15381 Artificial Intelligence: Assignment 3

Due November 9th, beginning of class

November 9th, 2010

Instructions: There are 4 questions on this assignment. Please send us email at *15381-tas@lists.andrew.cmu.edu* if you have questions. Refer to the web page for policies regarding collaboration, due dates, and extensions. The TA names listed next to each problem show which TA wrote and is responsible for grading which problem. However, please feel free to speak to any TA or instructor regarding any problem.

Late Policy: Each student is allowed up to 2 late days for the whole semester, to be used with advance permission only. That means you must contact an instructor and request permission to use a late day for an assignment. Any late assignment without an instructor-permitted late day will not be graded.

Collaboration Policy: You can discuss questions with classmates, but the write-up should be of your own. If you discuss the problems with collaborators, you must list their names on your write-up.

Outside Sources: We expect you to solve these problems with the help of the textbook and the lecture slides (and the TAs and instructors) rather than searching for previous solutions and copying them. If you use any source other than the textbook or lecture slides, you must cite the source.

Electronic Submission: Submit your images, .ply file and the screen shot on the Digital Dropbox under the course Blackboard. Compress all the files into one zip file and name the zip file as yourAndrewID_assignment3.zip. You will not get full credit if your code is not properly uploaded on the Digital Dropbox.

# 1   Free Space [6 pts] [Ben]

A. [3 pts] Symmetric

Given the above symmetric robot, inflate the obstacles in the following world. You can find this process described in Lecture 12. If there exists a path for the robot from Start to Finish, please show it.
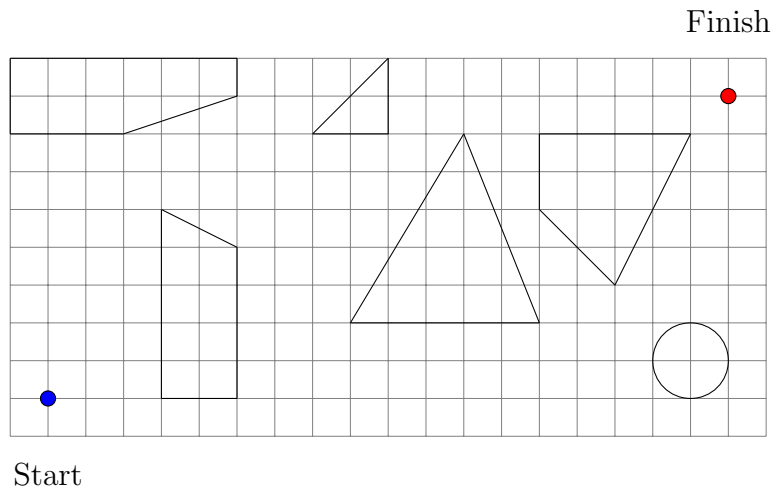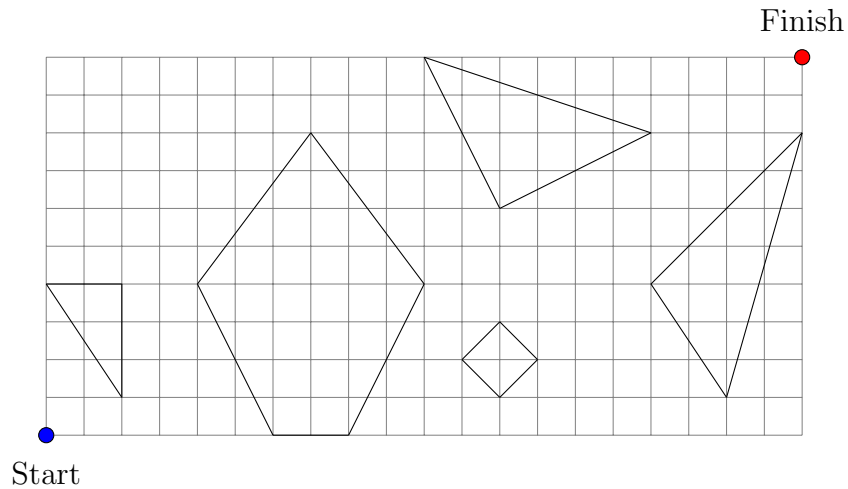
Finish

Start

B. [3 pts] Asymmetric

Given the above asymmetric robot, inflate the obstacles in the following world. You can find this process described in Lecture 12. If there exists a path for the robot from Start to Finish, please show it.
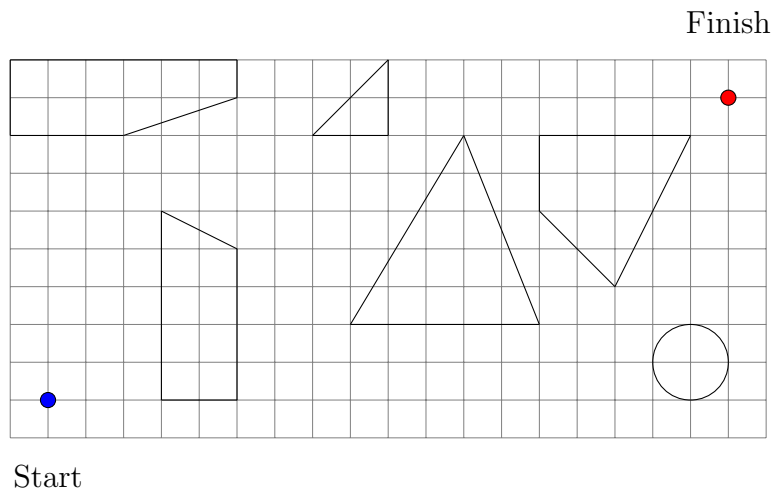
Finish



Start

2 Path Planning [24 pts] [Ben]

A. [5 pts] Visibility Graphs

Given the following world, construct a visibility graph using the sweep algorithm as shown in Lecture 12. Please highlight or color the shortest path for the robot from Start to Finish.
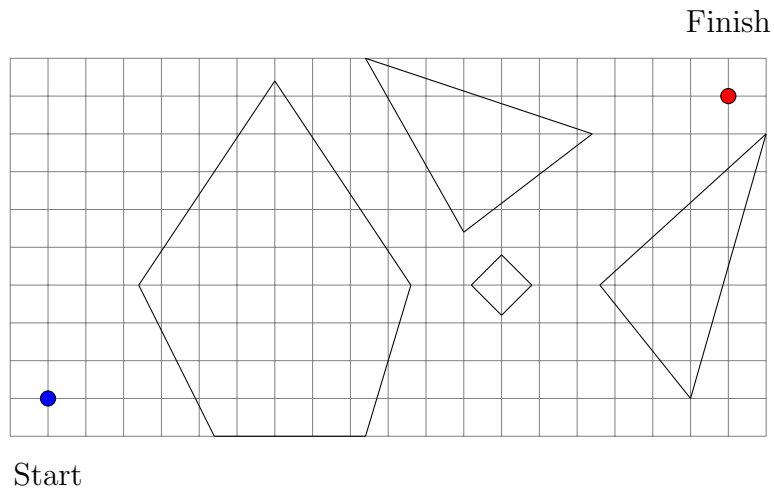

B. [5 pts] Voronoi Diagrams

Given the following world, construct a Voronoi diagram as shown in Lecture 12. Please highlight or color the shortest path from Start to Finish using only the edges of the Voronoi diagram.
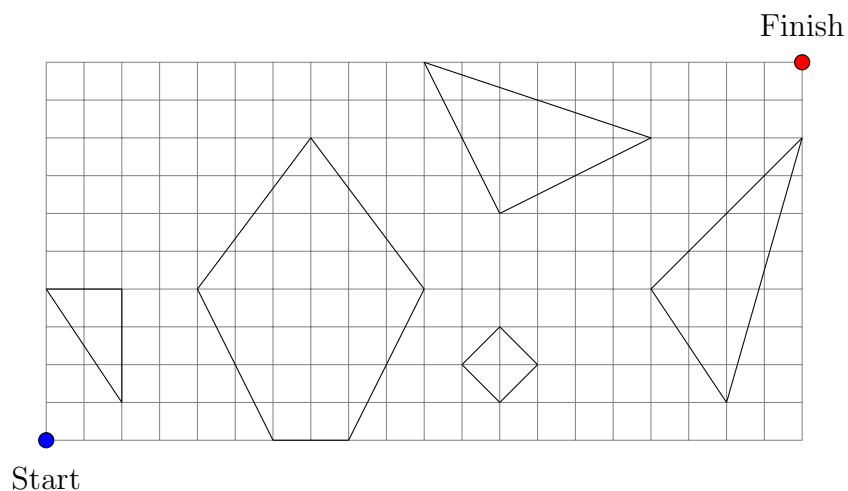
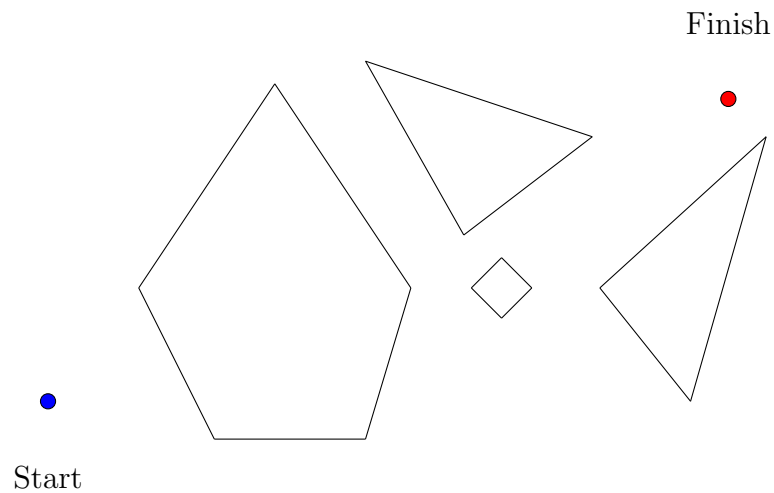C. [2 pts] Are the resulting paths in parts A and B the same or different? Why?

D. [5 pts] Approximate Cell Decomposition

Given the following world, construct an approximate cell decomposition as shown in Lecture 12. You may use the existing lines as an initial grid, before subdivision. Please highlight or color the shortest path from Start to Finish.

Finish

Start

E. [5 pts] Exact Cell Decomposition

Given the following world, construct an exact cell decomposition as shown in Lecture 12. Please highlight or color the cells along the shortest (in terms of cells) path from Start to Finish.

Finish

Start

F. [2 pts] Are the resulting paths in parts D and E the same or different? Why?

3 Surface radiance to image irradiance[25 pts] [Wooyoung]

The image irradiance refers to the power of the light, per unit area and at each point **p** of the image plane. The scene radiance is the power of the light, per unit area, ideally emitted by each point **P** of a surface in 3-D space. Given a thin lens of diameter d and focal length f, an object at distance Z from the lens, and an image plane at distance $Z\prime$ from the lens, with f,Z and $Z\prime$, we derive the relation between the image irradiance(E) and the scene radiance(L). Refer to Figure1 for notations.

Solid Angle

For the derivation we first need to recall the geometric notion of solid angle(Figure2(a)). The solid angle of a cone of directions is the area cut out by the cone on the unit sphere centered in the cone's vertex. It is a measure of how large an object appears to an observer looking from that point. A small object nearby may subtend the same solid angle as a larger object faraway. The solid angle $\delta\omega$ subtended by a small, planar patch of area δA at distance r from the origin is proportional to

$$\delta\omega \propto \frac{\delta A}{r^2}$$

Also the solid angle is proportional to the cosine of the angle between ψ the normal to δA and the ray that points from the origin to δA due to the foreshortening of the δA as seen from the origin. Therefore, the solid angle subtended by δA at distance r is defined as

$$\delta\omega = \frac{\delta A \cos\psi}{r^2} \tag{1}$$

Image Irradiance

The image irradiance at an image point p, as the ration between δP, the power of light over a small image patch, and δI, the area of the small image patch(Figure2(c)):

$$E = \frac{\delta P}{\delta I} \tag{2}$$

Power of Light δP

If δO is the area of a small surface patch around **P**, L the scene radiance at **P** in the direction toward the lens, $\Delta\Omega$ the solid angle subtended by the lens, and θ the angle between the normal to the viewed surface at **P** and the principal ray, the power δP is given by $\delta OL\Delta\Omega$(the total power emitted in the direction of the lens) multiplied by $\cos\theta$(the foreshortening of the area δO as seen from the lens):

$$\delta P = \delta OL\Delta\cos\theta \tag{3}$$

1. [1 Points] Combine Eq.(2) and Eq.(3) and express E in terms of L.

2. [8 Points] Let's evaluate $\Delta\Omega$, the solid angle subtended by the lens from $\mathbf{P}$.

    (a) Express the area δA of the lens in terms of its diameter d.

    (b) Express the angle ψ between the principal ray emitted from $\mathbf{P}$ and the optical axis of the lens in terms of α.

    (c) Express the distance of $\mathbf{P}$ from the lens center in terms of Z and α.

    (d) Using δA,ψ,$\mathbf{P}$ and Eq.(1), derive $\Delta\Omega$.

3. [4 Points] Derive the solid angle $\delta\Omega_I$, subtended by a small image patch of area δI.

4. [4 Points] Derive the solid angle $\delta\Omega_O$ subtended by the patch δO on the object side.

5. [4 Points] From the relation between $\delta\Omega_I$ and $\delta\Omega_O$, express $\dfrac{\delta O}{\delta I}$ in terms of α, θ, Z and f.

6. [4 Points] Plug $\Delta\Omega$ and $\dfrac{\delta O}{\delta I}$ into your answer to the 1.1 to finally obtain the desired relation between E and L.

4 Bundler[50 pts] [Wooyoung]

In this problem, we are going to reconstruct 3D structures of buildings on campus.

4.1 Building selection[10 pts] [Wooyoung]

Please refer to 15381Bunder.pdf posted on the Blackboard under Assignments for your building assignment. Where there is more than one student assigned to a building, I put information on which side of the building you are responsible for. Please refer to http://www.cmu.edu/homeimages/campus-map/CMU_MapColor_11x17.pdf for the location of your building.

4.2 Taking pictures[20 pts] [Wooyoung]

Take pictures of the building you are assigned with. For best reconstruction results, try to move your camera by little between consecutive pictures. To fully reconstruct a building,

we recommend taking approximately 100 pictures around your building. The recommended picture size is 2048×1536. Sample pictures are shown in Figure2. Upload your pictures on the Digital Dropbox. Note that your files will be publicized after the assignment. If you have any objection or concern, please contact the instructors. If you need to borrow a camera, please email Yaser.

4.3   Bundler[10 pts] [Wooyoung]

You can download Bundler from `http://phototour.cs.washington.edu/bundler/`. Download bundler-v0.3-binary.zip and follow the instruction below for installation for Windows machines.

1. Cygwin is a Linux-like environment for Windows install cygwin with perl and bash, http://cygwin.com/. It's better to intall all the packages if you are not familiar with to avoid some following errors.

2. Modify BASE_PATH in RunBundler.sh, it should be the path where you storage the 'Bundler'.

3. Download the SIFT demo probgram from `http://www.cs.ubc.ca/~lowe/keypoints/` and copy the siftWin32.exe to /yourpath/Bundler/bin.

4. Make sure that you camera model is in the /bin/extract_focal.pl, if not, then download from Internet and add it in the file.

5. Copy the images in the Bundler/, you can modify the dir in the RunBundler.sh as well.

6. cd /cygwindrive/yourpath/Bundler; sh runbundler.sh

For further instructions on installing and running Bundler, please refer to `http://phototour.cs.washington.edu/bundler/bundler-v0.4-manual.html`. Run Bundler on your images and submit your final .ply file. You can share the pictures with students who take pictures of the same building with you. Name your file as yourAndrewID.ply.

4.4   MeshLab[10 pts] [Wooyoung]

You can visualize your reconstruction result with MeshLab(`http://meshlab.sourceforge.net/`). Download MeshLabDevel_v130BETA_64bit_2010_10_11.exe and execute it. Open your final ply file you got above. Submit a screen shot of your result. Name your screen shot image as yourAndrewID.jpg. Figure3 shows an example.
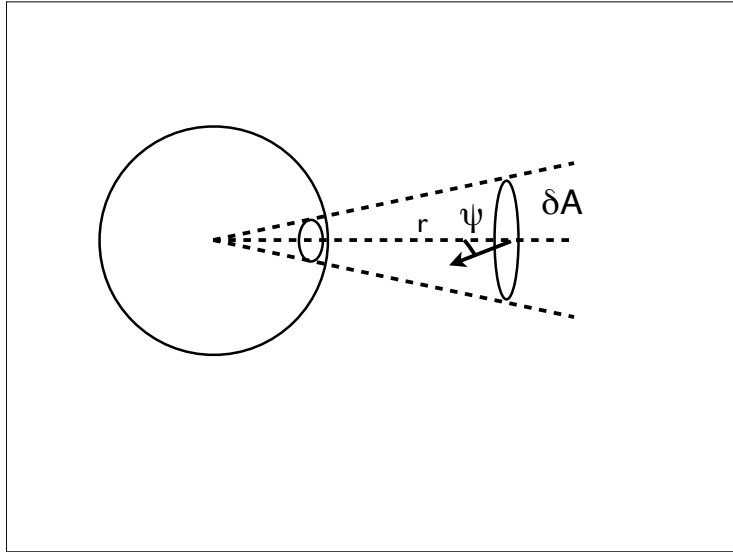
(a)
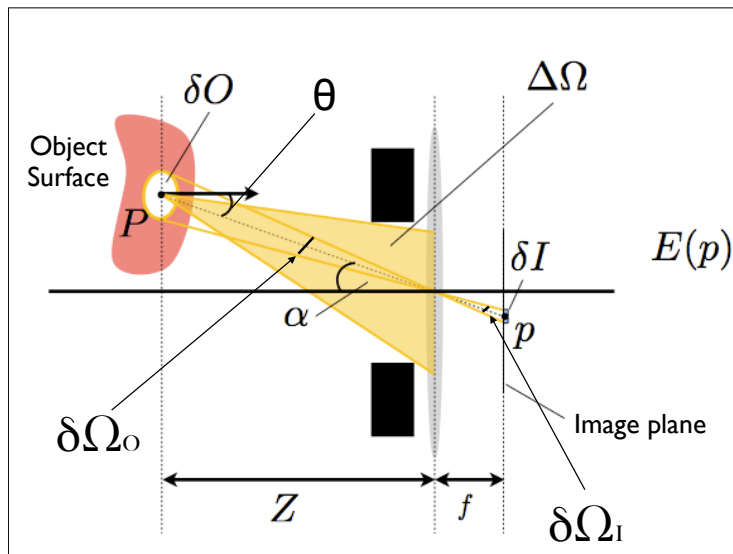
(b)

Figure 1: (a) The definition of solid angle , (b) Radiometry of the image formation process
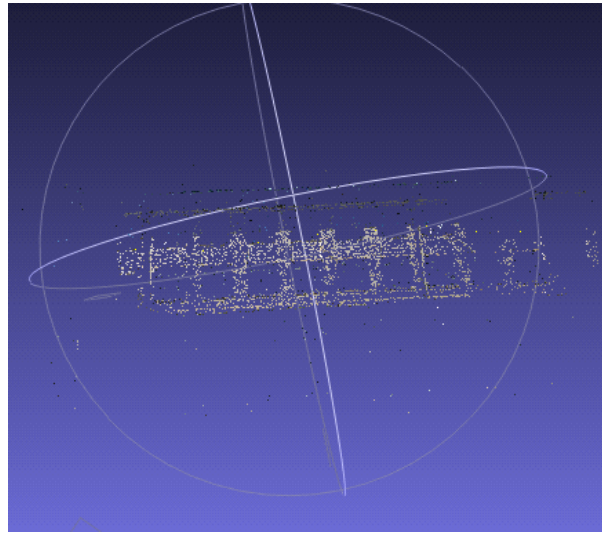
(a)

(b)

(c)

Figure 2: Sample pictures of a building on campus

Figure 3: Sample images taken consecutively