COT 4521: Introduction to Computational Geometry

Introduction

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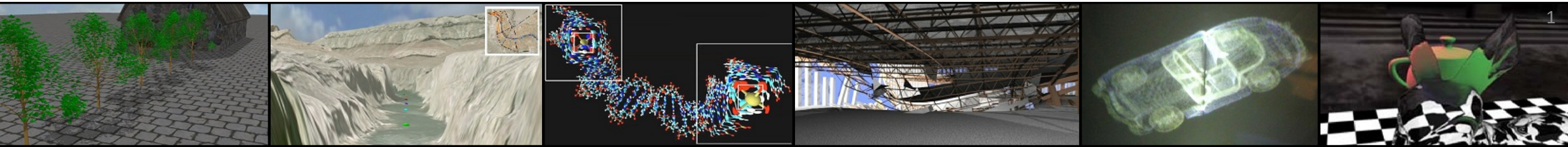


2004

Problem Domain

Computer Graphics

Problem Solving Approach

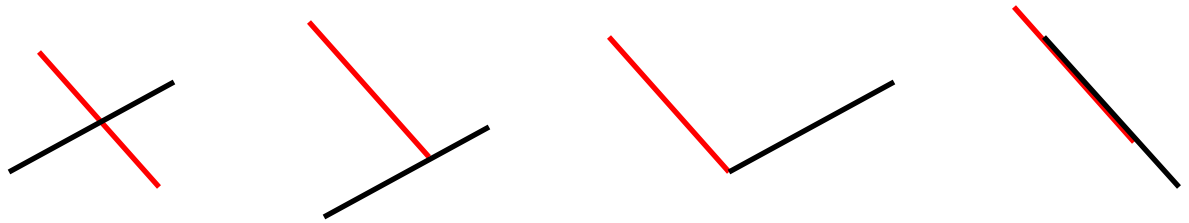
Geometric Approaches

Introduction

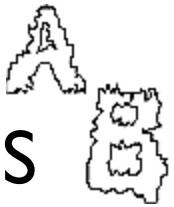
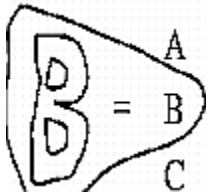
- What is computational geometry?
  - A subfield of the Analysis of Algorithms
  - Design of efficient algorithms and data structures for geometrical problems
- Started in mid 70's
  - started out by developing solid theoretical foundations, but became more and more applied over the last years
- Deals with geometrical structures
  - Points, lines, line segments, vectors, planes, etc.
- We'll focus mostly on 2-dimensional geometry, but 3D will be covered when possible

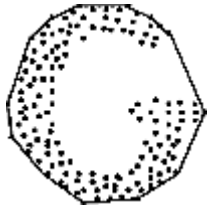
What makes Computational Geometry problems so Interesting/annoying?

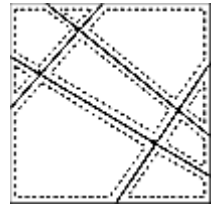
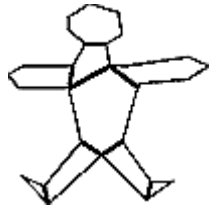
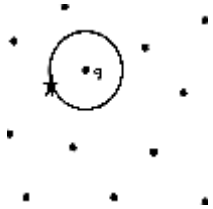
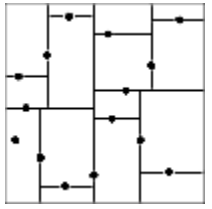
- Complexity
  - Curse of dimensionality
- Precision error
  - Avoid floating-point computations whenever possible
- Degeneracy
  - Boundary cases
  - For example, imagine how 2 line segments can intersect



Typical Computational Geometry Problems

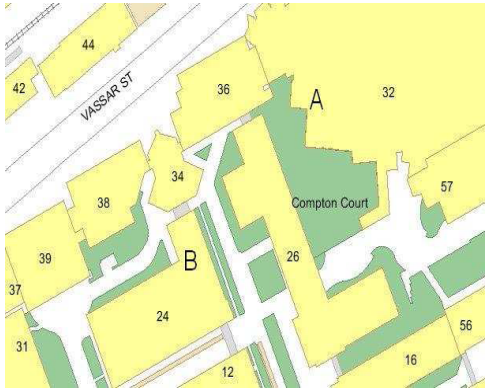
- Voronoi diagram 
- Simplifying polygons 
- Shape similarity 

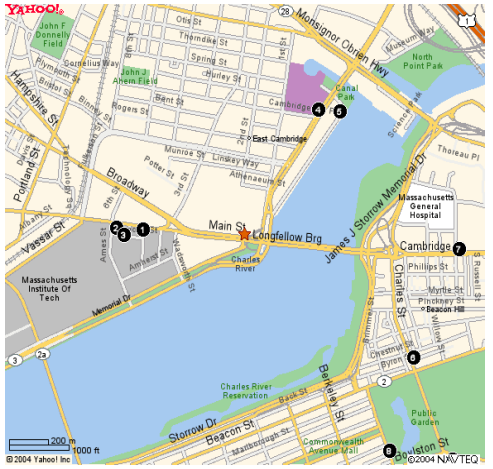
- Convex hull 

- Line arrangements 
- Polygon partitioning 
- Nearest neighbor search 
- Spatial organizations 

APPLICATIONS

- Computer Graphics
- Robotics motion planning
- Geographic Information
- CAD/CAM
- Collision detection
- Computer vision
- Molecular modeling
- VLSI design
- Data Mining, Machine Learning, and Visualization



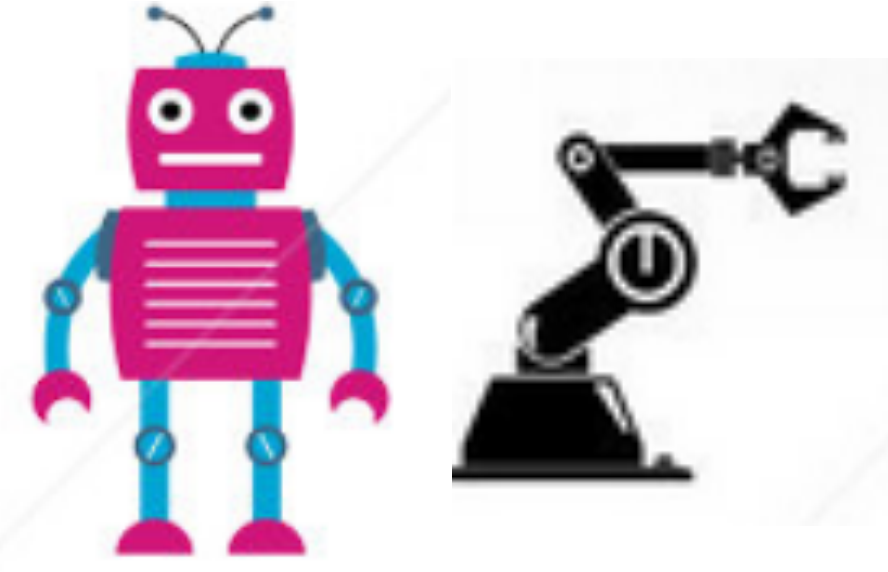


Applications of Computational Geometry

- Computer Graphics
  - For 2D graphics, typical questions involve the intersection of certain primitives, determining the subset of primitives that lie within a particular region, etc.
  - For 3D graphics, hidden surface removal

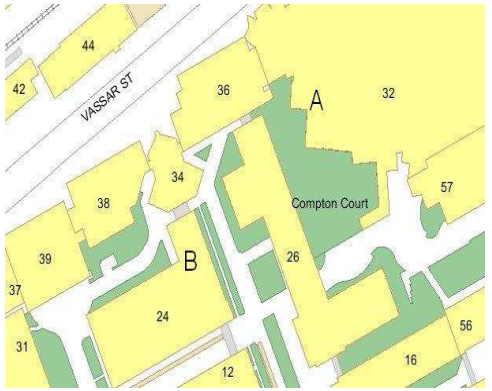
Applications of Computational Geometry

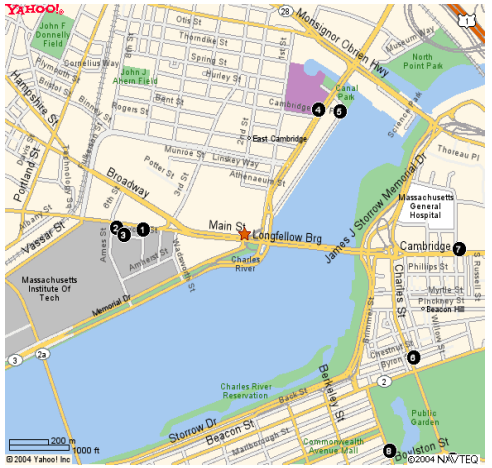
- Robotic motion planning
  - The geometric problem arise at many places because robots are geometric objects that operate in a 3D space



Applications of Computational Geometry

- Geographic Information system (GIS)
  - Stores geographical data
  - Can be used to extract information about certain regions and to obtain information between different types of data



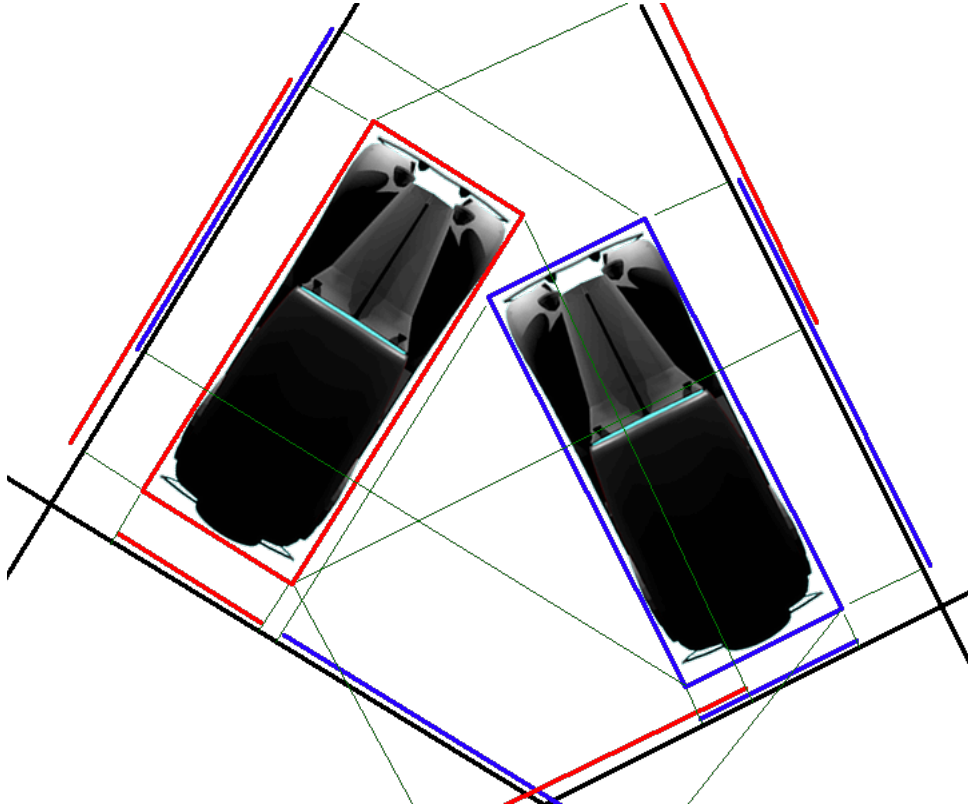


Applications of Computational Geometry

- CAD/CAM
  - Computer-Aided Design
    - Deal with intersections and unions of objects, with decompositions objects and object boundaries into simpler shapes, and with visualizing the designed products
  - Computer-Aided Manufacturing
    - Computer controls the actual manufacturing process

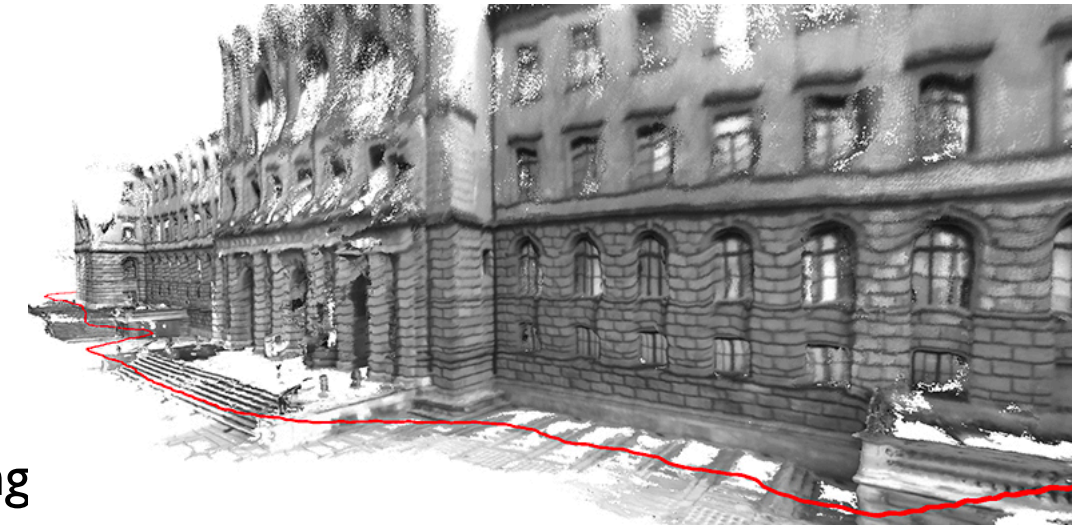
Applications of Computational Geometry

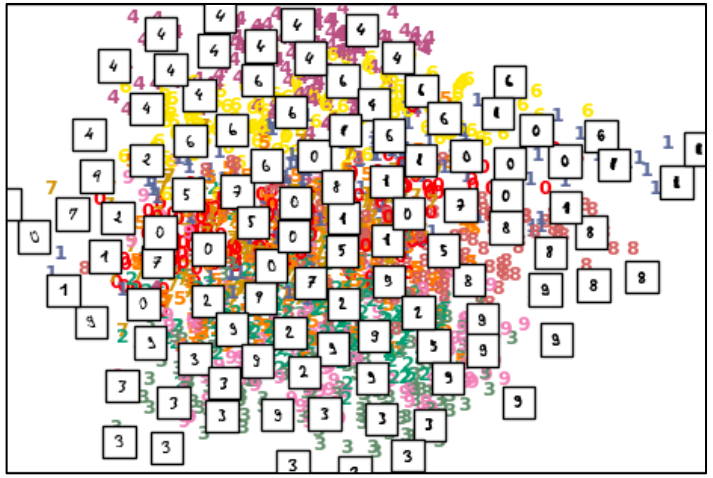
- Collision detection
  - Check whether two (possibly complicated) 3D objects intersect!
    - Approximate the objects by simple ones that enclose them (bounding volumes)
    - Popular bounding volumes: boxes, spheres, ellipsoids,...
    - If bounding volumes don't intersect, the objects don't intersect, either
    - *Only* if bounding volumes intersect, apply more expensive intersection test(s)



Applications of Computational Geometry

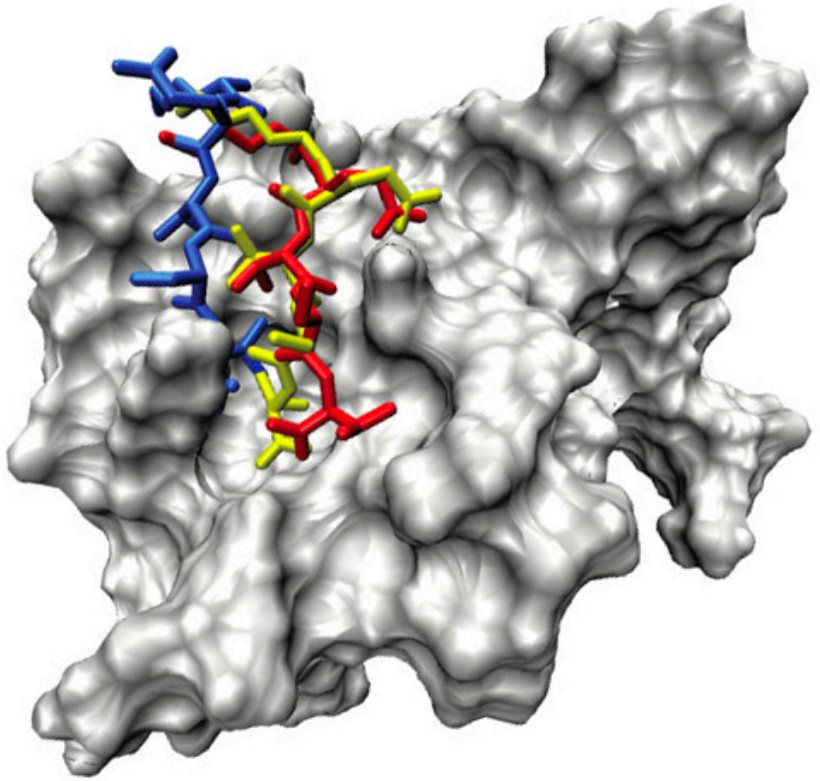
- Computer vision
  - Surface Reconstruction
    - Step 1: Scan the object (3D laser scanner)
    - Step 2: Create a triangulation
    - Step 3: process the triangulation (rendering *smooth* surface in R^3
    - Major Computational Geometry task: Create a "good" triangulation
  - Pattern recognition
    - Example: an optical character recognition system





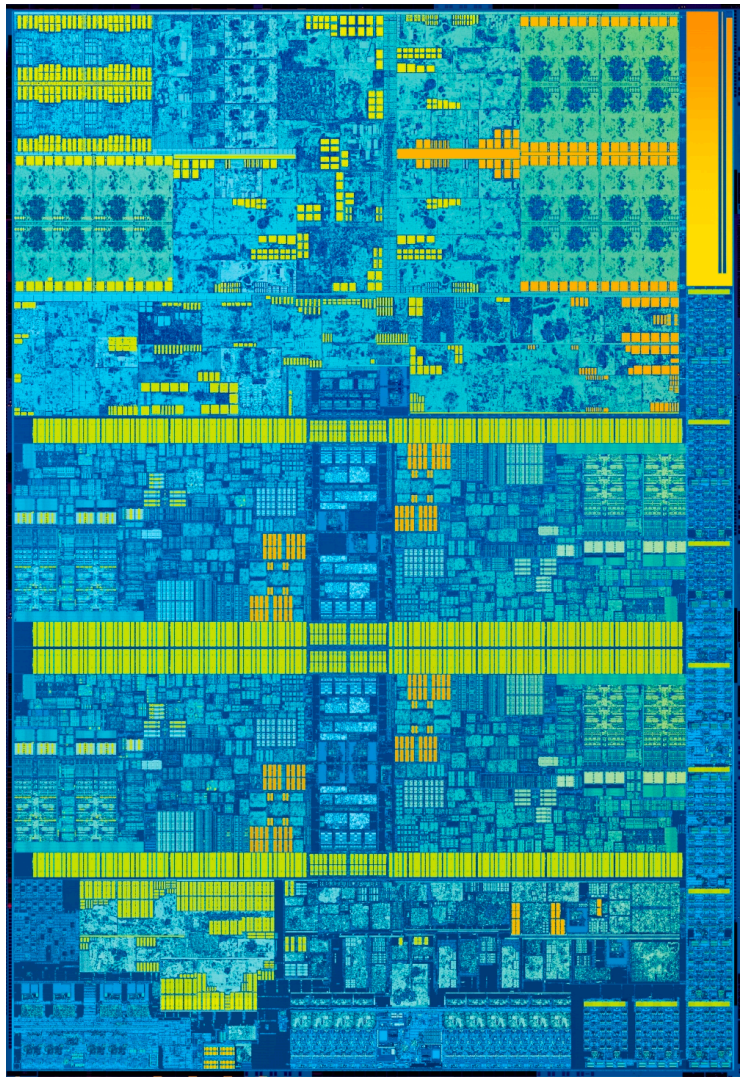
Applications of Computational Geometry

- Molecular modeling
  - Typical questions are to compute the union of the atom balls to obtain the molecule surface or to compute where 2 molecules can touch each other



Applications of Computational Geometry

- VLSI design
  - The process of creating an integrated circuit (IC) by combining thousands of transistors into a single chip



Applications of Computational Geometry

- Data Mining, Machine Learning, and Visualization
  - Many algorithms for operations such as clustering, dimension reduction, classification, and segmentation are based upon geometric approaches.