MATH in the MEDIA

A Monthly Magazine from the American Mathematical Society

Image of the Month

Tony DeRose talks about how math is used to create animations at Pixar.

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Tony Phillips' Take on Math in the Media

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This month's topics:

- The 3-body problem and free homotopy
- Percolation and fractal dimension
- "The Math Problem in *Good Will Hunting* Is Easy"

The 3-body problem and free homotopy

"Three Classes of Newtonian Three-Body Planar Periodic Orbits" was the highlighted article in the *Physical Review Letters* index for the week ending March 15, 2013. The article was mentioned in *Science* on March 15 and on *Science*'s webpage ("Physicists Discover a Whopping 13 New Solutions to Three-Body Problem", Jon Cartwright, March 8). Cartwright: "Can you predict how three objects will orbit each other in a repeating pattern? In the 300 years since this 'three-body problem' was first recognized, just three families of solutions have been found. Now, two physicists have discovered 13 new families." The authors (Milovan Šuvakov and Veljko Dmitrašinović of the Institute of Physics Belgrade) explain that they searched for periodic planar solutions involving three equal bodies and "collinear configurations with one body exactly in the middle between the other two, with vanishing angular momentum and vanishing time derivative of the hyperradius at the initial time." These restrictions cut the dimension of the parameter space of initial conditions down to two. In fact, as they set it up, Body$_1$ starts in the plane at coordinates $(-1,0)$, Body$_2$ at $(1,0)$ and Body$_3$ at the origin. Body$_1$ and Body$_2$ have the same initial velocity vector (u,v) and Body$_3$ starts with $(-2u,-2v)$. The authors systematically explored (u,v) space looking for conditions determining periodic orbits; using "steepest descent" they zeroed in on 15 pairs which gave orbits closing up (along with derivatives) to within one part in a million.

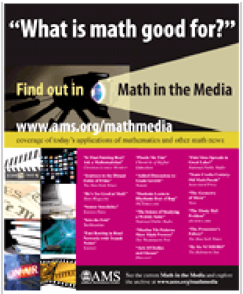
Math Digest

Summaries of media coverage of math

Math Digest Summaries posted April 2013:
Abel Prize winner Deligne; Pixar's Tony DeRose; will computers reign?...

"Should business be allowed to patent mathematics?", by Stephen Ornes. *New Scientist*, 18 March 2013.

Is mathematics discovered or invented? This question has been discussed many times and from many different points of view. "The latest incarnation [of the question] concerns something very down to earth: money," Ornes writes. "[M]athematics powers the algorithms that drive computer software, and software is big business, worth over US$300 billion a year to the global economy." He cites an article in the April 2013 issue of the *Notices of the AMS*, "Platonism is the Law of the Land," by David A. Edwards, who contends that mathematical ideas should be patentable. "[Edwards] argues patents should be granted for every new formula and algorithm, including those that power computer software," Ornes writes. "His position is extreme, but proponents of software patentability similarly argue that the system fuels growth and rewards people for their work." The article goes on to discuss some of the difficulties surrounding efforts to patent software. Some believe software *is* mathematics and therefore should not be



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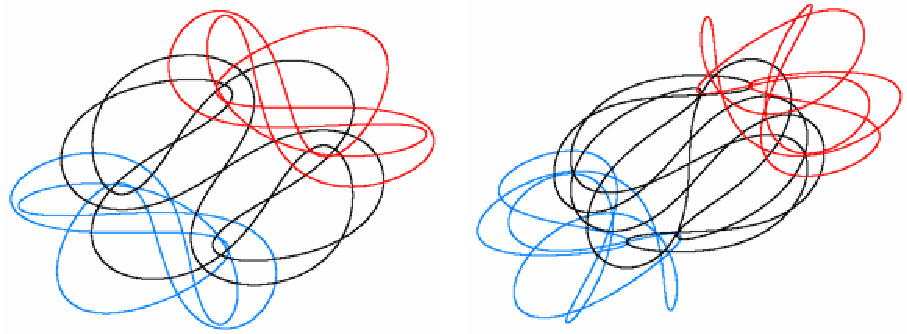
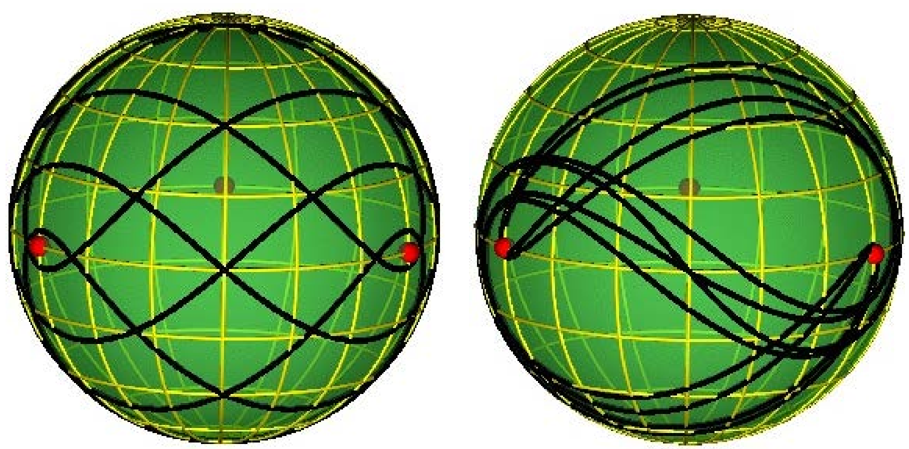


Two of the periodic orbits discovered by Šuvakov and Dmitrašinović: "Moth I" and "Yin-yang 1a." Images courtesy of Milovan Šuvakov.

The idea of a topological classification of periodic solutions to the planar 3-body problem goes back to Richard Montgomery (UCSC) in 1998. Mathematically speaking, a closed orbit determines a closed curve in the space of planar triangles with one fixed vertex. Putting the fixed vertex at the origin and labeling the other two by complex numbers gives a curve $(z_1(t), z_2(t))$ in ${\bf C}^2$; factoring out the scale gives a curve $[z_1(t): z_2(t)]$ in the complex projective plane which must miss the three points $\{z_1 =0,$ $z_2=0,$ $z_1=z_2\}$ where two of the bodies collide. This is a curve in a 2-dimensional sphere with three deleted points, topologically equivalent to the authors' *shape space*.



The curves in shape space corresponding to the Moth I and Yin-yang 1a orbits shown above. Images courtesy of Milovan Šuvakov.

Any closed curve in shape space is topologically characterized its free homotopy class; this can be

patentable. "The odds are stacked against them, though," Ornes writes, "there's too much money at stake."

--- *Allyn Jackson*

More . .

Reviews

Books, plays and films about mathematics

Citations for reviews of books, plays, movies and television shows that are related to mathematics (but are not aimed solely at the professional mathematician). The alphabetical list includes links to the sources of reviews posted online, and covers reviews published in magazines, science journals and newspapers since 1996.

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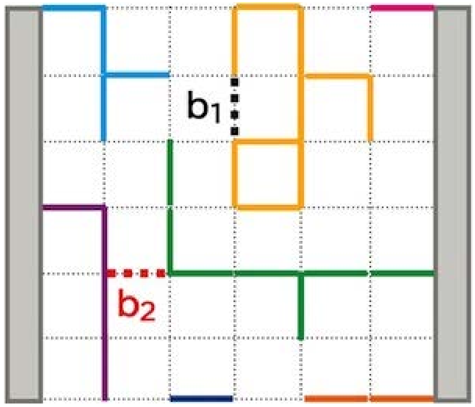
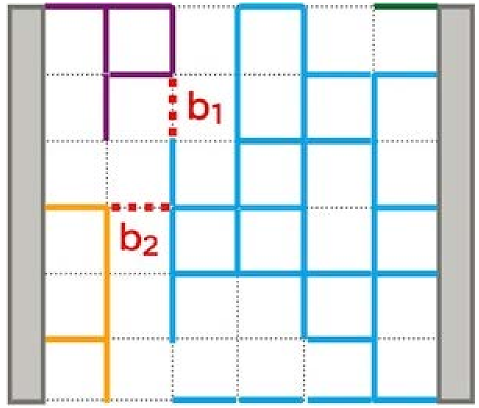
represented by the pattern (up to cyclic permutation) of its windings about any two of the deleted points. With the symbols a, A for counterclockwise (clockwise) winding about the one shown above on the front left, and b, B for clockwise (counterclockwise) winding about the one on the right, the Moth I orbit corresponds to the word $aBABabABAb$, and Ying-yang 1a to $aBABababABAb$. From this point of view, the 15 solutions Šuvakov and Dmitrašinović discovered correspond to 13 distinct topological types. The entire collection is displayed, with animations, along with some of the previously known solutions, on their website.

Percolation and fractal dimension

"Avoiding a Spanning Cluster in Percolation Models," by Y. S. Cho, S. Hwang, H. J. Herrmann and B. Kahng (Herrmann at ETH, the others at Seoul National University), appeared in *Science* on March 8, 2013. One family of percolation models examines the formation of a spanning cluster connecting two opposite sides of a system in Euclidean space, as new bonds are randomly added to the system. Their study by mathematical simulation dates back to Erdös and Rényi in 1960. Recently the ER model has been modified by imposing a rule that suppresses the formation of a large cluster. "Because of this suppressive bias, the percolation threshold is delayed; thus, when the giant cluster eventually emerges, it does so explosively." This leads to a phase transition, between the unconnected and connected states of the system. This article investigates the nature of this transition, in the case where m random bonds are selected at each step, but bridge bonds (which would make the connection) are discarded (as long as this is possible), and one of the remaining is chosen at random to be added to the system. The "time" (actually, the ratio of occupied bonds to unoccupied bonds) at which it becomes impossible to choose m non-bridge bonds is the *percolation threshold* t_{cm}; for $m>1$ this is larger than the percolation threshold $t_c = t_{c1}$ for ordinary percolation ($m=1$).

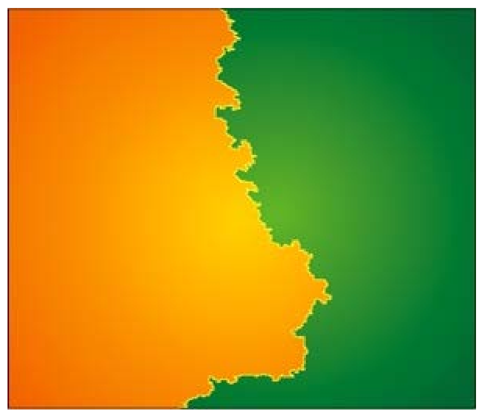


An example where $m=2$. Here the square lattice has linear size $L=7$, spanning goes from left to right, and the system is in a non-critical state. The random process has produced two candidate bonds, $\sf{b_1}$ and $\sf{b_2}$. Since $\sf{b_2}$ is a bridge bond, $\sf{b_1}$ is selected at this step.



Later in the evolution of the same system, beyond the critical time t_{c2} when it first becomes possible to have two candidate bridge bonds. That has happened here. One will be chosen and a spanning cluster will be formed. Images courtesy of Byungnam Kahng.

The authors examine the dependence of t_{cm} on m (which is allowed to be non-integer), on L (the linear size of the system) and on its dimension d. In particular they discover a critical value m_c for the parameter m. For $m < m_c$, as L increases, $t_{cm}(L)$ decreases and converges to t_c; while for $m > m_c$, as L increases, $t_{cm}(L)$ increases and converges to 1. This critical value is related to the fractal dimension d_{BB} of the set of bridge-bonds by $m_c = d/(d-d_{BB})$.



A two-dimensional system ($d=2$) with $L=300$ and $m=5$ is shown just before the percolation threshold t_{c5}. The set of bridge bonds has fractal dimension $d_{BB}=1.22$. *Larger image*. Image courtesy of Byungnam Kahng.

"The Math Problem in *Good Will Hunting* Is Easy"

Posted on *Slate* March 13, 2013 by David Haglund was a piece embedding an clip from Brady Haran's

Numberphile math video collection. It's about the mathematics in the 1997 movie *Good Will Hunting*. In the clip, "James Grime, a mathematician at Cambridge University, argues that one of the math problems Will Hunting solves, posed by an MIT professor to his students as a challenge of epic proportions, really isn't that hard." The problem was to draw all the nonhomeomorphic irreducible trees with 10 vertices. Drawing those ten may be "easy," but how about proving that there are no others?

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