Teaching methodology of science through programming*

An Abstract of a Lighting Talk and a Faculty Poster

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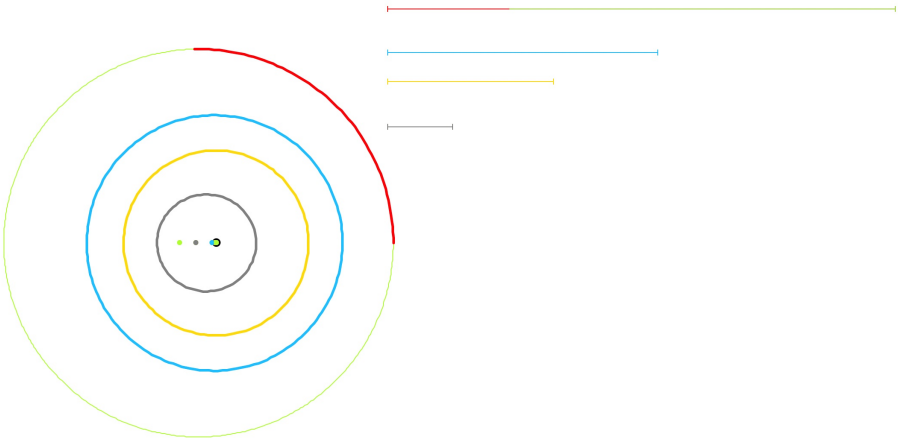
1 Summary

Unlike other simulations of planetary motion, our Kepler's World executes a computational science experiment, based on Newton's laws, testing each of the Kepler laws and providing the results in a visualization. It is written in Python 3 and relies only on the Standard Library in order to avoid additional installations. The experiment constitutes a basis for classroom activities involving simple programming and discussions of mathematics, physics, and most importantly, the methodology of science. While the instructor needs to demonstrate some versions of the experiment, programming activities for students are optional and not a prerequisite for other discussions. The activities are meant for upper-level high school or lower-level undergraduate students. Course materials for up to seven hours of instruction are freely available on GitHub for use and modification.

2 Kepler's World



The program outlines in green the elliptical orbit with the foci predicted by the 1st Kepler law, and makes a graph of a constant area-sweep speed predicted by the 2nd law, for times from 0 to the value of the orbital period predicted by the 3rd law. Then, it simulates the planet's movement based on Newton's laws, draws the scaled-down path of the planet, and graphs the area sweep speed. If the predicted and simulated graphs coincide, the experiment supports Kepler's laws. The program also prints the error of the simulation and has various options.

3 Topics of class activities

Programming: add Pluto and Halley's comet; modify the simulation to show the orbit if the gravity were inversely proportional to the 1st or 3rd power of distance.
Mathematics: the equation of the ellipse; locus of constant sum of distances from the foci; parameters of the ellipse.
Physics: adding velocities as vectors; Newton's 2nd law of motion; the law of universal gravitation; Kepler's laws; vis-viva equation; orbital period equation.
Methodology of science: branches of natural science; comparing logic, mathematics and natural science, theorems vs. laws of science; the scientific method; experimental, theoretical, computational methods; qualitative vs. quantitative statements; Ockham's razor; recurrent/periodic processes; visualization vs. simulation; representation; discrete vs. continuous; local vs. global; the Shell Theorem, abstraction vs. simplification; units of measurement and dimensional analysis; approximations; absolute and relative errors; metric prefixes; floating point numbers IEEE 754-2008.