Assignment #2 (30 marks)

Written part due: March 8th, Wednesday, in class.
Programming part due: March 8th, Wednesday at 11:59 pm.

Problem 1 (22 marks + possible 3 bonus): Playing Tetris with a robotic arm

You will upgrade the Tetris-FallingFruits game in assignment 1 into 3D, and control a robot arm to play this game. Check out the sample code for a robot arm in:

http://www.cs.unm.edu/~angel/BOOK/INTERACTIVE_COMPUTER_GRAPHICS/SIXTH_EDITION/CODE/CHAPTER08/
and look into example1.cpp and associated shaders.

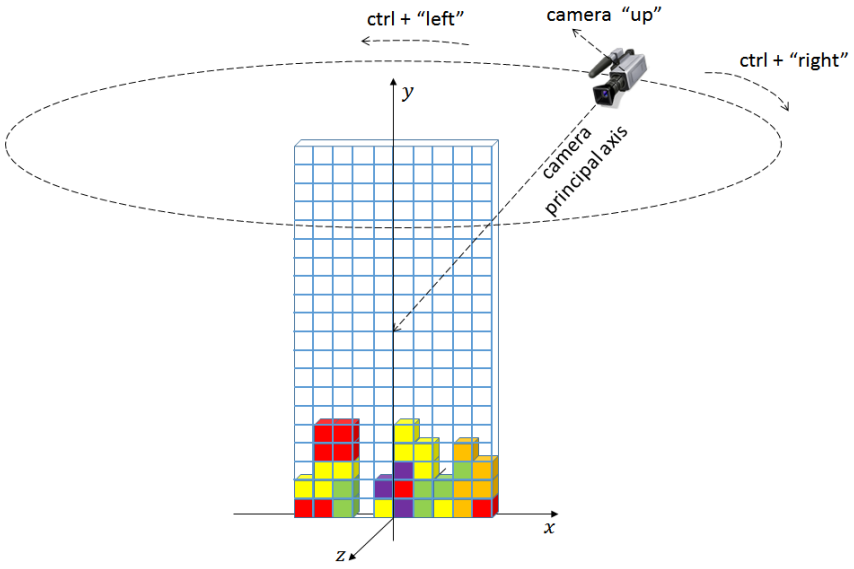
(a) [4 marks] Upgrading Assignment 1 to 3D

Upgrade your Tetris-FallingFruits game to 3D by turning each fruit from a 2D square to a 3D cuboid. The centers of all fruit cells are constrained in a 2D plane, e.g. $z = 0$. Draw the entire 3D grid--1 by 10 by 20--using faint lines. You can keep the same game logic at this stage.

In case you feel uncomfortable with your implementation of Assignment 1, you can begin with the sample code (solution) provided for Assignment 1. (This sample code is not yet available and may take a few days to be ready.)

(b) [4 marks] Viewpoint Changes

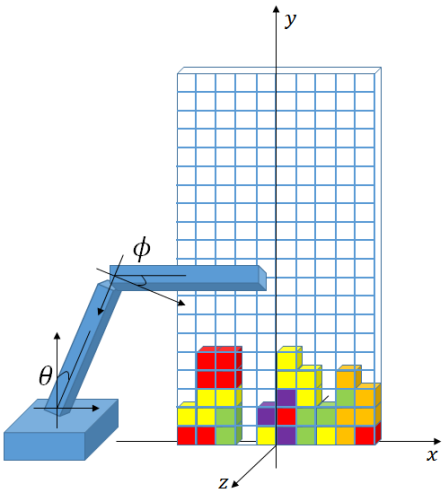
The "ctrl" key will be combined with the "left" and "right" key to control the camera's movement on a circular orbit that is parallel to the x-z plane with a center on the y axis. The camera always looks at the center of the Tetris window. Its "up" direction lies in the plane spanned by the y axis and the camera's principal axis – the line connecting the camera center and the "Lookat" point.



(c) [4 marks] Control of the Robot Arm

Put the robot arm in the 3D space of Tetris tiles. The central axes of both lower and upper arms will be limited in the same plane as fruit cuboids. In this way, the lower arm is controlled by a rotation angle θ, and the upper arm is controlled by an angle ϕ. Use the "a"

(or "d") key to increase (or decrease) the angle θ, and the "w" (or "s") key to increase (or decrease) the angle ϕ. Set the arm length and base height appropriately, such that it can reach **every** location of the Tetris window.



(d) [4 marks] Game Logic

New Tetris tiles only appear at the tip of the robot arm. Rotate the robot arm to put it at desired locations. At this stage, it is OK to ignore the collision between the new tile and existing ones. Use the "space" key to drop a Tetris tile from the robot arm. The tile's position should align with the grid, i.e. snapped to the nearest grid position. Once a tile is dropped, it can either float at the location it is dropped, or keep dropping downward until it hits some other tiles (like in Assignment 1).

In this assignment, you don't have to shuffle the fruits, since the "space" key is used for dropping. If you want to keep this feature, you might use ctrl + "space" for shuffling. The "up" key is still reserved to rotate a tile. The "left" and "right" keys are disabled. Press 'q' to quit and 'r' to restart. Eliminating full rows and three fruits with the same color is optional and will not be judged since it is evaluated in Assignment 1.

(e) [4 marks] Collision Detection

The new Tetris tile can only be dropped at places without collision with existing tiles. When the tile is attached to the robot arm, we allow collision, but will highlight collision cases by turning the tile to grey color (so that the player knows it cannot be dropped).

Also, if any cell of the tile (when its location is rounded to the nearest cube of the unit grid) is outside the playing area, turn the tile grey.

(f) [2 marks] Timer

The placement of each tile is limited to a certain amount of seconds. Display the remaining seconds (as a text message) for the current tile on the top of the window.

When the time is out, the tile on the arm will be automatically dropped at the current location. If the tile is greyed when the timer expires, then the game is ended. (But not your application…when a game ends it should be possible to play another game.}

(g) [3 marks] Bonus Points

Extend the playing area to *n* by 10 by 20, where *n* is a number specified by the user at the beginning of the game. Also add a parameter to the robot arm model that allows rotation of the entire arm around the vertical center axis of the base, and user controls for that parameter. Inform the user what these controls are at the start of the game.

As the robot arm rotates, by default the tile should be translated but not rotated—it stays oriented the way it started. The user can use the 'rotate' key to rotate the tile 90 degrees around a vertical line through its centerpoint.

Add the tiles consisting of four cubes that vary in x, y, and z. There are three of these, and two are mirror-reflections of each other. All of them fit in a 2 by 2 by 2 grid. The back slice is an "L" shape with three cubes, and the front slice is one cube in front of one of the back-slice cubes. Which back-slice cube the front-slice cube it is in front of determines the type of the shape.

Note that the above steps build on top of each other, in order. You need not submit individual programs to correspond to these steps. If you can implement all the required parts, a single, complete program is sufficient. ***Skeleton code*** for Tetris and Robot Arm are provided.

Submission: All source codes, a ***Makefile*** to make the executable called ***FruitTetris3D*** (the make command should be make), and a ***README*** file that documents any steps not completed, additional features, and any extra instructions for your TA.

Problem 2 (3 marks): Back face culling.

Suppose we have a scene with a single, fully opaque, convex object, which is entirely inside the view volume. The convex object is specified by a mesh.

Under orthogonal projection, will back face culling alone be guaranteed to produce the correct set of visible polygons? Why or why not?

Under perspective projection, is it true that back face culling alone is guaranteed to produce the correct set of visible polygons? Why or why not?

Problem 3 (5 marks): BSP vs. depth-sort.

Show that the back-to-front display order determined by traversing a BSP tree is not necessarily the same as the back-to-front order determined by depth-sort, even when no polygons are split. To receive full mark on this problem, the number of polygons you use for your example must be the smallest possible and you also need to prove that the number of polygons you used is the smallest possible. **Hint: mostly you need an example. The rest is easy.**