Computational Geometry

A Lecture in the Freshman Seminar Series: Puzzling Problems in Science and Technology



Nov. 2018



Computational Geometry



About This Presentation

This presentation belongs to the lecture series entitled "Puzzling Problems in Science and Technology," devised for a ten-week, one-unit, freshman seminar course by Behrooz Parhami, Professor of Computer Engineering at University of California, Santa Barbara. The material can be used freely in teaching and other educational settings. Unauthorized uses, including any use for financial gain, are prohibited. © Behrooz Parhami

Edition	Released	Revised	Revised	Revised	Revised
First	Nov. 2016	Nov. 2018			





What Is Computational Geometry

Study of algorithms which can be stated in terms of geometry

Digital / Discrete geometry: Drawing lines, circles, ... Smallest bounding box/circle or sphere Largest empty box/circle or sphere Line-segment intersection problems Closest / Furthest pair of points Hidden surface / line determination Shading and texture

Robot path planning with obstacles







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Warm-Up Puzzle

Four circles on a plane are drawn so that each touches the other three:

If the radii of three of them are 3, 4, and 5, what is the largest possible size for the fourth circle:



Digital / Discrete Geometry: Objectives

Geometric shapes formed from pixels (drawing or recognizing):

Digital straight lines of different slopes (1 or 1/3) and thicknesses; drawing a straight line between two given points

Digital circle of a given radius (5) and line thickness; Digital disk

Various other shapes: Square; Triangle; Heart; Diamond; US map









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Digital / Discrete Geometry: Straight Lines

The digital geometry of straight lines and line segments:

Digital straight lines of different slopes (1 or 1/3) and thicknesses Drawing a digital straight line between two given points Intersections and other problems for digital lines and line segments



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Digital / Discrete Geometry: Circles, Disks, ...

Geometric shapes formed from pixels:

Digital straight lines of different slopes (1 or 1/3) and thicknesses Digital circle of a given radius (5) and line thickness; Digital disk Various other shapes: Square; Triangle; Heart; Diamond; US map









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Slide 7

Digital / Discrete Geometry in 3D



Digital straight lines and curved paths Digital 3D shapes: Cube; Sphere; Cone; ...



Optical Illusions via Shading



















Seeing What Isn't There









Slide 12

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The Graphic Designs of M. C. Escher







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Slide 13

More Works by M. C. Escher



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Slide 14



Illusary Motion and Other Neat Visual Tricks

Straight-line motions create the illusion of circular motion: 2-minute video: http://www.youtube.com/watch?v=pNe6fsaCVtI



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More Visual Tricks and Optical Illusions

A collection of 10 neat visual tricks and optical illusions: 4-minute video: http://www.youtube.com/watch?v=-IWk5NkxQF8



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Patterns Seen Under a Strobe Light

3D-printed sculptures come to life when spun under a strobe light 3-minute video: http://vimeo.com/116582567



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Dot-Matrix Printing and Display

The surface of paper or monitor is viewed as a huge dot matrix:

Black or colored dots are places at appropriate positions to form letters, shapes, or images of interest



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Design of Fonts and Font Families

A font is a set of geometric dot patterns for letters and symbols:

Arial Helvetica Times New Roman Courier Palatino Garamond Bookman

Verdana Georgia Comic Sans Trebuchet Arial Black Impact





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Dot-Matrix Displays Are Everywhere

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Artful Computational Geometry



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Slide 21

Randomly-Generated Digital Art









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Computational or Algorithmic Art



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Slide 23



Some Applications of Computational Geometry

Maps & navigation (Google Maps) Airspace design & air-traffic control Protein structure prediction Computer-aided design









Triangulation and Its Use in Map-Making

A triangle is fully specified by: Lengths of its 3 sides One side and its two adjacent angles Two sides and the angle between them



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Slide 25

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Triangulation for GPS Calculations

Distance and angle to 4 GPS satellites used to compute position



Robot Motion Planning

Robot is first taught a task such as spooning or stirring: It then executes the task will dealing with unforeseen circumstances. 3-minute video: http://www.youtube.com/watch?v=oY1FfytaD-c



Nov. 2018



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