Algodoo: A Tool for Encouraging Creativity in Physics Teaching and Learning

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Algodoo: A Tool for Encouraging Creativity in Physics Teaching and Learning

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Algodoo (http://www.algodoo.com) is a digital sandbox for physics 2D simulations. It allows students and teachers to easily create simulated "scenes" and explore physics through a user-friendly and visually attractive interface. In this paper, we present different ways in which students and teachers can use Algodoo to visualize and solve physics problems, investigate phenomena and processes, and engage in out-of-school activities and projects. Algodoo, with its approachable interface, inhabits a middle ground between computer games and "serious" computer modeling. It is suitable as an entry-level modeling tool for students of all ages and can facilitate discussions about the role of computer modeling in physics.

Introduction

Algodoo is designed with the constructionist learning[1] approach in mind, allowing users to construct mathematical and scientific knowledge by creating interactive simulations based on Newtonian mechanics and geometrical optics. The software is a result of new technology in terms of faster computers and better numerical solving methods,[2,3] which have made it possible to build high-performance computational physics engines that, with the addition of a user-friendly interface, are also accessible to users without previous knowledge in computational physics.

There are other examples of simulation environments for learning physics, e.g., PhET simulations[4] and Physlets.[5] Algodoo differs from these environments mainly by being less restricted, leaving the user the freedom to create elaborate simulations that combine many different mechanisms or phenomena. Its open-endedness can be both a benefit and a drawback. In this paper, we present its potential for creative engagement.

The first version of Algodoo was released in 2008 under the name of Phun. Within days the software gathered a large community of users who recognized its possibilities for creating simulations and using it as a tool kit for demonstrations, computer games, or storytelling.[6] Through the education community, Phun found its way into classrooms, where students of different age groups could build relatively advanced physics simulations to explore and investigate diverse phenomena and processes. Further development, which has to a high degree been user driven, has led to the more educationally complete product Algodoo. In these later versions new features have been added, such as force and velocity visualization, graph plotting, and multiple ways of sharing and organizing user-created environments ("scenes") and lessons. These features make Algodoo more attractive as a teaching and learning software in physics and technology.[7]

Algodoo is currently available as a free download for Windows and Mac OS and is also available for iPad for a price of $5. It is also well suited for use on interactive whiteboards (IWBs), with no additional cost, since it is free for Windows and Mac platforms. An inexperienced user can learn more about Algodoo by visiting the online Algodoo forum (accessible through the official website), or going to YouTube to search for and watch video tutorials and demonstrations generated by an online community of Algodoo enthusiasts.

Useful features

In addition to allowing each individual user to create highly customizable environments—the so-called scenes—Algodoo offers a rich repertoire of possibilities for different representations. For example, it allows the user to selectively display vector arrows of forces acting upon a selected object, the sum of all forces on an object, and their Cartesian components. It allows real-time plotting of multiple quantities, from position, velocity and acceleration, force, momentum, and angular momentum to different forms of energy. Another example of a useful representation tool is the tracer. A tracer, which can be attached to any part of an object, leaves a trace of a pre-set duration on the background, allowing the user to track its movement. Properties of objects such as their mass (or density), coefficient of friction, restitution (bounciness), or index of refraction, as well as their visual appearance, can be adjusted through an easily accessible pop-up menu, or simply by choosing among common materials such as steel, wood, stone, gold, or rubber. More "global" physical parameters such as the strength of gravity or air resistance can also be adjusted through a dedicated menu. This allows for a great flexibility in simulating hypothetical scenarios that are impossible or very difficult to achieve in school labs (for example, turning off gravity or quickly changing the refractive index of a lens). Any setup or scene that we prepare can be saved in a small (< 1 MB) file and then opened on any computer with an installation of Algodoo. The scenes can also be shared with other users through a built-in online depository. This allows sharing and collaboration among students, taking scenes home from class, bringing them to school after preparing them at home, etc.

Ways of using Algodoo for learning and teaching physics

Below, we provide a list of examples that suggest and illustrate six different ways of using Algodoo in physics instruction.

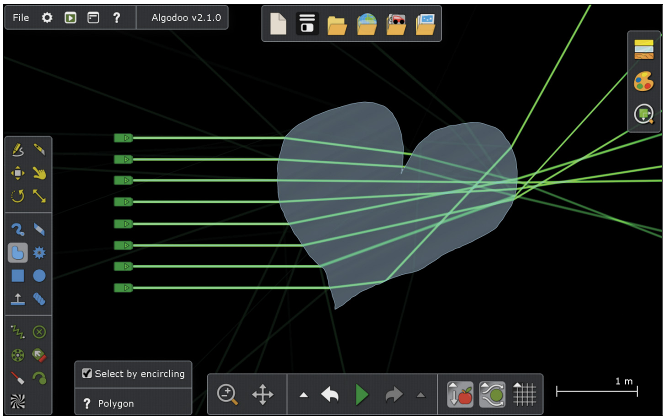

Fig. 1. An array of light beams passing through a user-drawn heart-shaped "lens." One can adjust the positioning and rotation of each individual light source, the array as a whole, as well as the heart-shaped "lens." The wavelength (color) of the light as well as the index of refraction of the heart can also be adjusted. Lenses of more familiar shapes can also be made by graphically adding and subtracting different shapes, such as circles and rectangles of custom sizes.

1. Visualization

Algodoo's user-friendly graphical interface (Fig. 1) allows the user to create customizable visualizations to accompany and improve explanations and serve as observational displays to provide students with vivid images. Students and teachers can decide to keep it quick and simple, or modify the scene (conceptually and visually) to meet their specific needs and requirements. The scenes can be edited on the spot, as new ideas arise, allowing continuous adjustment of the scene.

2. Problem-solving tool

Students and teachers can use Algodoo to design and run "quick and dirty" simulations in order to start building an understanding of concrete problems. They can make use of various representational possibilities (Fig. 2). One can display force or velocity vector arrows, or a plot of kinetic energy. Both vector arrows and plots are drawn in real time while the simulation is running, but can also be paused to allow a step-wise analysis.

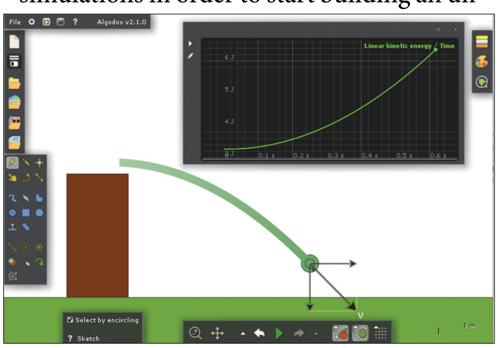

Fig. 2. A quick and easy simulation of horizontal projectile motion, accompanied by the visualization of the traveled path (the tracer tool), the velocity vector arrow (with horizontal and vertical component vectors also displayed in real time), and with plotting of kinetic energy vs. time.

3. Investigating phenomena and processes

The interactivity and flexibility of Algodoo makes possible an investigative approach to new physics topics, including topics where there are few possibilities for real experiments, such as astronomy, for example. The combination of Algodoo and modern hardware touch-screen interfaces, such as the interactive whiteboard (IWB), provides a hands-on learning environment in the classroom, even in topics where student physical engagement was traditionally not common, or even completely absent. One such example is using the combination of the IWB and Algodoo to help students learn about the orbital motion of planets and satellites by allowing them to create and throw planets into orbit around a massive star[8,9] (Fig. 3). Note that it is much more convenient and less awkward to throw planets into orbit on an IWB than by using a computer mouse.

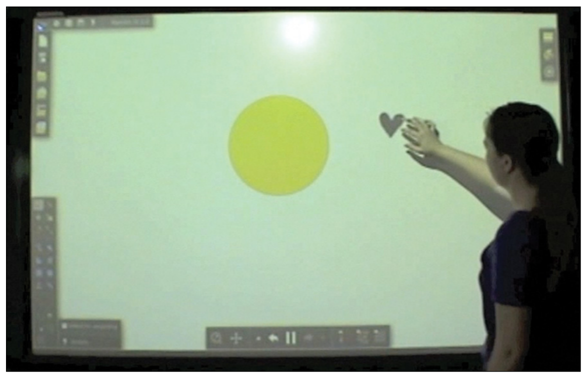

Fig. 3. Algodoo in combination with touch-screen interfaces, such as the interactive whiteboard, allows students to engage in hands-on investigation on an expanded range of topics, including those that traditionally do not offer such opportunities. In the above image, a student is throwing a heart-shaped object (that she created on the spot) into orbit around the massive star-like yellow object. If thrown with an appropriate velocity, the object will start orbiting the "star" on an elliptic orbit.

4. Student project work

Student engagement with Algodoo may not only be limited to the classroom. Since it is freely available, runs on different platforms, and allows easy transfer of saved scenes across computers and platforms, it is very well suited for projects where students work outside of school. An example is a Swedish national competition in technology and physics for lower secondary schools, which got students engaged in a month-long project with the goal of designing a vehicle in Algodoo that would take part in a simulated obstacle course race (Fig. 4). While such a task can be used as an engineering challenge, or simply as a way for the students to get familiar with Algodoo through play, it can also be used to address topics like torque (the motors in the vehicle's axes have adjustable torque) and friction (the properties of surfaces determine how well the vehicle can climb uphill).

Fig. 4. A student-designed simulated vehicle on an obstacle course in Algodoo.

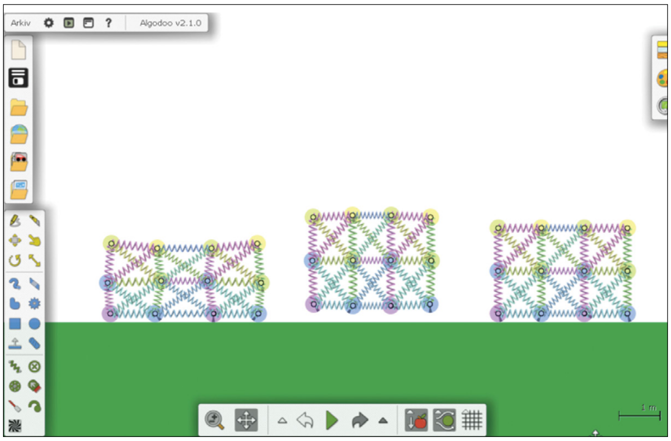

Fig. 5. Particle-spring models of an elastic object such as a sponge. Changing the properties of the constituent parts of each sponge (the spring coefficients and damping, the masses of the particles) affects the sponge's elastic properties.

5. Computer modeling in physics

When we encounter the limits of a computer-based physics model, we can use this as an opportunity for discussion of the role of mathematical and computer modeling in physics. Algodoo can serve as an entry point for such discussions, without demanding of the students an extensive previous knowledge of mathematics and programming. The software allows the user to manipulate many parameters, but does not make explicit the underlying mathematical and programming architecture. Therefore, it makes it possible for students to explore computer models and their limitations in an accessible way.

One example of such an activity is creating a simple mechanical model of a sponge using a particle-spring model. We can alter the elastic properties of the sponge by changing the properties of the springs (spring constant, damping) and masses of the particles that constitute the sponge (Fig. 5). We can observe and explore the mechanical properties of sponge models created in Algodoo by exposing them to different types of mechanical stress (squeezing, pulling, etc.) and by changing their physical properties on the go, even while the simulation is running.

Such a simulation can be the starting point for students' own mathematical modeling and programming. This example has previously been studied in the context of learning about mathematical modeling in undergraduate physics, where students were found to draw on their existing physics knowledge to enhance the learning of new physics, as well as the development of modeling skills.[10]

6. Science centers

Algodoo provides an investigative environment that is suitable for use in public settings such as science centers (Fig. 6), especially in conjunction with touch-screen interfaces such as interactive whiteboards and tablets. These easily accessible interfaces provide visitors with possibilities for spontaneous exploration of diverse topics and may decrease the need for the introduction to and the administration of experimental laboratory equipment to the visitors. The open environment at a science center can cater for many types of interactions between visitors, as well as for individual visitors' interaction with different digital artifacts. This way, it provides possibilities for the visitors' creative exploration and inquiry at different levels.

Fig. 6. Group of students engaged with Algodoo at the science center Umevatoriet, Sweden.

Conclusion

Algodoo provides teachers and students with a wide variety of possibilities. It allows teachers to create custom-made interactive and eye-catching simulations, which can also be adjusted on the spot to respond to student suggestions and ideas. On the other hand, put into the hands of students, with its user-friendly interface, it can help unleash the students' creativity and motivate them to engage in design and exploration, while at the same time serving as a first step into the world of computer modeling in physics.

However, even though Algodoo or other similar software can be used in many different contexts and types of activities, we suggest teachers use it wisely. Experiments with physical equipment play a central and essential role in physics. We do not suggest teachers should replace real experiments with computer simulations, but rather use them to augment and amplify the impact of real experiments, or use them where real experiments are simply not available. Another characteristic of Algodoo that might be held against it is its black-box nature, as the details of the underlying mathematical and programming architecture are not being made explicit and available to the user. Nevertheless, we believe that despite this possible drawback, Algodoo's user friendliness and accessibility make it attractive to students and teachers as an entry-level modeling tool. Furthermore, with appropriate support from the teacher, it can take on the role of a catalyst for discussion about the role of computer modeling and numerical problem solving in physics.

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