion/SEASONS/seasons.html.

6. Conclusions

This project has demonstrated that Amphion has the potential to be useful in K-12 education. Amphion was used to create animations that became the heart of two different web sites, each dedicated to a notoriously difficult space science concept. In each case, Amphion was able to do something a bit different than traditional methods, and thus was a powerful supplementary teaching tool. But in fact this is only the beginning for the development of educational uses for Amphion. In the future, students will be able to interact more directly with Amphion and through the use of simplified templates conduct their own investigations of space science phenomenon. Each of these web sites is a rough draft, they need refinement, rewriting and the inclusion of supplementary materials, such as lesson plans, correlations with standards, and follow up assignments and activities, which will make them more useful to classroom teachers. In refining these web sites we hope to get input from the educational community to make them as practical and useful as possible.

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