This is currently a collection of notes and work in progress.

# Architecture

In reality, the core architecture is just the simple “Model-View-Controller” pattern, or for this application, more logically phrased as a “Controller-Model-View” pattern. Specifically:

## Controller

This lion-share of the application complexity in both code and CPU consumption is in this domain. Specifically, each incoming Camera Image Frame is fully analyzed in an attempt to recognize a Rubik Face. Then, additional processing is performed in class StateMachine to determine if the Model (or State) should be changed, and, when all six sides of the Rubik Cube have been recorded, the TwoPhase Rubik Cube Logic solution is called.

## Model (or State)

Rubik Cube state is captured in the simple class StateModel.java. Besides the cube six faces, a small amount of additional data (state) is held in this class. Otherwise, this represents pretty much the full state of the system.

## View

There are actually four separate “Views,” they are:

### Diagnostic Annotations

A wide range of diagnostic information is available through the Menu->Annotation user interface. This is rendered using OpenCV on the frame image itself. Information broader that what is in state is offered.

### Pilot Cube

At the time of this writing, the Pilot Cube is immature, but its long term purpose is to represent the state of the cube both in tiles and faces, and eventually to show requested Cube Rotations. This is rendered using OpenGL.

### Requested Text Directions

Text instructions to user to rotate entire cube or rotate an edge can be optionally displayed as a text message. This is rendered using OpenCV on the frame image itself.

### Requested Arrow Directions

Graphic instructions in the form of 3D arrows are rendered in a fashion overlaying the cube itself with proper position, orientation and size.

# Notes

* Prefix Rubik on all allows for easy identification and use of common names like Util and Controller.
* Significant use of public key word on member variables.
* Public vs Private: Member data is often made public in this implementation. Compliance with the convention of keeping member data private as much as possible results in too much code being in a very few files: particularly cube state and face state information. The convention of getters and setters is possible, but really accomplished nothing in terms of member data containment. I believe this issue is practically an outcome of the use of the MVC design pattern.
* Inter UI vs Frame thread contention handled by use of simple Boolean variables: i.e., atomic by nature.

# Event Model

## Thread Model

Main Thread: - That which constructs the app?

UI Thread: - Menu events are handled here

OpenCV Frame Thread: - Camera Frame image is provided and processed.

OpenGL Thread: - Separate thread on which OpenGL renderers are executed.

## Tracking and Feedback

For simplicity, no frame to frame information path exists. That is, each frame is processed without any information from the previous frame.

# Architecture

## Image Processing

## Face Recognition

## Cube Model (i.e., State)

## Gesture Recognition

# Image Analysis Design

The main part of this application is image recognition

The top-level design description is according to the Sonka, Hlavac and Boyle text.

## Boarders

More specifically, in this application, “contours” are obtained and used.

## Curves

## Segments

## Syntactic Description

## Syntactic Recognition

## High Level Image Representation

## Image Understanding

# Class Diagram of Persistent Objects

**+**

Activity

Menu and Params

Image Recognizer

App State Machine

State Model

Face

Instructions View

Overlay View

Pilot Cube View

# Class Diagram of Per-Frame Objects

**+**

**+**

**+**

Rubik Face

Rhombus

Polygon

Contour

Constant Tile Color

Least Means Square

Profiler

Frame

Measured Tile Color

# Parameters

The image recognition process uses many “offline parameters” that can be adjusted to improve the process. Manual adjustment is, of course, undesired. However, achieving automatic (i.e., “online”) determination of these parameters shall be part of the maturing of this application.

All determined, more or less, empirically.

These parameters can be adjusted using the menu option “parameters.” All parameters are modeled as double precision floating point, and the purpose they serve in the application is as follows:

## Gaussian Blur Kernel Size

The square kernel size of the Gaussian Filter. The default is set to 3. The filter sigma will be computed from the kernel size using the formula: sigma = 0.3\*((ksize-1)\*0.5 - 1) + 0.8.

## Canny Edge Upper Threshold

Gradient threshold at which an edge is declared to exist.

## Canny Edge Lower Threshold

Gradient threshold at which an edge (once detected) is declared to no longer exist.

## Dilation Kernel Size

## Minimum Contour Area Size

Minimum contour area size to be considered a tile candidate.

## Polygon Epsilon Threshold

## Minimum Parallelogram Area Size

Minimum parallelogram area size to be considered a tile candidate.

## Maximum Parallelogram Area Size

Maximum parallelogram area size to be considered a tile candidate.

## Parallelogram Angle Outlier Threshold

The angles (in degrees, there are two angles) that the parallelogram sides make with respect to the absolute coordinate system is calculated. The mean of these angles among the entire candidate set is calculated. They should roughly have all the same value. If any parallelogram exhibits a sufficiently different shape (i.e., angle of sizes) it is rejected.

## Face Least Means Square Sigma Threshold

Threshold for residual Least Means Square error of fitting Parallelogram centers into a 3x3 grid as defined by their candidate grid location and their actual measured centers. If the residual is less than this value, the candidate tile grid locations are considered valid.

## Manual Luminous Offset

# Stable Face Recognizer State Diagram

Other State Member Data:

Last :== Last Valid Face Object

Count :== Integer for counting

On Face Event

[ Face == null ]

Count = 0

[ Face != null ]

Last = Face

Count ++

[ Face == Last && Count < 4 ]

Count ++

[ Face == Last && Count >= 4 ]

[ Face == Last ]

[ Face != Last ]

[ Face != Last]

Count = 0

[ Face == Last ]

[ Face != Last && Count < 4 ]

Count ++

[ Face != Last && Count >= 4 ]

On Stable Face Event

Off Stable Face Event

# Application State Machine State Diagram

Other State Member Data:

Status :== True if all six sides of Rubik Cube have been observed

Count :== Integer for counting

On Face Event

Off Stable Face Event

On Stable Face Event

Count= 0

[ Count >= 4 ]

[ Count < 4 ]

Count++

[ Status == False ]

Count = 0

[ Status == True && colors OK ]

[ Status == True && colors ! OK ]

## App State Definitions

START: Ready

GOT\_IT: A Cube Face has been recognized and captured.

ROTATE: Request user to rotate Cube.

SEARCHING: Attempting to lock onto new Cube Face.

COMPLETE: All six faces have been captured, and we seem to have valid color.

BAD\_COLORS: All six faces have been captured, but we do not have properly nine tiles of each color.

VERIFIED: Two Phase solution has verified that the cube tile/colors/positions are a valid cube.

WAITING: Waiting for TwoPhase Prune Tree generation to complete.

INCORRECT: Two Phase solution has analyzed the cube and found it to be invalid.

SOLVED: Two Phase solution has analyzed the cube and found a solution.

DO\_MOVE: Inform user to perform a face rotation

WAITING\_FOR\_MOVE\_COMPLETE: Wait for face rotation to complete

DONE Cube should be completely physically solved.