Accelerometer Pen

CRITICAL DESIGN

MEET THE TEAM

Kyle Buchanan

Theodore Pham

James Chang

Motivation

- Technically challenging
- Good way to create backup notes
- Could be utilized by groups such as SSDS
- Lots of room to expand or narrow scope

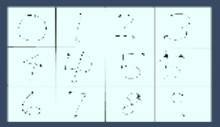
Functionality

- Recognition of shapes, symbols, and numbers on a flat surface
- Wireless communication of written character from pen to board
- Incorporates an accelerometer to measure the acceleration of the pen - Built in non-fillable pen cartridge for visibility of written work
- Displays user written input on a LCD screen
- Uses flash memory to store the character templates
- User click to activate writing sensor
- Power button to turn the pen on/off

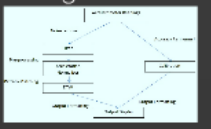
Pattern Recognition

- Selected Algorithm is Dynamic Time Warping
  - Finds optimal matches between time series
  - Used in other pattern matching applications
  - Uses dynamic programming to find ideal paths

Pattern Recognition



Design: Software



Design Calculations

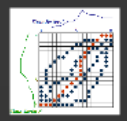
- Data Filtering: 44 FLOPS
- DTW algorithm:
  - time cost: O(n^2)
  - space cost: O(n)
- Battery Runtime on 8 h wake/ 4 h sleep cycles
  - Coin Cell Battery: ~3.00 h
  - Rechargeable AA:~29.40 h
- I/O rates: 36 bits/interval
- Xbee modules: 625 bits per 2.5 ms
- Flash memory required per character: ~3.5 kB
- Onboard Flash: 4 MB ~= 1165 patterns

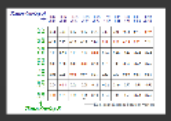
Challenges Thus Far

- The Bluetooth module could not act as a Master to poll data from the accelerometer without a microcontroller so we decided to use wireless Xbee module instead.
- Trying to fit all components into a reasonable sized pen body.
- Accurately prediction of accelerometer output data

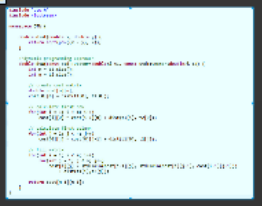
Design: graphical hierarchy of source code

Design: Software





Awesome Code



Optional Features

- Extra button to change pen functionality to perform basic arithmetic
- Option to allow pen to be user dependent (calibrates pen according to users initial written input pattern)
- Ability to recognize alphabets (in future - handwriting)
- Design a GUI for character display on the computer
- Sensor activated without use of a button trigger or pressure sensor
- Incorporate Bluetooth and integrate this new design so that users can connect the pen to their smartphones and generate outputs to an app

Components

- Implementation on DE2 Board:
  - Xbee transceiver module
  - USB connection to computer
- Implementation on Pen Unit:
  - Xbee transceiver module
  - Accelerometer
  - Power Source
  - Switches (Trigger, Power)

Results of Unit and Integration Testing

DTW algorithm test
- Test input with 4095 data points
- runs in 0.172s using an i7@3.4GHz

Application Notes

Although we do not have application notes of our own yet, we are using an Xbee module from a past project on 2012.

Design: Hardware

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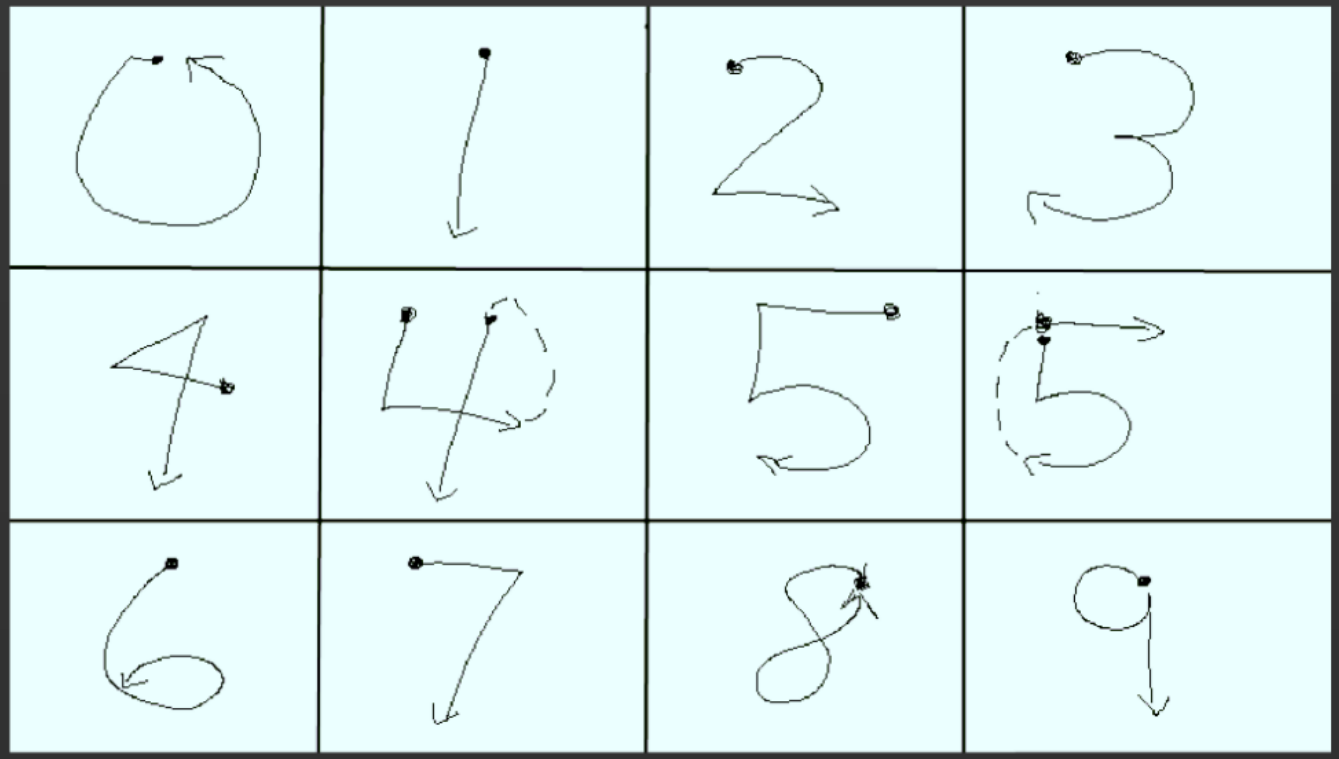

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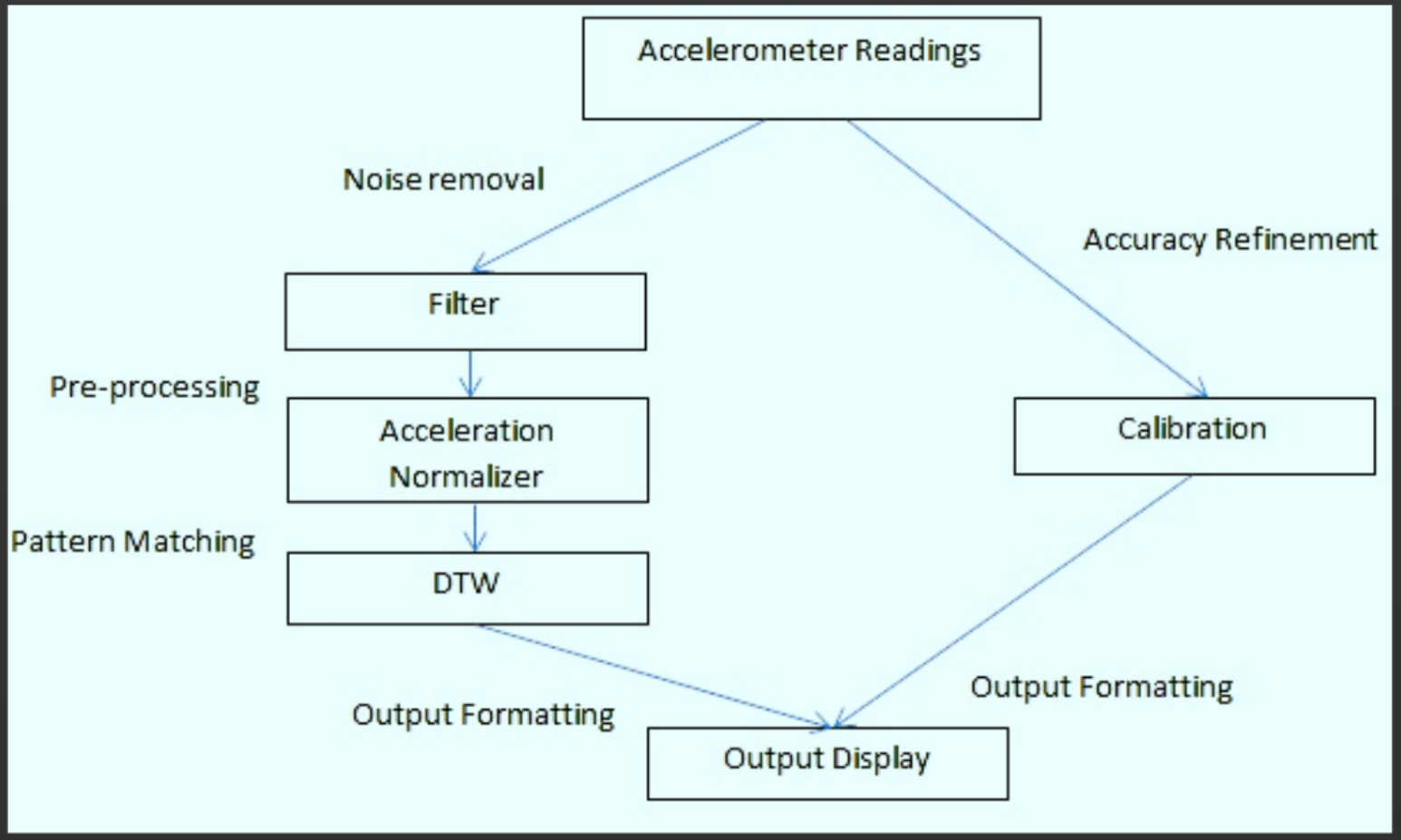

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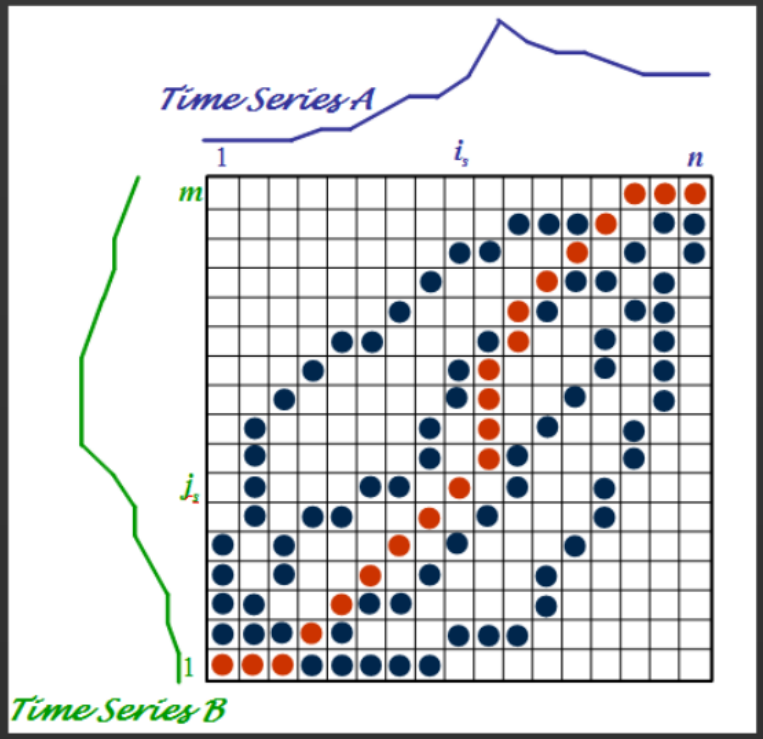


Time Series A

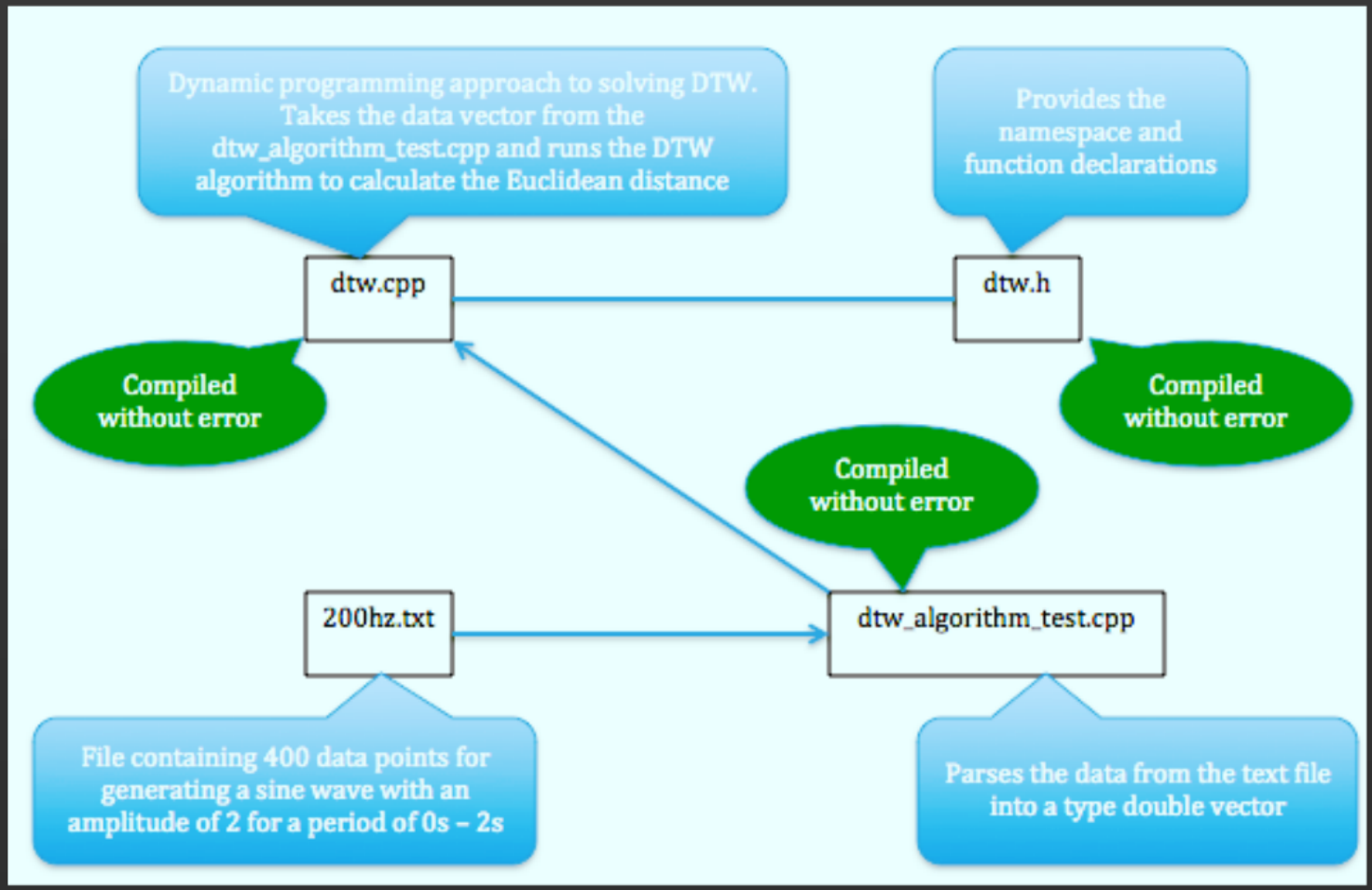
-0.87	-0.84	-0.85	-0.82	-0.23	1.95	1.36	0.60	0.0	-0.29
-0.88	-0.91	-0.84	-0.82	-0.24	1.92	1.41	0.51	0.03	-0.18

1.94 1.97	0.51	0.51	0.49	0.49	0.35	0.17	0.21	0.33	0.41	0.49
0.77 0.74	0.27	0.27	0.26	0.25	0.16	0.18	0.23	0.25	0.31	0.68
-0.17 -0.32	0.13	0.13	0.13	0.12	0.08	0.26	0.40	0.47	0.49	0.49
-0.58 -0.63	0.08	0.08	0.08	0.08	0.10	0.31	0.47	0.57	0.62	0.65
-0.71 -0.68	0.06	0.06	0.06	0.07	0.11	0.32	0.50	0.60	0.65	0.68
-0.65 -0.62	0.04	0.04	0.06	0.08	0.11	0.32	0.49	0.59	0.64	0.66
-0.60 -0.46	0.02	0.05	0.08	0.11	0.13	0.34	0.49	0.58	0.63	0.66

Euclidean distance between vectors

Time Series B

Design: graphical hierarchy of source code



Awesome Code

```cpp
#include "dtw.h"
#include <iostream>

namespace DTW {

    double dist(double x, double y) {
        return sqrt(pow((x - y), 2));
    }

    //dynamic programming approach
    double dtw(const std::vector<double>& t1, const std::vector<double>& t2) {
        int m = t1.size();
        int n = t2.size();

        // create cost matrix
        double cost[m][n];
        cost[0][0] = dist(t1[0], t2[0]);

        // calculate first row
        for(int i = 1; i < m; i++)
            cost[i][0] = cost[i-1][0] + dist(t1[i], t2[0]);

        // calculate first column
        for(int j = 1; j < n; j++)
            cost[0][j] = cost[0][j-1] + dist(t1[0], t2[j]);

        // fill matrix
        for(int i = 1; i < m; i++)
            for(int j = 1; j < n; j++)
                cost[i][j] = std::min(cost[i-1][j], std::min(cost[i][j-1], cost[i-1][j-1]))
                    + dist(t1[i],t2[j]);

        return cost[m-1][n-1];
    }
}
```

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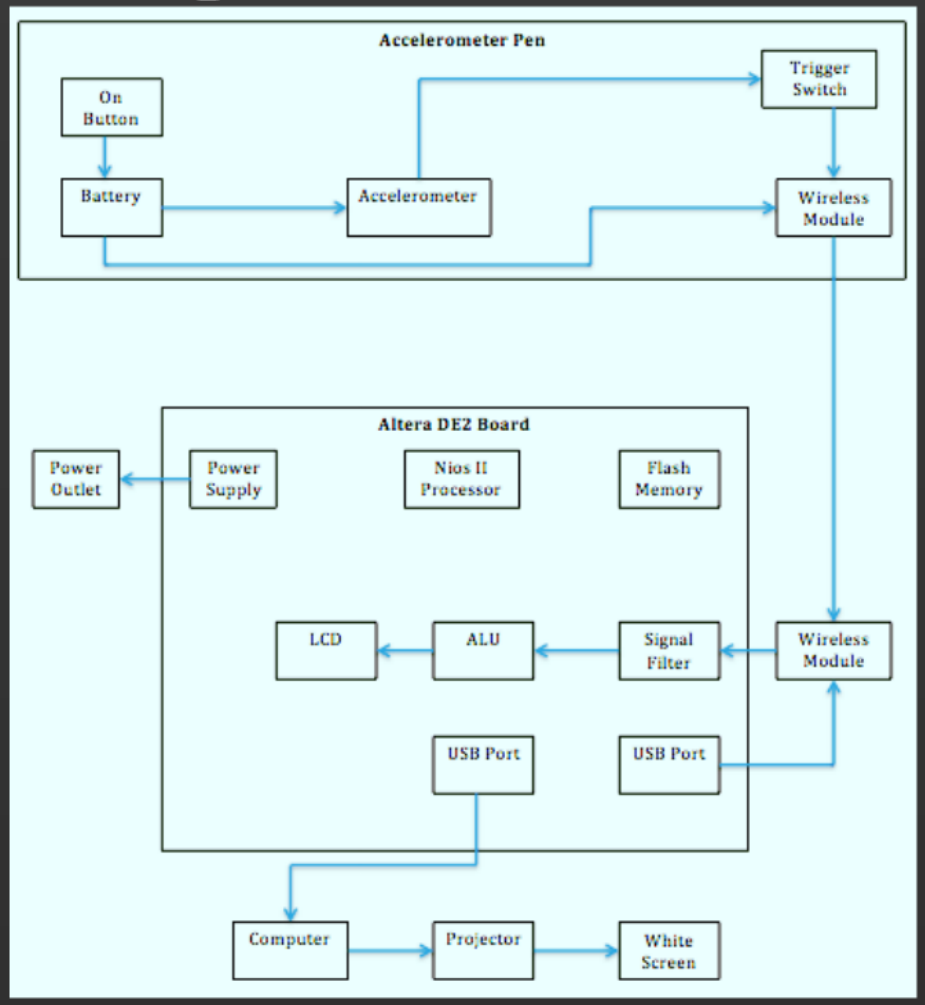

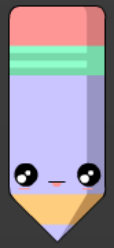

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DTW algorithm test

- Test input with 400 data points
- runs in 0.171s using an i7@3.4GHz

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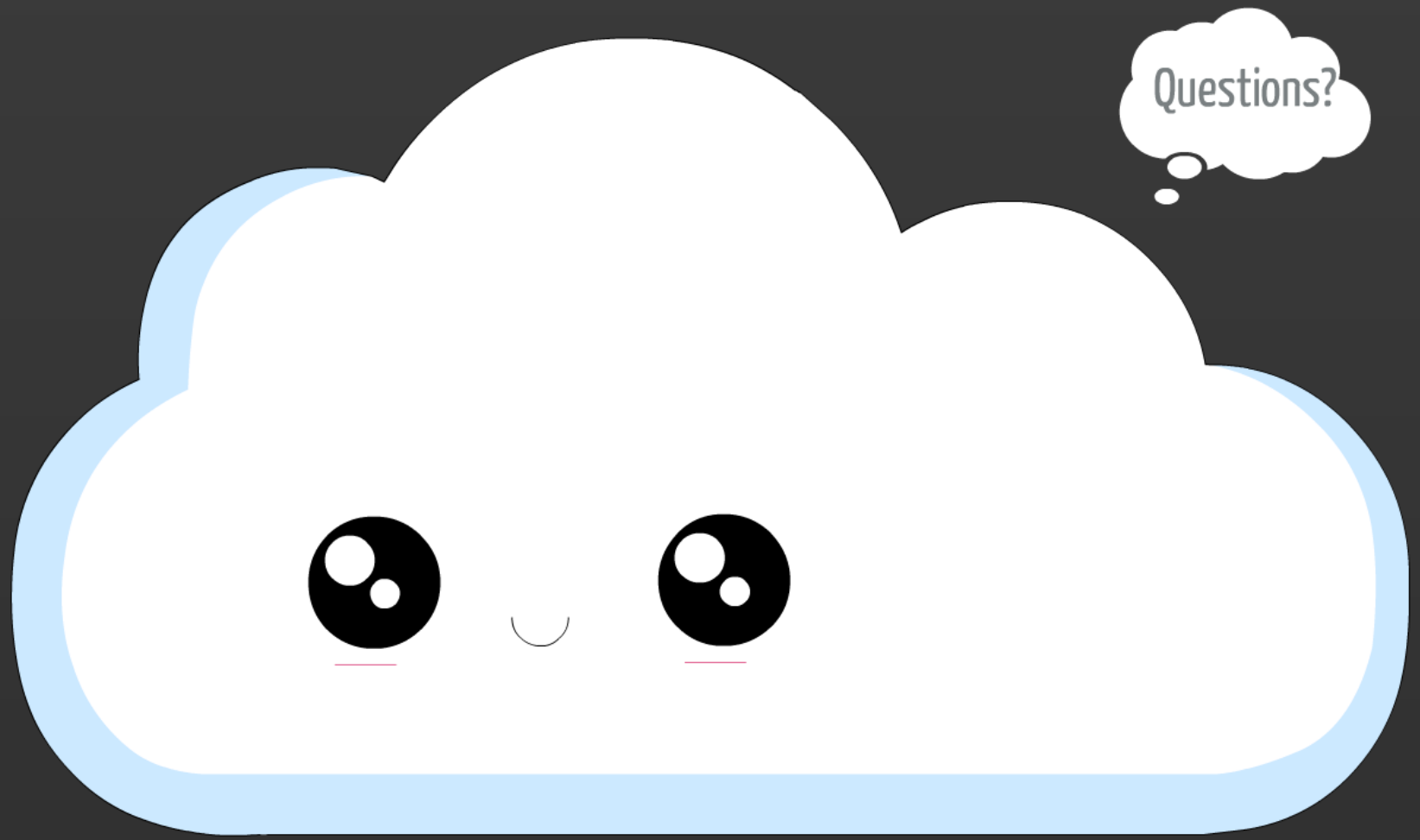

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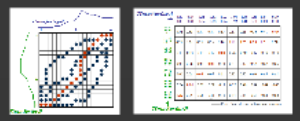

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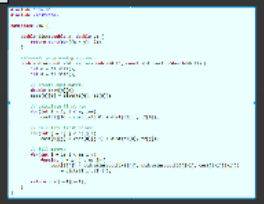

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