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Science ASSISTments: Creation of Engaging Visual Objects for Microworlds

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DOCUMENTATION REPORT

Science ASSISTments: Creation of Engaging Visual Objects for Microworlds

An Interactive Qualifying Project Report

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Abstract

This document describes programming effort and instructional documentation contributing to the goals of the Science ASSISTments project. An existing spreadsheet containing past MCAS test question numbers was updated with an improved system for viewing the questions in the ASSISTments server. New graphics for a Microworld under development were created, and a detailed tutorial was written to assist future efforts in visual object construction.

Table of Contents

1.0.0 Introduction

In early 2000 through 2004, Neil Heffernan of Worcester Polytechnic Institute worked with colleagues at Carnegie Mellon University to create and test an intelligent tutoring system to assist middle and high school students with mathematics. It featured hints, scaffolding responses to incorrect answers, and "buggy" messages to help guide students toward the correct answer. An entirely web-based interface was used for compatibility with the wide range of computers used at public schools, with reports automatically recorded and distributed to teachers and researchers. To keep the bandwidth requirements as low as possible, a data transmission language, namely XML (http://www.w3.org/XML/) was selected that minimized traffic between the student computers and the ASSISTment servers.

One of sources of data used along with the math ASSISTments program is the Massachusetts Comprehensive Assessment System (MCAS) for Math, a state-wide test administered to all students beginning in 5th grade. The full set of MCAS tests cover mathematics, science and technology, history and social science, and English language arts, and school-level results are easily accessible at a statewide level. Many of the example questions presented to students for practice in the Math ASSISTments project were derived from past MCAS questions. However, while a valuable tool, the MCAS has the limitation of testing only content knowledge, and like many standardized tests it does not evaluate the student's skills in critical thinking or skills at conducting inquiry, the latter of which are necessary in science literacy (Rutherford, J. & Algren, A, 1990).

In 2007, Neil Heffernan teamed up with Dr. Janice Gobert, a Professor of Learning Sciences at WPI, to extend the ASSISTment platform to middle school science; the project began with Physical Science. The goal here is to generate a question and response structure similar to the existing mathematics ASSISTments system but adapt this for science learning. Gobert and Heffernan acknowledged that learning science had a critically different ingredient compared to Math, namely, inquiry. Thus, the system requires the development of interactive microworlds so that students can conduct scientific inquiry. Regarding inquiry, students need to learn how to formulate a meaningful question, propose a possible solution, develop and conduct an experiment, and determine what the results mean in relation to their question (National Research Council, 1996). Thus, the focus of the tutoring system in Science ASSISTments is to focus primarily on teaching inquiry skills, rather than simply covering science content.

Working with graduate and undergraduate students, Dr. Gobert successfully created a simple physics simulation, i.e., the ramp environment, in which students could test ideas, record data, and respond with their conclusions (cf. Gobert, J., Beck, J., Sao Pedro, M., Heffernan, N., & Richardson, J., 2008). The ramp environment consists of a pair of ramps on which balls roll, and the student chooses from a variety of different options, i.e., variables, such as ramp steepness, run length, ramp surface, and ball type. Students are allowed to change as many of the variables listed above as they wish at first, but the system gradually guides them to implement an experiment using the "control for variables" strategy, namely, keeping all variables constant while manipulating only one. Initial pilot testing was conducted in a set of middle school classes; some items were revised and then data were collected with an additional set of 5 classes using the ASSISTments system. The results of this study and others were promising regarding the efficacy of teaching students inquiry strategies (cf. Gobert, J., Beck, J., Sao Pedro, M., Heffernan, N., & Richardson, J., 2008). Subsequent to this study, Dr. Gobert was awarded an additional research grant to expand the project from Physical Science to additional domains of the middle school science curriculum, namely Life Science and Earth Science (Gobert, Heffernan, Koedinger, & Beck, 2009).

While inquiry instruction and assessment remain the primary focus of the Science ASSISTments project, the science topics of study can and are being used to reinforce material tested by the MCAS. The MCAS Science and Technology portion is divided into a variety of subcategories, depending on the grade level of the individual exam. Fifth through eighth grade level exams each have the categories Earth and Space Science, Life Science, Physical Science, and Technology/Engineering. The high school level exams have similar topics, but with a much higher level of detail. The origin of these topics is the Massachusetts Curricular Framework (MCF henceforth), a state sanctioned document that outlines all the content knowledge students should possess by the time they graduate high school. While this is a noble goal, many students only learn how to memorize facts and procedures, and do not learn how to use their knowledge to solve new problems. This issue extends all the way up to the national level, with the National Science Education Standards (NSES), from which the MCF inherited some of its science curriculum.

This issue has not gone without notice; many people have voiced concerns and proposed additions to the NSES to address the issue of scientific inquiry in the classroom. The trouble is that inquiry is very difficult to quantify and evaluate in an affordable manner in public schools. Current recognized tests for inquiry utilize short answer responses or a report (cf., Gotwals & Songer), which must be individually hand graded by scientific education professionals for accurate results. Even more accurate assessment can be accomplished with a hands-on experiment, since all aspects of the student's skills can be observed (Baxter and Shavelson, 1994; Ruiz-Primo and Shavelson, 1996).Unfortunately, these exams are prohibitively expensive, and tend to be non-standardized. The Science ASSISTments project is an attempt to solve this dilemma using a virtual environment in which students are provided rich interactive Microworlds to experiment with, while the system records their actions; these tasks serve as performance assessments of student's inquiry skills. Given combinations of variable selections, they can set up and run trials, gather data, and make conclusions. Carefully designed algorithms will then be developed to analyze students’ strategies and in turn will suggest alternatives to hone their inquiry strategies with the goal of both supporting student’ acquisition of content knowledge and inquiry skills. Assessment results regarding students’ inquiry skills are sent to teachers, and any students having trouble will be flagged and will receive individualized help within the ASSISTments system and, hopefully by the teacher as well.

2.0.0 My roles in the project

2.1.0 Classification of past items on the Mass. Curricular Framework

Since the MCAS exam is a very important part of the evaluation process, questions issued from Mass. Dept. of Education from previous exams are excellent practice for the students. Hundreds of questions have been entered into the ASSISTments system, and a detailed list of them has been created in a Google Doc spreadsheet by students under the direction of Cristina Heffernan, a project manager for the ASSISTments project. Some very basic information about the question was included in this matrix, but it did not allow for easy browsing of questions by topic. Since all of the questions are derived from the MCF, I was charged with creating a classification system for the problems out of the MCF itself, so that problems matching particular requirements could be easily queried. This feature is important to future analyses by the Science ASSISTments team so that they may easily select and aggregate items to test for transfer of knowledge from what they learned in the Science ASSISTment system to the content being evaluated by the MCAS science test.

2.2.0 Development of Graphical Elements for the Phase Change Microworld

Dr. Gobert’s Ph.D. student Mike Sao Pedro and Masters student, Nate Krach, spearheaded the technical aspects and general design parameters of the Phase Change Microworld. Mike’s previous experience with the design of the ramp microworld provided an excellent starting point for the application structure of the phase change microworld. As the science behind the Phase Change Microworld was a bit more complex than the ramp microworld, Nate focused on developing the necessary equations and the overall flow of the pedagogical structure. It was my duty to translate Nate's designs into graphics that responded to Mike's programming system. I also wrote a document describing in great detail the process of creating objects in Laszlo, which will be used in all future microworlds constructed for this project.

3.0.0 Materials Development

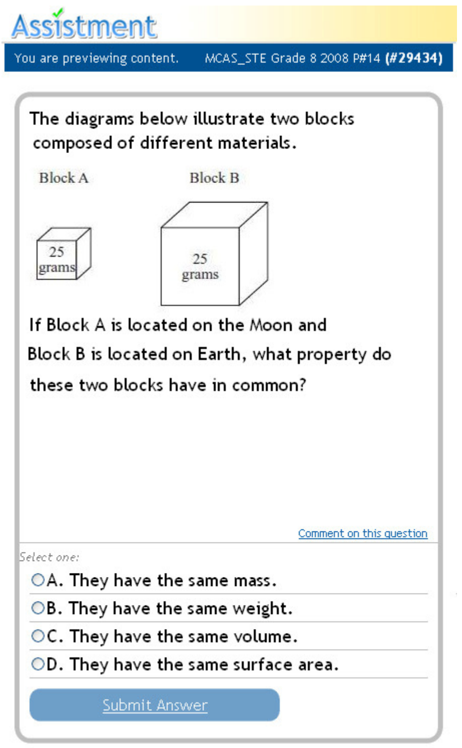
3.1.0 MCAS Problem classification

As mentioned before, the MCAS exam questions from previous years are available freely on the official MCAS website (http://www.doe.mass.edu/mcas/). So far, the last five years of exam questions are entered into the Science ASSISTments question database, in both the fifth and eighth grade categories. Unfortunately, these questions are only identified by a number in the database, which makes it relatively useless to search through when looking for a particular problem. To help organize the problems within the database, an online spreadsheet was created to associate each problem's ASSISTment number with a variety of other associated data; namely the problem's answer, the testing year it belonged to, the original problem number within the year's set, and the subject matter of the problem.

While the MCAS website was a little more useful than randomly opening and looking through a list of numbers, it still required users to look for a number on a page with over 200 problem numbers listed. In page searching (ctrl+f in most browsers) helps of course, but still takes extra time and effort. Ideally, users should be able to view the question content on the spreadsheet in a little popup next to each number, but the programming functions were not available to accomplish this. The next best thing was to have a link that opens a new webpage with a preview of the problem. This was implemented using the GoogleDocs built in function hyperlink(*link_address*, *display_text*). Fortuitously, the preview address for any problem in the ASSISTments system begins with the same address, and only the ending number distinguishes one problem from another. By concatenating this string with the value of problem number column in the spreadsheet, it was very easy to add a new column next to the problem numbers with a working link to the problem. The final result is that viewing a problem whose number you see on the spreadsheet requires holding the “ctrl” key and clicking the “view” link next to the problem, rather than navigating for upwards of 30 or more seconds on the ASSISTments problem listings page.

While this is a marked improvement, it still does not differentiate problems; in the near future researchers and programmers will need to find problems relating to very specific science content, and the current basic topics associated with each problem are much too varied to be useful. The Massachusetts Curricular Framework (MCF) governs the content for all problems in the MCAS exam, and thus is the perfect problem classification system, complete with detailed descriptions for each requirement. The MCF for grades 6-8 is divided into 4 main topics, each with a varying number of branching subcategories. The complete framework documentation is longer than this report, but can easily be viewed in PDF and Word doc format at http://www.doe.mass.edu/frameworks/current.html.

To make these standards useful to the spreadsheet, each standard was assigned a code. The first set of character in the code signified to which of the four primary topics the standard belonged; PS = Physical Science, ESS = Earth and Space Science, LS = Life Science, and ET = Engineering/Technology. Each subcategory within these primary topics is assigned a number, and so are naturally the next two characters in the code. The last single character exists in case the subcategory needs to be further subdivided; this occurs almost exclusively for the Engineering/Technology topic. Once I had established the coding system, I began assigning a code to each problem to classify it within the MCF.



Assistment

You are previewing content. MCAS_STE Grade 8 2008 P#14 **(#29434)**

The diagrams below illustrate two blocks composed of different materials.

Block A 25 grams

Block B 25 grams

If Block A is located on the Moon and Block B is located on Earth, what property do these two blocks have in common?

Comment on this question

Select one:

A. They have the same mass.

B. They have the same weight.

C. They have the same volume.

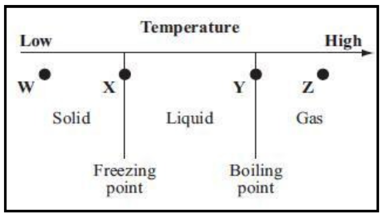
D. They have the same surface area.

Submit Answer

Properties of Matter - 1	PS-01-1	Differentiate between weight and mass, recognizing that weight is the amount of gravitational pull on an object.
The Earth in the Solar System - 10	ESS-10-1	Compare and contrast properties and conditions of objects in the solar system (i.e., sun, planets, and moons) to those on Earth (i.e., gravitational force, distance from the sun, speed, movement, temperature, and atmospheric conditions).
The Earth in the Solar System - 8	ESS-08-1	Recognize that gravity is a force that pulls all things on and near the earth toward the center of the earth. Gravity plays a major role in the formation of the planets, stars, and

While this appears to be a fairly straightforward concept, I found it to be difficult to assign only one code to each problem, as they often incorporated concepts from a variety of different standards. After working through several problems, I decided that each problem could be associated with up to three standards, the first being most relevant and the last least relevant. For example, problem #28434 can be seen in the problem preview above, and the related standards in the table adjacent.

- Question #29436:
  - Ms. Bristol measured the mass of a closed beaker containing several ice cubes. The mass was 100 g. An hour later after the ice cubes had melted, Ms. Bristol measured the mass of the beaker again. What was the mass of the beaker of water the second time?
- Question #29499:
  - The diagram to the right shows how a change in temperature affects the physical state of a substance. Each of the labeled points represents the same substance at a different temperature. Which point represents the substance in the physical state with the particles moving the **least**?



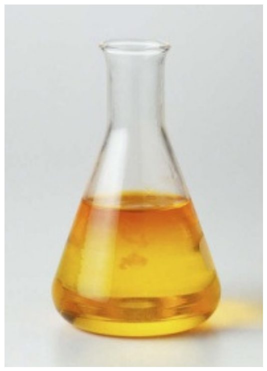
- Question #29517
  - A pot of cold water was heated on a stove until the water boiled. Which of the following best explains why the water was able to boil?
    - A. The hot stove absorbed cold from the pot.
    - B. The cold water absorbed heat from the pot.
    - C. The hot stove gave off heat to the surrounding air.
    - D. The cold water gave off cold to the surrounding air.

Once all problems have been classified with this system, researchers will be able to locate all programs related to one or more standards very quickly. This will allow them to select a set of problems that will be very relevant to a particular topic, specifically the content or subjects relevant to a microworld. For example, some problems relating to the phase state of a material: (These were found simply by checking problems listed as Physical Science from 2008). In sum, this table can be used to easily identify assessment items that can be used to evaluate the transfer of knowledge from our microworlds to MCAS questions.

3.2.0 Phase Change Microworld graphical development

When I began development of the graphical aspects of the phase change microworld, Mike had a skeleton microworld for me to work with (change capitalization throughout doc—it should not be capitalized). It had a few basic graphics for me to use as a starting point, as well as a number of variables that controlled various physical properties such container size and amount of ice. I began by embellishing the existing variables in both the microworld and the drawing objects so that additional properties such as scale and color were easily changeable. Then I decided to find a different shape for the container, and settled on a very stereotypical flask that can be seen in the image to the right. This object is fairly complex, and I spent some significant time breaking it down into lines and points that Laszlo's procedural drawing system could understand.

I started this process by tracing the image in Microsoft Word using only straight lines and 3-point spline curves. These accurately simulate the drawing tools Laszlo uses (namely the lineTo() and parabolicCurveTo() commands), so I could plan which curves to draw. Next I divided up the image into a grid that intersected major points and lines on the image. Using a common "origin" point at the base of the flask, I could then identify each point around the



perimeter like a “connect-the-dots” drawing. By using only fractional relationships between the positions, I could scale the image by changing only the height and width variables while managing to keep the proportions realistic. This whole procedure is detailed in the last section of this paper. While an outline serves as a good representation of the object, additional details improve the visual appeal of the Microworld. I added details around the lip of the flask, and created a partially transparent gradient to give it some depth. To increase the flexibility of the shape, I also added some variables that control the neck width and height.

The next shape I created was the ice, for which I made into a cylinder that would just fit through the neck of the flask. While this might seem an unrealistic shape for ice to take, it greatly simplified the animation of melting since the ice will only melt on the bottom, thus requiring only a change in the height. Cubes floating would require more movement and complex changes in two dimensions. The height of the ice is set by a slider the student sets before the experiment begins. Its position and width is driven entirely by the Flask object, and additional calculations assure that the correct volume of ice is displayed. This means that the ice height is also influenced by the width of the flask neck in relation to the overall width. However, scaling factors have been added so that the ice volume is not impacted by changes to the Microworld scale. As a final touch, once the ice height has been lowered all the way, the remaining “disk” of ice is erased.

To simulate the liquid water in the flask, I created a copy of the flask object. All the lines are identical, but have been made transparent. The purpose was to create a “container” for another gradient, this one much more complex and animated. By adding a few extra colors near the “surface”, I created a fairly convincing meniscus layer. Unfortunately, the gradient is linear, and looks a little strange in a simulated 3D flask. I originally intended to use an oval gradient, but Laszlo has not fully implemented this function and only purely circular gradients are rendered. Further work using curves may create a more realistic liquid.

Lastly, I migrated three control sliders from the previous ball-ramp Microworld. I reassigned their values to attributes relevant to the phase change Microworld, namely flame strength, substance volume and container volume. I experimented with different values, and selected a range for each that made reasonable changes to the objects. For example, I found a maximal value of ice so it went almost to the top of the flask, and a minimal value that still filled enough of the flask to cover the base when melted. Now that the code is integrated and working, additional controls can easily be added to control any attribute in the Microworld.

3.3.0 Expected Pedagogical Utilization of Phase Change Microworld

National Science Education Standards have several "strands" of inquiry development. By combining them with the Mass Curricular Frameworks for grades 6-8, we can effectively tutor both inquiry development and scientific content. The detailed record of choices made by each student as they design and conduct experiments provides an accurate measure of their inquiry skills. The following sections explain in detail how each of the NSES Inquiry Strands are implemented within the Phase Change Microworld.

3.3.1 Strand 1: Hypothesizing and Forming Predictions

In a preliminary exercise, students will be given a graph, with data points in a linear trend, and will be asked to predict the value of the next several points. For example, they may have a temperature versus time graph of ice as it is heated. The first couple of data points show that temperature of the ice is steadily rising as energy as added over time. Once the temp reaches 0 degrees Celsius however, the students will be asked if the temperature will continue to rise at the same rate, a slower rate, or remain constant at 0 degrees until all the ice is melted. By choosing one of these options, the student has effectively established a hypothesis that will then need to be supported or refuted by the experiment within the microworld.

3.3.2 Strand 2: Designing and Conducting Experiments

Now that students know the overall topic, and what they are trying to prove, they need to choose an experimental set up. This involves setting parameters such as heating strength, amount of ice, volume of container, and so on. At first, the students can set these values to whatever they want and run a trial of the experiment. If the hypothesis was something easy (e.g. “If I heat ice, its temperature will rise at a constant rate until it evaporates”), then a single trial will be enough to refute the theory. If it is more complex (e.g. “If I use different flame strengths to heat water, then the time from complete melting to the point of boiling will be directly proportional”), many trials will be necessary. Additionally, students will need to identify explicitly which variables are dependent, and independent, i.e., those that need to remain constant for the experiment to be valid. If the student is not using an appropriate Controls for Variables Strategy (CVS), the system will begin to ask prompting questions and eventually disable controls on variables that need to remain constant for a valid experiment.

After each trial, the student will be required to create a spreadsheet of relevant data, namely measurements of various physical properties in the microworld. If data needs to be collected over time during a trial, they may be prompted to setup a data recording widget. Alternatively, they could pause the experiment at different times and manually record various data points. A variety of extraneous data will most likely be available, and the students will need to record only the data that is relevant to their particular hypothesis. It will be up to the student to determine when enough trials have been completed, so that the next phase of the experiment can begin.

3.3.3 Strand 3: Representing and Analyzing Data

Once the student has completed enough trials and collected some valid data, they will need to perform graphical and numerical analysis of their data. This could mean constructing a plot of their data on a graph, creating a table of their data, or predicting new data. Students will be expected to recognize trends, both visually on graphical plots and numerically by examining data. They will also be expected to notice whether or not new data supports predictions that are based on older data, thereby supporting a trend across trials. If their predictions or theories were incorrect, responses in open response format will be collected in order to be able to characterize their reasoning associated with their interpretations.

3.3.4 Strand 4: Abstraction and Mathematical Modeling

Once initial observable trends are determined and it is verified that enough data has been collected, more rigorous statistical calculations and abstract reasoning will be required. This may involve calculating the slope of a linear trend, or comparing the trends of different trials as a variable such as heat strength was varied.

3.3.5 Strand 5: Communicating and Defending Ideas

Traditionally, the NSES Inquiry Strand requirement calls for this section be written entirely in open response format, and is intended to show the student's skill at defending or refuting their original hypothesis, using the collected data as evidence. Unfortunately, this approach makes this section the most difficult to evaluate with an autonomous system such as ASSISTments. Although there are some natural language processing systems available, they are not suitable for our data, nor is an auto-scoring feature of students' open response data within the scope of the Science ASSISTments project. Instead, some sort of basic "fill-in-the-blank" analogue to the hypothesis creator used back in Strand 1 may be possible, and that would allow for rudimentary evaluation of the student's overall correctness. However, the bulk of the final analysis of the student's skill in this strand will need to be hand scored, as was done in the IQP project by Patrick Sebuwufu (Sebuwufu, 2009), also supervised by Dr. Janice Gobert.

3.4.0 Documentation for future Development of Microworlds

Following the wisdom of the old saying “Give a man a fish, feed him for a day… Teach a man to fish, feed him forever”, I began documenting the work and techniques I used to create the basic shapes and objects used in the Phase Change Microworld. This document is intended for anyone who needs to create a visual object in Laszlo within an established Microworld. Very little previous programming knowledge is necessary to create basic shapes, and even advanced animations can be achieved with a little help from the senior software writers. The full text can be read in Appendix A.

4.3.0 Concluding Remarks

By the end of the Science ASSISTments project, at least five different Microworlds will be created. Initial topics and a basic layout of a few are already being designed and developed. Further work on the Ball-Ramp Microworld and of course the Phase Change Microworld will continue, and new ways to challenge students within the Microworld frameworks will be developed so that more complex inquiry opportunities can be explored. The extensive logging capabilities will provide a rigorous and large dataset, which the project researchers can analyze to determine the effectiveness of different methods of tutoring inquiry. With the highly scalable nature of the ASSISTments system, eventually any school interested in tutoring or evaluating inquiry could simply sign up online and begin using it.

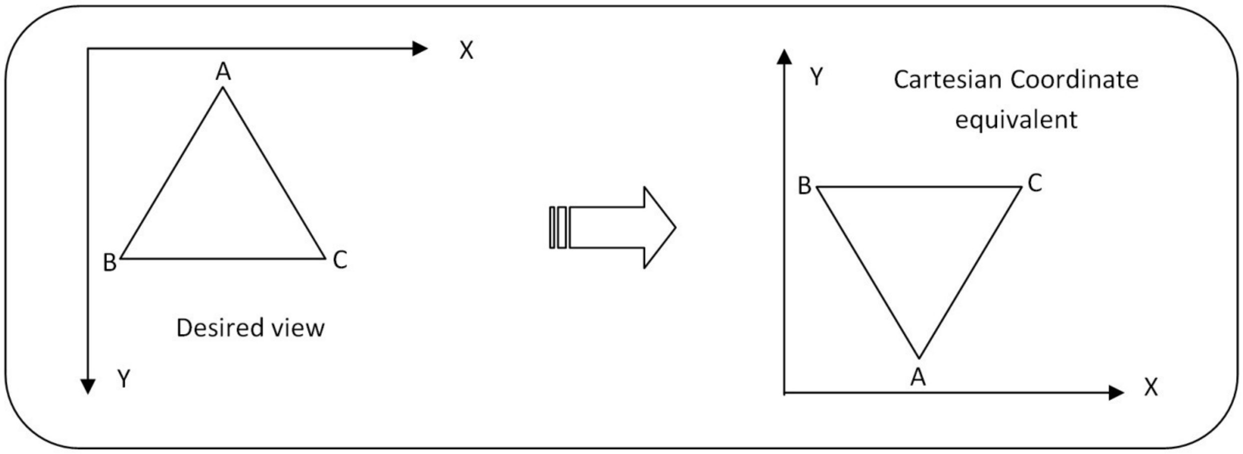
Appendix A: Guide for creating visual objects in Laszlo

Laszlo (http://www.openlaszlo.org/) is a language that was written to proceduralize the process of creating animated graphics on a website. What this means is that nearly any aspect of a drawing can be animated independently from the other parts, and the animation parameters themselves can be driven from entirely customized equations. Traditional methods of animation have limited control over movement, allowing some options in speed, start/stop accelerations, and path. Laszlo can assign any equation to the motion, so that Newtonian physics and other laws of motion can be used. This document was written to aid in the creation of new Microworld graphical objects by anyone working on the Science ASSISTments project, regardless of their programming background. It will also standardize the minimum basic attributes that every object must have so that animation algorithms can be simplified and reused.

A.1.0: Creating Basic Shapes:

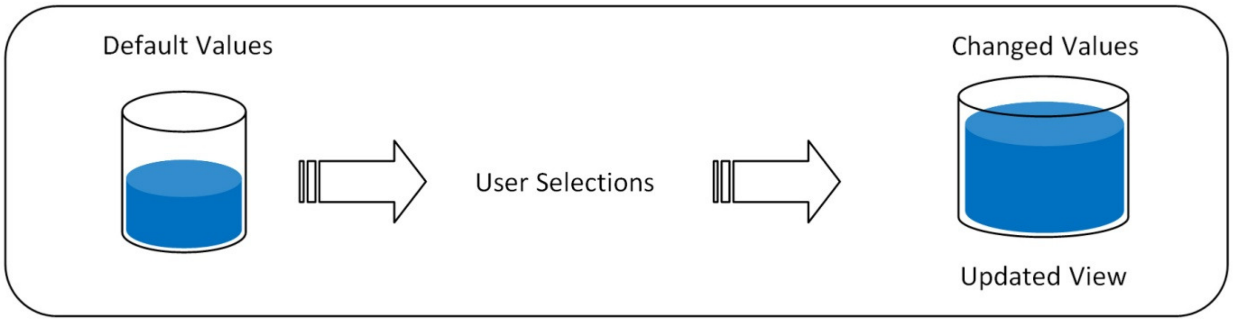
Laszlo uses a "canvas" system to draw the objects it displays. This canvas is a grid of pixels, each with an X and Y coordinate. These coordinates can be negative, allowing for objects to go out of the visual area. Avisual object is usually represented by a series of points, much like a "connect-the-dots" picture from a children's book. The lines between the points can be modified in a variety of ways, so that different types of curves are possible. Once the points return to the first position, the area enclosed by the lines can be "filled in" with colors, either solid or a wide range of gradients. Both the lines and the fill colors have controls for transparency as well.

Creating objects in Laszlo is fairly simple. Each object is created with a "<drawview>" tag, and requires three basic parameters: a name, a height, and a width. By default, the top left corner is located at the (0,0) position on the canvas. X positions move positively to the right, while Y positions

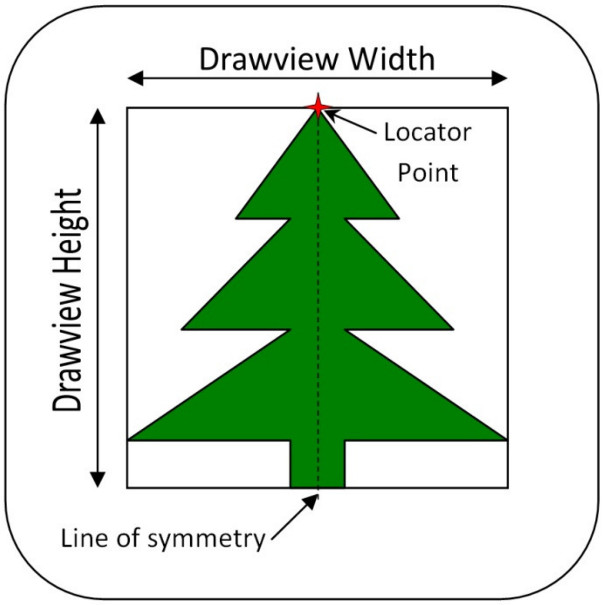


move positively downward. This means that if you want to draw a triangle with specific points in a Cartesian coordinate system, you must think of it as being upside down. While this might seem like a simple concept, it can be far more complicated for complex shapes involving large numbers of points. I have found that when drawing using lines in a computer system, it is advantageous to use as few numerically assigned values as possible. When building a Microworld, the graphics you are creating usually represent the properties selected by the end user, and the size, shape, color, and a variety of other characteristics will influence what is being drawn. This means that there will be properties in the Microworld class that your drawing object will need to access in order to be correctly dimensioned or colored.

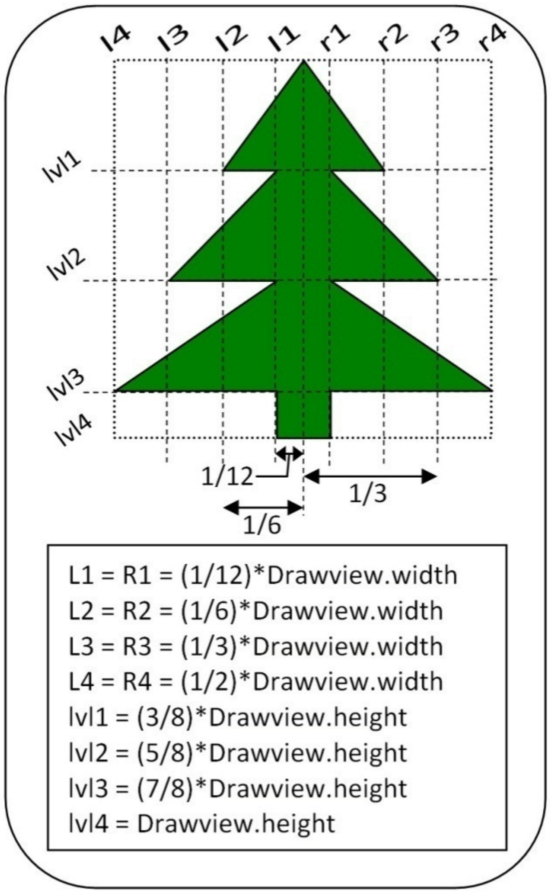
As stated before, the size and width of the drawing area is a required part of the <drawview> declaration. These properties can be easily assigned from attributes that are assigned to the Microworld<class> itself. To illustrate, assume we have a world in which a liquid is to be held in a



container. The user selects how much liquid and what size of container, and the “world” stores these values in its attributes. It then activates a drawing update, and re-draws your object; in this case the container and the liquid.



The position of each point used in the drawing should be relative to a locating point and the size of the <drawview>. If the item being drawn is symmetric across either a vertical or horizontal line (or both), it can be useful to have this point on the line of symmetry. To start, we will use a relatively simple shape: a pine tree. For this example, we will use the top of the tree as the locator point, which is on the X axis at the midpoint of the line representing the <drawview> width. The syntax and mechanics of actually assigning this value to the locator point will be covered in the next chapter. For now we will focus on the concepts involved in defining an object.



L1 = R1 = (1/12)*Drawview.width
L2 = R2 = (1/6)*Drawview.width
L3 = R3 = (1/3)*Drawview.width
L4 = R4 = (1/2)*Drawview.width
lvl1 = (3/8)*Drawview.height
lvl2 = (5/8)*Drawview.height
lvl3 = (7/8)*Drawview.height
lvl4 = Drawview.height

The first step is to divide the object into a grid that intersects as many of the critical points as possible. Generally, this will be three to five lines, as illustrated on the right side of the figure below. Each line needs a simple name to indentify it, such as “lvl2” or “r1”, so that when assigning values to points you can keep everything organized. The next step is to estimate the ratio of the space between each line to the width of the draw view, so that relative distances can be determined. Either decimal or fractional values can be used, and they can be adjusted later quite easily. These ratios are going to be added or subtracted from the locator point's X or Y value.

A.2.0: Recommended Variables

Generally, when assigning variable names to each of the lines you drew, you want to keep them short and simple. The syntax for variable declaration is quite easy; "**var***variable_name***=***variable_value***;**". The variable value can be just about anything, but for our purposes numbers are generally the most useful. Since the locator point is going to be the crux of all calculations, I usually call it "base_x" and "base_y" for the x and y components of the point. The "code box"below has a variety of syntax not yet introduced, which I will now explain. Laszlo uses a "tagging" structure was originally developed for displaying information on the web in a more attractive way than just text. The basic idea is that you "wrap" the text you want to display in a package that instructs the browser to show that text is a specific way. This package is defined by opening and closing "tags" that each have a different meaning to the browser. If you want large text to begin the page of text, you can use one of several "title" or "header" tags. If you want to create a link,

```
<drawview name="example" width= "50" height= "70">
<attribute name= "x_loc"value= "${0.5*this.width}" />
<attribute name= "y_loc" value= "${0*this.height}" />
<handler name= "oncontext">
      varbase_x = this.x_loc;
      varbase_y = this.y_loc;
      var l1 = base_x – (1/12)*this.width;
      var l2 = base_x – (1/6)*this.width;
      var l3 = base_x – (1/3)*this.width;
      var l4 = base_x – (1/2)*this.width;
      var r1 = base_x + (1/12)*this.width;
      var r2 = base_x + (1/6)*this.width;
      var r3 = base_x + (1/3)*this.width;
      var r4 = base_x + (1/2)*this.width;
      var lvl1 = base_y + (3/8)*this.height;
      var lvl2 = base_y + (5/8)*this.height;
      var lvl3 = base_y + (7/8)*this.height;
      var lvl3 = base_y + this.height;

      //drawing instructions here

</handler>
</drawview>
```

there is a special “a” tag. Within each tag itself, a variety of properties can be set, such as font size, the link destination, or simply a name to allow for in-page navigation. In the case of Laszlo, these tags define instructions for the system to execute when the page is loaded.

The <attribute> tag defines just that: an attribute within the <drawview> object that can be animated and accessed by any other functions. It is similar in essence to a “var” variable, but var’s can only be defined in and accessed by their own tags. The tags that can contain code (including the declaration of “vars”) can be either a <handler> or a <method>. A <handler> is basically that: it handles changes or events within the <drawview>. The name is very important, and every <drawview> must have one <handler> with the name “oncontext”. This is executed once, when the rendering system first runs through your code. The <method> tag is more of a general purpose function container, and while it is not a necessary part of a <drawview> object, it can be very useful for dividing up independent operations you want your <drawview> to do.

As I mentioned before, the purpose of tags is to wrap up the enclosed text, and the last few items above are called “close tags”, and are easily identified by the leading ‘/’ within the tag. Every tag must have a closing tag, and just like preparing a bunch of items for shipping, each tag should be closed before the preceding tag is closed. It wouldn’t make much sense to seal up the main container while the smaller boxes inside are still wide open can spill and mix up. Just like the recipient trying to sort out the mess, the program that reads your code will be very confused. To further the analogy, you can’t close the smaller boxes once you’ve sealed the main container either. As can be seen with the <attribute> tags, you can also close the tag by ending the declaration with a ‘/’. This is like putting an index card with information in the shipping box; it has value on its own without actually holding anything within.

There are some important and easily overlooked details in the code box that should be noted and explained. First, when writing code within a <handler> or <method> tag, every instruction must be terminated by a semi-colon (‘;’). This notifies the system when each instruction is finished, and when the next instruction starts. It is theoretically possible to write your whole program on one line, but that would make it a little difficult to read or edit. Next, when I declared the “x_loc” variable, the “value” property had some odd characters mixed in. Namely the “${ … }” characters. This little “sub-wrapper” (for lack of a better term) instructs the system to evaluate any variable and mathematic operations contained within the curly brackets. This must be used whenever assigning values within a tag declaration. These are NOT needed between the opening and closing tags of a <handler> or a <method>. Note that in the declaration of the <drawview>, the height and width properties simply use quotes with the numeric values inside. While you could use the evaluation “${ … }” sub-wrapper for everything, it helps with the speed of displaying the object if you use it as sparingly as possible. Especially for animations, when it has to evaluate every variable hundreds or thousands of times per second.

The “this.____” syntax is important for calling the various functions and variables associated with the object within the <handler> and when using the evaluation sub-wrapper. It originates from java and java-script, the foundation of Laszlo’s architecture. Every function you will be using needs to have an object of some sort associated with it, either to act on or to originate from. Commands can’t come from nowhere, and either the <drawview> or some object within it needs to be attached to each instruction. When referring to <attributes> of the <drawview>, simply using a “this.” plus the attribute’s name will resolve to the “value” of the <attribute>. While it is possible to assign a different value to the attribute using the this.*attrubute_name* notation within a <handler> or <method>, it is better practice to vary the value with an animator, and simply use the value as is within your functions.

A.3.0: Stroke Functions and Modifiers

Getting back to the connect-the-dots analogy, when you want to draw the lines, first you have to choose something to draw with. Similarly, we have to tell the system what kind of line to display as it connects the points, and what color to put in the enclosed area. The “strokeStyle” property instructs the system to use the indicated color, which can be in one of two formats: a 6 digit hexadecimal (0x000000 is black, 0xFFFFFF is white) or a CSS color string (#00FF00 or #0F0 is green). If you have Photoshop available, the color picker tool can be helpful in choosing the color you want to use. Similarly, the “fillStyle” property allows you choose what color the interior of the object will have. This is optional, and if left undefined the object will consist of only the lines described by the movement instructions. Additionally, the thickness of the line is defined with the “strokeWidth” property; a value of ‘1’ is kind of like choosing a finely sharpened pencil, while a 4 would be a marker. Since we are creating a pine tree, I chose the fill color to be a dark green, with a thin black boarder for definition.

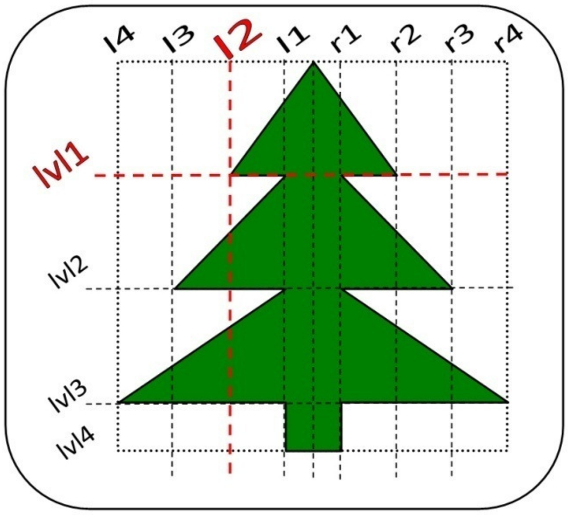
```
<drawview name=“example” width= “50” height= “70”>
<attribute name= “x_loc” value= “${0.5*this.width}” />
<attribute name= “y_loc” value= “${0*this.height}” />
<handler name= “oncontext”>
           varbase_x = this.x_loc;
           varbase_y = this.y_loc;
           var l1 = base_x – (1/12)*this.width;
           var l2 = base_x – (1/6)*this.width;
           var l3 = base_x – (1/3)*this.width;
           var l4 = base_x – (1/2)*this.width;
           var r1 = base_x + (1/12)*this.width;
           var r2 = base_x + (1/6)*this.width;
           var r3 = base_x + (1/3)*this.width;
           var r4 = base_x + (1/2)*this.width;
           var lvl1 = base_y + (3/8)*this.height;
           var lvl2 = base_y + (5/8)*this.height;
           var lvl3 = base_y + (7/8)*this.height;
           var lvl3 = base_y + this.height;

           this.strokeStyle = 0x000000;
           this.strokeWidth = 1;
           this.fillStyle = 0x009900;

           this.beginPath();
           this.moveTo(base_x, base_y);

           //drawing instructions here

           this.closePath();
           this.stroke();
           this.fill();

</handler>
</drawview>
```

Once we’ve chosen a “writing utensil”, so to speak, we need to indicate to the system that we’re ready to start drawing, which is where we use the “beginPath()” function. The pair of parenthesis indicates that we are calling a function with no inputs. If you are unfamiliar with the requirements of functions, imagine that you are telling someone to do something. If you say “blink”, most people would know how to accomplish this task without any further information. A more complex command might be "go"; the person would want to know where you wanted them to go, and just stare at you blankly as a response. "Go… to your room" would be more likely to be understood and executed. This is why the command following "beginPath()", namely "moveTo(base_x, base_y)" has the variables for the x and y components of the locator point you defined before as "arguments". It tells the system that you want to move the "tip" of your "drawing utensil" to this point, without actually making a line. By default, the system starts drawing at the point (0, 0), in the upper left corner of the canvas.

To finish explaining the last new commands in the code box, "closePath()" instructs the system to "close" the last object it drew. Operationally, this means it draws a line back to the first position from which it started drawing. While this command is not a requirement for the system to draw the lines, it must be used if you want to fill the object with a color, even if you have returned to the starting point with your drawing instructions. "stroke()" signifies that you are finished drawing the shape, and it should render the lines on the canvas, and "fill()" instructs the system to fill the interior of the shape with whatever color you set with the "fillStyle" property.

A.3.1: lineTo(x , y);

At last we get to actual instructions for drawing lines. Once again, the command for drawing a straight line is a function that needs two inputs. Thanks to the work we did before with our drawing and setting up the variables, we simply need to use x and y values of each point that is intersected by a vertical and horizontal dashed line. The first point is illustrated in the figure to the right.



```
<drawview name=“example” width= “50” height= “70”>
<attribute name= “x_loc” value= “${0.5*this.width}” />
<attribute name= “y_loc” value= “${0*this.height}” />
<handler name= “oncontext”>
          varbase_x = this.x_loc;
          varbase_y = this.y_loc;
          var l1 = base_x – (1/12)*this.width;
          var l2 = base_x – (1/6)*this.width;
          var l3 = base_x – (1/3)*this.width;
          var l4 = base_x – (1/2)*this.width;
          var r1 = base_x + (1/12)*this.width;
          var r2 = base_x + (1/6)*this.width;
          var r3 = base_x + (1/3)*this.width;
          var r4 = base_x + (1/2)*this.width;
          var lvl1 = base_y + (3/8)*this.height;
          var lvl2 = base_y + (5/8)*this.height;
          var lvl3 = base_y + (7/8)*this.height;
          var lvl3 = base_y + this.height;
          this.strokeStyle = 0x000000;
          this.strokeWidth = 1;
          this.fillStyle = 0x009900;
          this.beginPath();
          this.moveTo(base_x, base_y);

          //left side of tree
          this.lineTo(l2, lvl1);
          this.lineTo(l1, lvl1);
          this.lineTo(l3, lvl2);
          this.lineTo(l1, lvl2);
          this.lineTo(l4, lvl3);
          this.lineTo(l1, lvl3);
          this.lineTo(l1, lvl4);

          //right side of tree
          this.lineTo(r1, lvl4);
          this.lineTo(r1, lvl3);
          this.lineTo(r4, lvl3);
          this.lineTo(r1, lvl2);
          this.lineTo(r3, lvl2);
          this.lineTo(r1, lvl1);
          this.lineTo(r2, lvl1);
          this.lineTo(base_x, base_y);

          this.closePath();
          this.stroke();
          this.fill();
</handler>
</drawview>
```

I chose to construct the pine tree in a counter clockwise direction, going down the left side, and up the right side. Since our tree is symmetrical, the right side instructions are very similar, only using the ‘r1’ through ‘r4’ variables and the reverse order. The last instruction, “this.lineTo(base_x, base_y)” is actually unnecessary, as the next instruction (“this.closePath()”) would draw the same line. It is still good practice to close your shapes, since your last line may need to be a curve.

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