

DIPOLE LATTICE

ATUL SINGH ARORA



Upscaling a nano-structure

Dr. Ravi Mehrotra
National Physical Laboratory, New Delhi

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Atul Singh Arora: *Dipole Lattice*, Upscaling a nano-structure,

Every honest researcher I know admits he's just a professional amateur. He's doing whatever he's doing for the first time. That makes him an amateur. He has sense enough to know that he's going to have a lot of trouble, so that makes him a professional.

— Charles F. Kettering (1876-1958) (Holder of 186 patents)

ACKNOWLEDGEMENTS

I thank Dr. Ravi Mehrotra for well conceiving the experiment and guiding me through the process of its realization.

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¹ This section can be skipped, without any loss of continuity.

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ACRONYMS

PROLOGUE

Atoms and molecules are far too small to be observable as individual entities, with our eyes alone. Scientists have come a long way at understanding *their* world. It has been attempted to recreate a specific micro-structure, at a scale where we can directly observe it.

The configuration we've studied here, is that of a Magnetic Dipole Lattice, viz. Magnetic Dipoles that can only rotate about their axis, placed on a grid. Their physics by itself is rather interesting and can be simulated to observe the dynamics. The experiment is expected to show the same dynamics, that of the microscopic world, only directly observable.

1.1 PRIOR ART

TODO: Complete this part after understanding the physics and simulations on the system.

1.2 EXPERIMENTAL SETUP

The upscale version consists of Physical Magnetic Dipoles, that rest on near zero friction spots on a grid. A camera sits on top, with all the dipoles in its field of view. The Lattice Analyser takes the input from the camera and simulates the given temperature through a hardware unit and the coils attached to each dipole. It is that simple.

For implementation details, you may read the following sections.

1.2.1 *The Dipole*

According to the current design (as of May 19, 2013), the Magnetic Dipole is built off of two small cylindrical rare earth magnets, attached to a needle, with their flat face's surface normal perpendicular to the axis of the needle. The needle rests in an assembly with a glass slide at the bottom. This keeps it upright and nearly free of friction. Each dipole further has a circular disc on top, with its centre passing through that of the dipole. The disc has a pattern printed, designed to find its angular position using a camera. Further, the dipole assembly also has two coils along an axis perpendicular to the needle.

1.2.2 *Lattice Analyser*

This is the application that

1. records the dynamics of the system
2. calculates the required field strength of each electromagnet

using a webcam and computer vision techniques. The results of the latter part depend on the temperature that is to be simulated; temperature is not maintained by providing heat, but instead by providing a certain distribution of speeds to the dipoles.

1.2.3 *Temperature*

This is the hardware unit, (will be built around an ATmega 16) that provides the coils with the current as calculated by the Lattice Analyser (using a USB interface).

2

WATCH IT GROW

2.1 SENTIMENTAL INTRODUCTION¹

Science often seems like a blackbox that relates observables. Even more often, it is rather convenient to lose touch of observables altogether, and wander in the blackbox. Performing an experiment, gets one closer to nature, to the roots of the subject.

2.2 THE JOURNEY

2.2.1 *Look it has begun*

This experiment wasn't started from scratch. My guide, Dr. Ravi Mehrotra, had already worked with a team and created the Dipoles as described earlier. The team had also worked on the image detection algorithms, but their work wasn't usable.

There were three tasks at hand, of which one had been significantly simplified by the prior work.

1. The Dipole

This had one apparent problem; the dipoles had to be made virtually frictionless (which is not to say they had excessive friction, infact they would oscillate atleast about 8 times before stopping aligned with earth's magnetic field)

2. The Image Analysis

This part I had to start from the beginning with two basic objectives, as stated earlier; measuring the angle of the dipoles and evaluating the current to be pumped based on the temperature selected.

What was known soon, was that C++ will be used for programming and linux would be the operating system, to facilitate USB interface with the AVR (next step)

3. The Current Control Hardware

This is simply for providing a current pulse proportional to the intensity calculated by the lattice analyser. Some schematics for this were available, but were found to be inaccurate and incomplete.

¹ this section can be skipped, without any loss of continuity.

2.2.2 Time Line

Listed below is the event log, which has the progress as and when it was made.

Time Line

```
SUMMER '13 TIMELINE
--
** July 26, Friday: Not well again. Tried to work on the documentation

* July 25, Thursday: Working on setting up latex on linux along with dOxygen for documentation. The latex bit failed. There were various problems even after painfully installing TeXlive to work with ST3, while compiling the classic thesis template.

* July 24, Wednesday: [Project Milestone] Completed testing with a 2x2 lattice, with energy pumping and it worked just fine! Obviously it required a lot of debugging, for electronics never works at once. Plus there were other software issues.

* July 23, Tuesday: [important day] Finalized the HSV colour filter. Further added calculation of temperature using a timed average. Added support for making the pin configurations readable from file. Then temperature ran into issues and was fixed (int char problem) and put the last piece of the puzzle.

* July 22, Monday: Figured out the best way to make temperature take generic inputs for triggering the electromagnets. Further the ellipse detection was made more strict to disallow ellipse/circles that are not of suitable dimensions. Further worked on an HSV colour filter instead of the RGB model to support higher speeds.

** July 20 and 21, Saturday and Sunday: Working on the documentation.

** July 18 and 19, Thursday and Friday: (Not well) [at home] Tried to setup plplot in windows using CMake and VS11 (2012) failed. Tried with minGW that too failed. Tried upgrading Sublime Text 3 to work with latex, that too failed. Working on updating the documentation. Also worked on the secondary project with some success.

* July 17, Wednesday: (Not well in the morning) Physically completed construction of four new dipoles, ready to be tested as a 2x2 lattice.
```

- * July 16, Tuesday: The modding problem was fixed (using modular arithmetic) in the dipole angle detection also. Dipole oscillations were setup with energy pumping using the temperature. Another dipole was also tested. Colour correction was changed from being based on RGB to HSV. This improved dipole detection at higher angular velocities.
- * July 15, Monday: Attempted an upgrade of the gstreamer plugin which failed.'tempreature' was made functional again and damping was tested using the realtime graphs. The modding problem in the angle detection for deciding when to fire the electromagnet was also fixed.
- ** July 12-14, Friday to Sunday: Working on a secondary project.
- * July 11, Thursday: A simple two point setup was created with one needle held from the top and bottom (used magnets to start with then removed them for testing damping) using glass slides and it seems to be better than what we've seen so far . Further, with plastic it is highly damped. However, we tried to mount the needle on both sides with screws (for a metal cavity) and the damping was very sensitive to the amount of pressure. Further the idea is hard to implement cause the vision detection can't be done on it then, atleast the way we're doing it now. Also, camera calibration was implemented to correct for camera defects using a chessboard pattern. The systematic errors didn't disappear.
- * July 10, Wednesday: A little more of error analysis and dipole air elevation setup for all the dipoles was done (the fourth was setup and left for drying). Used an interesting method for making the dipoles. It was found during tests that with the heavy bottom, the needle setup (with the pointed edge up !) had almost the same damping as that of the air elevated setup. Further it was concluded that more accuracy is required for the air elevation setup to work properly. It was hypothesized that the main source of 'angular friction' were the guides that held the needle upright and not the needle tip.
- * July 9, Tuesday: Did the error analysis. Used a hell lot of GnuPlot. Experimentally (that is in the physical world) setup the third dipole.
- * July 8, Monday: Working on writing a method to record all the observations into a file. Further figured out what and how to do, for estimating errors and accounting for the systematic errors. Further started the dipole modifications for setting up the first dipole for air elevation. This was done and found to have worked rather well. Better than the needle counter-parts (but no reliable comparison can be made yet, the systems compared weren't 'identical enough')

- ** July 6 and 7, Weekend: Spent on an alternate project
- * July 5, Friday: Two interesting things were done; one the long lingering bug in the modding was resolved using assistance from the atan2 approximation. Second, the aluminium disk was fitted on a needle and left to dry. Exciting cause that would finally conclude whether the air elevation method could work or not.
 - * July 4, Thursday: Cmake was fiddled around with and a graph for kinetic energy added. There was a periodic shoot up in the value which was caused by a mod problem in the angles. It was rectified. The dipole's hardware modification has also been initiated.
 - * July 3, Wednesday: Realised that a DIY air hockey table would be a better way of searching and it was. In the latticeAnalyser implemented dual graphs (one for the angular position and the other for the velocity). Also implemented the atan2 function for correcting the angle problem that used to occur.
 - * July 2, Tuesday: Figured how to use plplot, the basics. Got it up and running for 3d points and surfaces. Figured how to use grids, labels and enabling realtime support. Built and merged a minimalistic version of the same to the latticeAnalyser
 - * July 1, Monday: Air hockey tables were searched for some toy ones found too. Attempted the writing of an algorithm for auto numbering of points in a lattice. Figured it was not straight forward to implement with the usual C++ syntax. Will instead made provision (partially) for swapping manually. Also, plplot, a suitable plotting library was found and installed.
- ** June 9 - 21 : Monsoon School; Physics of Life, NCBS Bengaluru
- * June 7, Friday: [Project Milestone] It was realized that neither the sachetIO was required (the data length can be increased to 128 bytes without any difficulty just by changing the report length in the USB HID configurations), nor was a current amplifier. However, today a dipole was made to turn continuously using the latticeAnalyser and the temperature. It was found that the current is more than sufficient for the current task. Further, for now, pins of the MCU can directly be used. Stage one has been accomplished . Now it remains to reduce friction (for the damping is far too high) and to finalize the circuit for the setup. Then the actual experiment begins.

- * * June 6, Thursday: Added a buffer function to the sachetIO library. Looked up methods for current amplification
- * * June 5, Wednesday: Created and tested sachetIO, a library for sending large arrays, required for communicating over HID USB. This was debugged and tested. Non buffered version is ready.
- * June 4, Tuesday: Successfully linked the latticeAnalyser (after compiling half of it with C, the rest with C++). Modified temperature to include a simple protocol and using that controlled the electromagnet of a single dipole from latticeAnalyser.
- * June 3, Monday: Started with the hardware. Configured SP12 (the programmer) then bootloaderHID, flashed a board to support a bootloaderHID interface.

- ** June 1 and 2, Saturday and Sunday: Updated the documentation

- * May 31, Friday: Tried all sorts of methods for air suspension which failed to work satisfactorily. Despite suspension, we couldn't achieve a state that had low enough torque (either perturbation or friction, atleast one was visible)
- * May 30, Thursday: The vacuum cleaner setup had to be used. The box was drilled accordingly and the test failed partially anyway. Which is to say that if it is light enough, the suspension does take place, however the vertical oscillations can not be removed.
- * May 29, Wednesday: The pump was built but it failed the test. The air pressure generated was negligible. i7 was configured alongside and the Lattice Analyser was built on it (had to make the multi threading optional using macros) using OpenCV with OpenTBB. Tests were run and it was found to be fast enough for an 8 x 8 dipole matrix.
- * May 28, Tuesday: Multi-threading retried, wasn't quite functional last time. Looked up various techniques for multi-threading and froze an algorithm. The pump couldn't be built for parts weren't available.
- * May 27, Monday: Multithreading attempted and succeeded, although not a very good release. Making progress in installing IPP.

- * May 21 - 26, Tuesday to Sunday: Not well; Succeeded in compiling the code in windows. It's slower. Looked up multithreading using C++ 11

- * May 20, Monday: Time Lag measured and found to be roughly 3 to 4 frames behind. Not quite acceptable. Attempting to install OpenCV with IPP

- ** May 18 and 19, Saturday and Sunday: Completing the documentation for the same. Thought of a way of testing the time lag.

- * May 17, Friday: The algorithm was successfully completed to measure 360 degrees. PLUS, completed the frame recording, identification of each dipole as unique and dumping the data out in file AND its testing with uniform motion which it passed with flying colours (which is to say in the visible range!, because proper standard deviation tests haven't quite been done yet) The vision part of the analyser is almost done .
- * May 16, Thursday: Working on dipole detection. The algorithm has started to work partially. It still does a mod 180 detection.
- * May 15, Wednesday: The magnetic lifting worked, but friction reduction failed. Rather interestingly the dipole would align to the suspension magnet's field. Plus, today the spot recognition algorithm was finalized and it seemed to be perfect.
- * May 14, Tuesday: Trying to get the webcam to work, eventually acceded to installing everything on a desktop machine. Worked on reducing the friction further
- * May 13, Monday: Completed the proof of concept version of the latticeAnlyser. Tomorrow we plan to print the coloured ovals and test
- ** May 11 and 12, Saturday and Sunday: Read the opencv tutorials when the algorithms started appearing and fitting the bill!
- * May 10, Friday: Continued with the setup, finetuning, installing other applications, making a documentation alongside for better support next time, added a shared folder between windows and linux
- * May 9, Thursday: Managed to get a few things up and running, still setting up ubuntu to run with hardware acceleration, failed at trying to get the webcam to work, installed the build tools, opencv etc.
- * May 8, Wednesday: Met with Dr. X (forgot the name of the person at NPL I'm working with) and concluded OpenCV and linux are what I'll use. Initiated the downloading of required applications, including virtual box and an ubuntu image

2.2.3 Construction of the Dipole

To remove the friction, there were various ideas, including use of a super conductor. However, eventually three methods were considered and experimentally tested.

1. Ferro-Fluid:

As it turns out, there are substances that have a ferro magnetic properties but in the liquid form. Consequently, a strong enough magnet would glide if coated with this substance.

Experimentally, it was found that the friction was higher than the ‘needle on glass’ setup.

2. Magnetic Levitation:

A magnet can easily suspend another magnet, granted it doesn’t flip. This idea was used and a magnetic cylinder was placed coaxial to the needle, using a cylindrical eraser and glue. Beneath the glass slide, an identical magnet was placed with the face that repels upwards.

Experimentally, again it was found that the motion was more damped than the ‘needle on glass’ setup. The reason for this case was obvious after a little analysis and closer observation. The dipole would align to the field of the magnet, viz. the magnetic field was interfering with the dipole.

3. Air Levitation:

To test this, the very first requirement was a source of stream of air. For this, we started small. We arranged for a small USB fan from a colleague. The next task was to channel the flow of air. This was accomplished by attaching the front part of a Pepsi Bottle such that the larger diameter was closer to the fan and the mouth of the bottle had the chord stuck to it (could still be moved if required), as diagrammatically given in [Figure 1](#). The final setup has been given in [Figure 2](#).

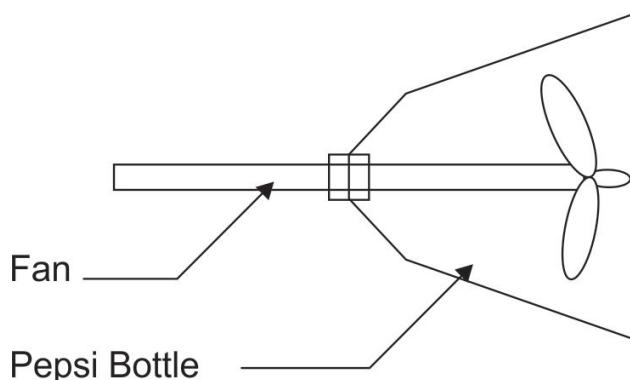


Figure 1: Fan Setup

This failed miserably for the air pressure would fall the moment the assembly covered the fan. Introducing slits to allow air to flow in created no appreciable difference. This idea had to be



Figure 2: Final Fan Setup

dropped in favour of the vacuum cleaner setup as shown in [Figure 3](#)



Figure 3: Vacuum Cleaner Setup

The vacuum cleaner was used as a blower and connected to a box using a pipe. On one of the faces of the box, four holes were drilled (which were later enlarged). These were covered to increase the pressure when required. On the open hole, one dipole was placed (which had to be re built with a minor modification, refer to [Figure 4](#)) with a disc at the bottom. This is when an apparently bizarre observation was made. At a given pressure, it was found that the dipole could remain suspended in air beyond a certain height (and obviously there was an upper bound for the same). However, for heights lower than that, the dipole would fall. The explanation which seemed to resolve this was that the air could spread while rising sufficiently only

beyond that height to apply pressure at a large enough surface area, thus create enough force. Albeit the experiment was not performed under precisely the same conditions, when it was repeated with a larger disc, the same problem was encountered, suggesting that there may be more to the explanation that deduced so far. Other geometries at the base (other than the disc) were also tried, such as a cone and a thermocol sphere, neither of which worked at low pressures which were enough to suspend the disc based setups. Further, at high pressures, disturbances in the form of torque in the dipole's axis of rotation begin to appear, which are fatal for the experiment.

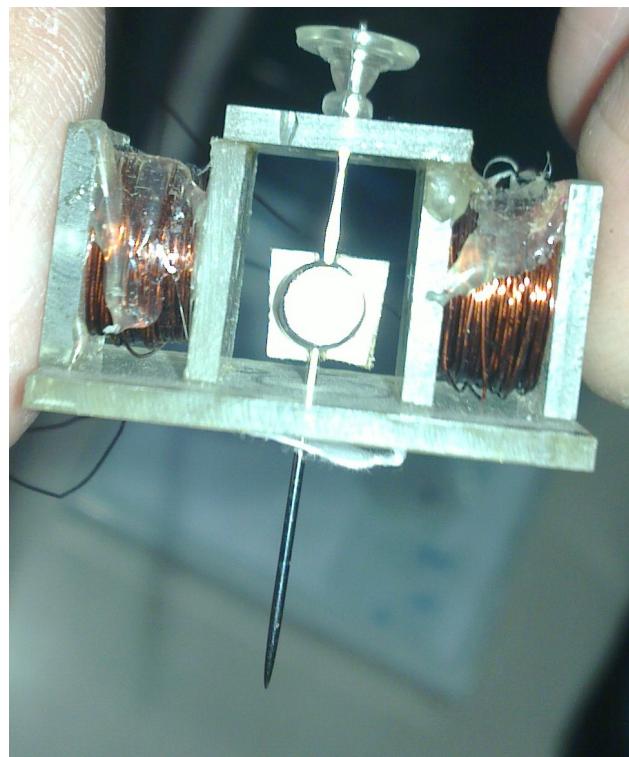


Figure 4: The Modified Dipole

Other problems with air-suspension included damping in the vertical direction. Once the dipole reaches the vertical equilibrium point, it overshoots just as an oscillator. Since the friction at the plates holding the needle vertical is negligible, the oscillations don't get damped quick enough. This was experimentally observed also. The energy ratio between the rotational part and the translation part, in the earth's field, was calculated and found to be approximately one for the given setup.

The most stable we could achieve with this setup was using a cylindrical projection from which the high pressure air escapes and a disc of comparable size attached to the dipole. This did

get suspended satisfactorily, unlike the other methods where the suspension could not be maintained at the desired height, however the needle became rather wobbly and unstable resulting in increased friction.

Online research indicated that air-bearings do function well enough and so do the boards of air hockey. These will be explored in the coming weeks to improve upon the methods to achieve the desired results.

THE DIPOLES

Air hockey table method, DIY air hockey was a better method of searching, got cues aluminium disk's introduction (For air suspension), after finalizing one, and testing it, we found comparable resistance with the inverted needle top on glass slide as opposed to when air suspended. Hypothesised that the main source of friction was infact the guiding edges, which provide the opposing torque. an interesting setup was devised, with only the needle edges held using a glass slide and magnets. resist friction etc. froze the design with aluminium disks at the bottom and made four good dipoles for testing in a 2x2 lattice

2.2.4 *Construction of the Lattice Analyser*

2.2.4.1 *Proof of Concept: Recognizing Patterns*

The lattice analyser has come a long way. Image detection trials were initiated with [Figure 5](#).

The idea was that once the ellipses have been detected, and they are different in colour, one can evaluate from their centroids, the position and the angle of the dipole. It must be stated that earlier it was attempted to use the greyscale image as was provided. However soon the shadow interference led to using coloured patterns instead. These patterns were not printed but displayed on a screen and the camera aimed appropriately.

So first, the algorithm for detection of relevant part of the image had to be frozen. There were two candidates for this

1. Hough Transform Method

Either one could use the already available in OpenCV, line detection or circle detection, both would've required changing the pattern on the dipole

Or one could use an ellipse modification for the same, which would require programming the algorithm.

2. Contour Detection and Ellipse Fitting



Figure 5: Sample Image

This method detects contours in a given image, and the OpenCV example also shows ellipse fitting for the same. This seemed promising too, but it seemed more expensive (computationally) than looking for predetermined shapes.

This work had been done within the first few days.

Next, a colour filter was to setup to improve the accuracy. When the algorithms were implemented, it was found that the Hough Transform method often misses detection of circles, refer to [Figure 6](#) (this is ofcourse after attaching a video stream instead of images to the code) as compared to contour detection [Figure 7](#).

After the detection, according the plan, two colours were to be used for the ellipses. However, running the hough transform twice would've dropped the detection speed to half, which wasn't worth it. It was then decided that the shapes should be made different instead of relying on two colours for the same information. After looking at various combinations, [Figure 8](#) was finalized, with an ellipse at the centre, and a circle along the minor axis for breaking the symmetry. This method did infact work as shown in [Figure 9](#).

2.2.4.2 Aftermath and Recognition Tests

The next challenge was to realize that a dipole detection can be missed and therefore mess up the counting, if that is the only way of uniquely identifying them. Unique identification is obviously required, as the external hardware must fire the coils of the right dipole. Thus a reference frame was used to uniquely identify the dipoles initially. This is

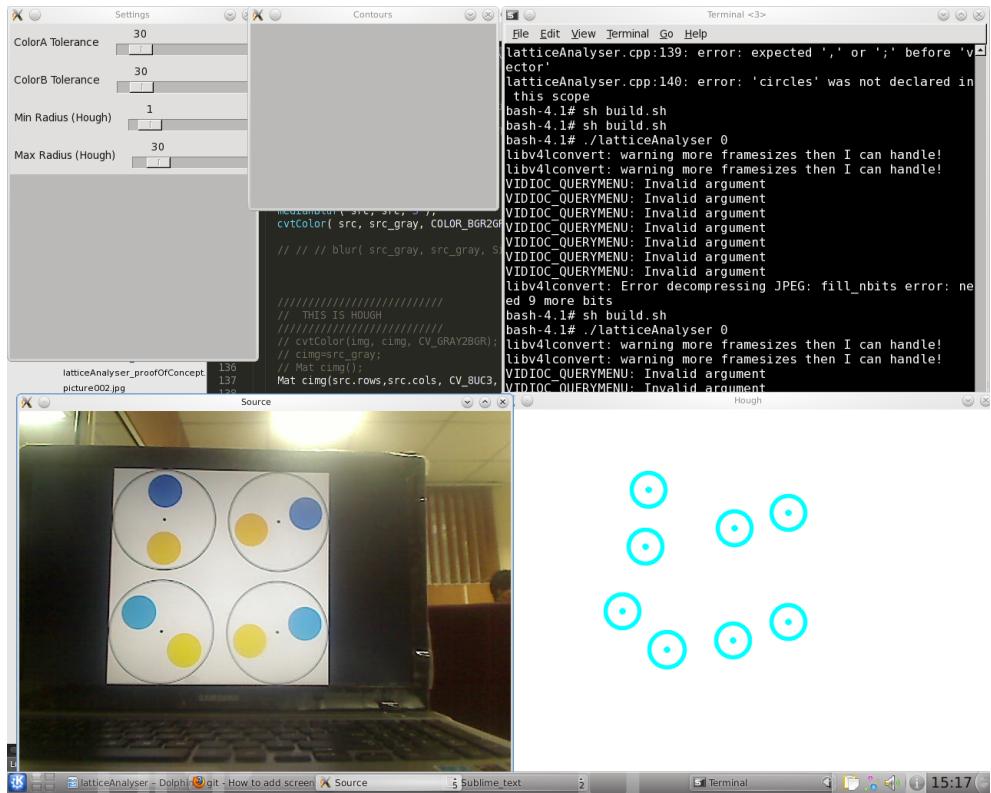


Figure 6: Hough Transform

expected to happen when they are stationary to get a good reading. In each frame, whenever a dipole is detected, it is associated with the dipole in the reference frame, by matching its location. If a dipole is not detected in a given frame, the software knows it was unable to record it and doesn't mess up neither the numbering nor the observations.

After implementation of the last part, an animation sequence was created in Power Point, with the dipoles rotating with a constant speed and the camera was aimed at the screen. A still from the same is given in [Figure 11](#). [Figure 10](#), shows the angular position versus time plot, for the first dipole and yes, it is linear, just as expected. Standard deviation tests are still to be done.

Further tests, relating to its timing were done and it was found that the processing itself was taking longer than the time taken by one frame in a 30 FPS video stream. This could be improved with the following

1. Intel Performance Primitives (IPP)

These are libraries that provide optimized algorithms for performing some of the basic tasks in OpenCV to speed up the overall computation

2. Multi Threading

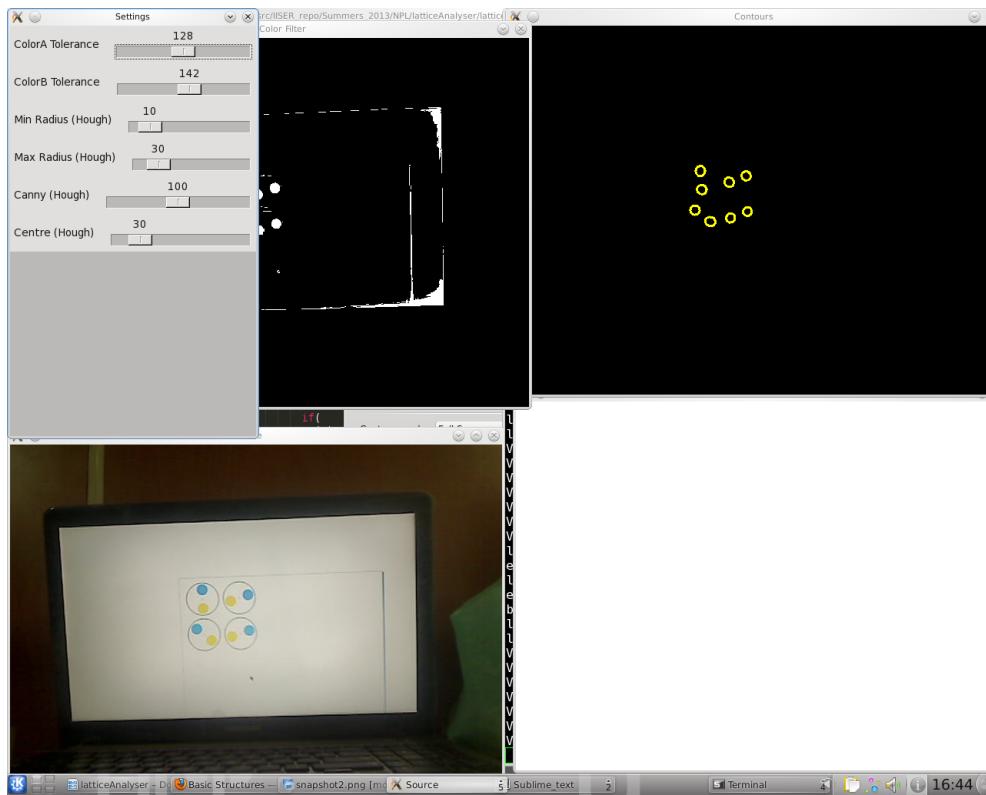


Figure 7: Contour Detection

Rendering the frames in a different thread could perhaps increase the render speed or atleast ensure it doesn't affect the rate of processing of the image

3. Camera Initial Delay

Despite a 30 FPS smooth video, there seemed to be an initial delay which persisted in the video preview of the camera. This can be corrected for by polling the camera quickly instead of processing the image each time.

4. OpenTBB

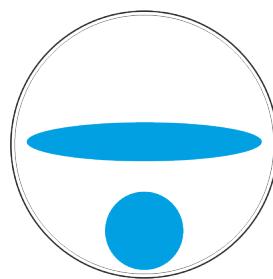


Figure 8: Final Pattern

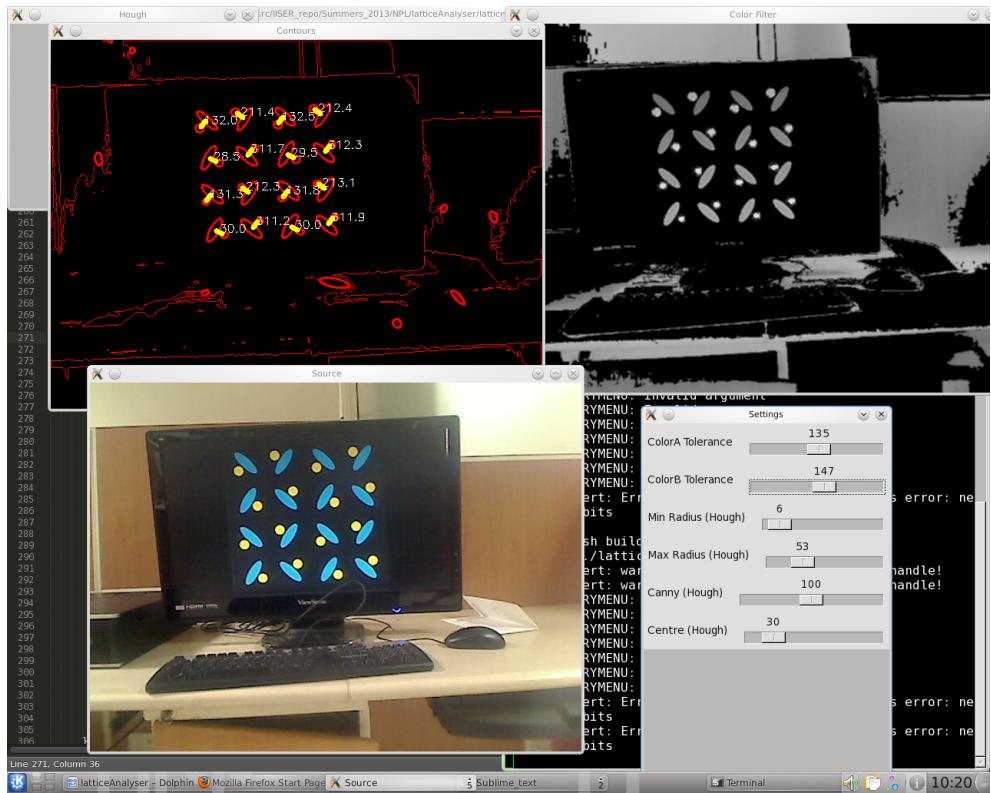


Figure 9: Multi Shape, Single Colour

To enable multi-threading within OpenCV to speed up the algorithms

5. Hardware

The results obtained earlier were for a Pentium 4 HT system. A faster multi-core processor could produce potentially, better benchmarks.

Painstakingly, IPP was downloaded, built and integrated with OpenCV and re-built. There were various issues, starting from an incompatible version of IPP, to faulty documentation in OpenCV. The results did not improve however despite this. Perhaps the algorithms used do not rely on the methods optimized by IPP

Multi-threading was implemented using C++ 11. Various synchronization methods were looked up, including mutexes, unique locks; eventually atoms were used and tested with Visual Studio Express 2012 on windows (implicitly implying the application was first made to run on windows), as the linux machine had an older kernel and upgrading GCC wasn't recommended.

The camera's initial delay is caused by the initial stream. To rectify this, OpenCV has two methods, one for grabbing a frame, and the other for decoding it. If in a separate loop, the camera is polled regularly for frames, the delay is minimized. The frame can be decoded as

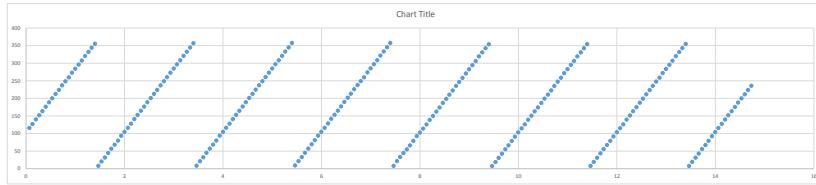


Figure 10: First Observation

soon as processing of the previous frame is over. This, as is suggestive, also requires multi-threading

OpenTBB is a library that is required to enable multi-threading support in OpenCV. This too had to be fiddled with for a while, before being built successfully.

The hardware was changed to an i7 machine which has more than enough cores and computation power.

These modifications were all combined and the code compiled using GCC (except certain parts of multi-threading, due to a compiler issue) and it was found to be able to process in about 25 milliseconds for an 8×8 matrix of dipoles. For a 16×16 matrix, the resolution of the camera (Logitech Pro 9000, 640×480 at 30 FPS) was found to be insufficient. Higher resolutions in the same camera did not have a 30 FPS temporal resolution. The alternative seems to be a camera for the Raspberry Pi which can be used over ethernet.

Further, the CLI of the program was modified to add support for inputting various commands, which would be required for testing the hardware (which is scheduled to be built this week).

2.2.4.3 ‘temperature’ compatible

And surprise surprise, the hardware interface was in fact done in the following week. Dr. Ravi Mehrotra had already created a simplified version of the Ob-Dev firmware for USB interface of an Atmega with the PC which was used. More on that is there in the tempera-

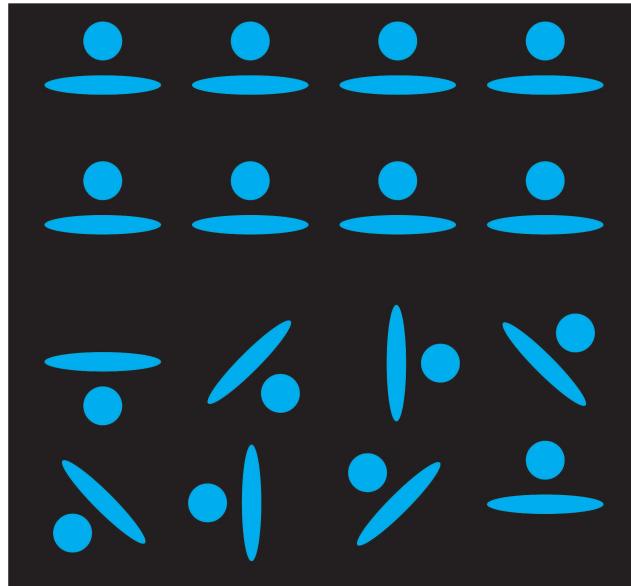


Figure 11: Final Test Pattern

ture section (which follows). The Lattice Analyser had to pump in energy to the system by providing angular velocity to the system of dipoles repetitively at suitable time intervals, viz. when the temperature of the system drops. The temperature is calculated in realtime using the RMS angular velocity of each dipole in the system. It was immediately realized after a closer look that since the time window between two frames is roughly 30 ms, it is not possible to energize all the dipoles with velocities picked from a given distribution of temperature. Further, since the motion of the entire system is coupled, it suffices to energize *some* dipoles sufficiently to maintain the temperature.

To achieve this the following were done (or algorithms for achieving them written) ²

1. The tools for compiling and programming the AVR installed
2. Bootloader programmed into the micro-controller along with the sample program given by Dr. Ravi Mehrotra
3. Communication with the PC was tested using the corresponding C example program for the PC
4. USB libraries were incorporated into the latticeAnalyser and linked (had to compile C objects with C++ objects)
5. A simple IO protocol between the Lattice Analyser and the microcontroller was written and tested.

² For completeness sake, it must be stated that some modifications had to be made before the colour filtration became functional

6. The coil of a dipole was tested with a set of 4 A4 batteries and some basic current calculations were done
7. The hardware was setup to include a small current limiting resistor (about 120 ohms) and the coil powered using the Lattice Analyser
8. (was not required) Worked on sachetIO; a library for breaking down a large chunk of data into sachets intended to be transmitted and combined after being received.
9. (was not required) Looked up methods to amplify the current, since the micro-controller's current wasn't found to be strong enough to align the needle of the dipole to it.
10. Discussion about how to implement the energy pumping (which is how the previous two steps were found to be pointless)
11. A 2×2 lattice of dipoles was setup.
12. The angular velocities of each dipole calculated
13. With each frame, the RMS angular velocity calculated
14. An algorithm for position and velocity based energy pumping written
15. Interface added to test the same by supporting inversion of force direction (so that it results in halting) and an option to make blind (viz. disable the algorithm and instead send pulses periodically in time)

The final result was that energy could be pumped into one dipole satisfactorily. The next step was to extend the algorithm to an arbitrarily sized matrix. Certain steps such as velocity calculations when dipole detection fails (at high speeds) has arbitrary inaccurate behaviour in the said version. Algorithms for finding the axis of the coil in the dipoles also needs to be finalized, for there are more than one ways of doing this, viz. powering the coils and reading the angular position of the dipole, finding the axis of the lattice by noting the Cartesian positions of the dipole, deduce it from the rest (initial) angular position of the dipoles which should be known given the lattice size, etc.

2.2.4.4 Adding Realtime Graphing Capability

Before working further on the aforesaid steps, realtime graphing was implemented. This was thought to be required for *seeing* what was happening, specially the angle detection and when it goes wrong. This is being emphasized because the angle detection would often result in incorrect angle calculation which was a serious issue.

After searching the internet for plotting methods, plplot was finalized as the graphing library to be used with C++. This was downloaded, built and installed. I wouldn't go into the implementation details, but would remark that it takes a little time to get everything up and running. The library supports various kinds of graphs. The two types of that were used for the project are

1. Realtime 3D plot
2. Strip chart

Further, the library provides multiple rendering options, of which for linux, a driver for the x11 graphics system was used for testing. In a single window all three graphs were created;

1. 3D: Angular Position vs Dipole ID vs Time
2. 3D: Angular Velocity vs Dipole ID vs Time
3. Stripchart: Average Square Angular Velocity (over dipoles) vs Time

Of course, these graphs weren't all added at once; [Figure 12](#), [Figure 13](#) and [Figure 14](#) tell the story. For the stripchart it must be remarked that it auto scales and shifts as the data flows in. This proved to be more useful than expected for debugging the mod problem (helped visually see the co-relation between other parameters and occurrence of the error). Further it was also useful in identifying periodic fluctuations (with a somewhat constant time period) in the third graph.

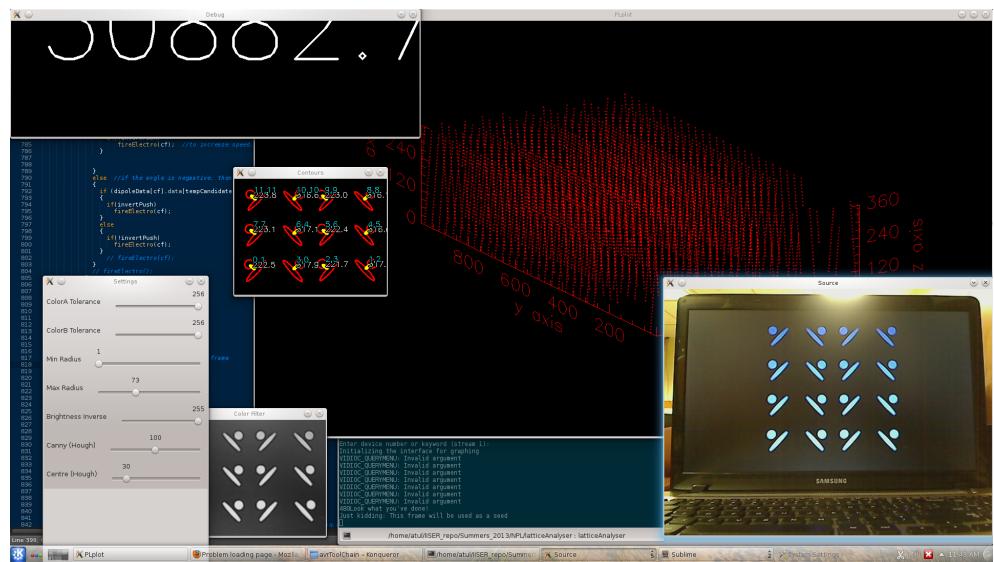


Figure 12: With the first graph

This will probably be the final user interface improvement for the Lattice Analyser.

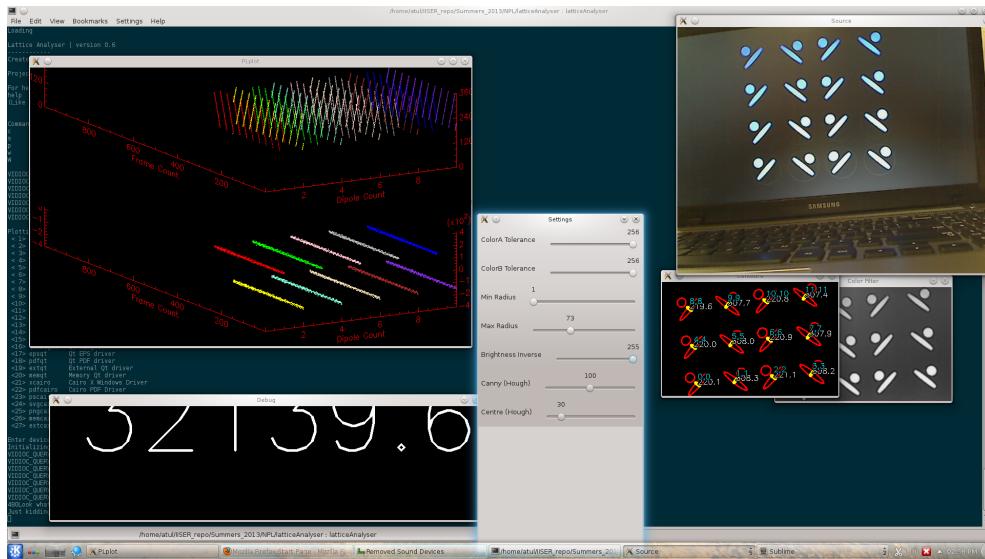


Figure 13: With the second graph

2.2.4.5 The Modding Problem

Consider an ellipse. To describe all its orientations uniquely, given it's position, we need a convention for defining the angle and the angle should span π radians. Only π radians are required as opposed to 2π simply because of the symmetry of the ellipse. TODO: Put an image of an ellipse with the angle. We therefore need more information than the angle of the ellipse, to determine the angle of the dipole. The design of the pattern takes care of it by providing a circle to break the symmetry. Simplistically, the problem is now solved, for the circle's position can easily be used to decide when to add π to the ellipse angle and you have the dipole's angle. TODO: Add an image showing the ellipse with a circle and the dipole angle changed accordingly.

Upon implementing this simple logic as an algorithm and testing, it was found that it runs into troubles very quickly and periodically. To understand, first assume that the ellipse reads zero degrees when horizontal and thus, the circle, if it is above the

atan2 approximation for correcting the angle problem, atan2 assisted angle approximation, modular arithmetic based approach for correcting the dipole angle detection (figured this from a simpler problem of firing the electromagnet)

mod problem for deciding when to fire the electro magnet, used modular arithmetic

RGB based colour detection to HSV based colour filtering, to improve high speed performance | various problems such as conversion of rgb to hsv and so on..

misc: cmake was fiddled around with, auto numbering of lattice points,

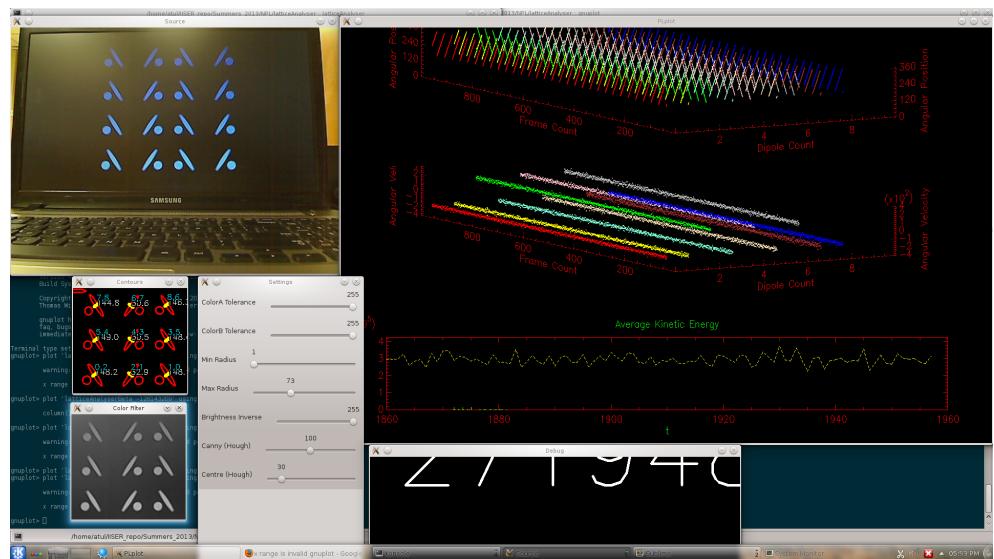


Figure 14: All the three graphs

writing all the data into a file, gstreamer plugins for reading x264 graph for kinetic energy added, there was a periodic shoot up, caused by modding problem

testing source of systematic error, eliminating a cause, camera defect | calibration. list the two kinds of defects

PHYSICS: error analysis: used a lot of GNUpot, to test the kind of deviations for a given dipole, in the angle determination when static, when moving. Then for a given point of time, the deviation in the angles of various dipoles. damping could be tested with realtime grpahs

Following is the source code of the same, which has been made available online.

latticeAnalyser.cpp

```

/*
filename: latticeAnalyser.cpp
description: This is the main application which analyses the
lattice and
    1. controls 'temperature'
    2. records dipole position (thus angular
       velocity) as a function of time
baby steps (TM):
    1. Proof of concept stage
        a. Find a suitable algorithm
        b. Make the required modifications
            i. Add a colour filter
                Implement two colours [done]
                Add two sliders for adjusting tolerance [done, but
                need to refresh something!]
```

Add GUI for selecting the colours [done, but not a
gui so to speak]
save settings [not doing it]

2. Look at it grow!
 - a. Enable screen cropping [done]
 - b. Write an algorithm for ellipse to dipole conversion [completed]
 - c. Save data for each frame using a circular array of sorts [done]
 - d. Output the data perhaps in a text file [done]
3. Testing
 - a. Test OpenCV's computation time [done]
 - b. Compiling it on Windows [done and as it turns out, useless]
4. Optimizing
 - a. Multi-threading frame fetching [done]
 - b. Multi-threading display update [done, but failed to improve, infact made it worse]
 - c. Multi-thread using mutex [done, no real difference but not slow either][it is actually very slow]
 - d. Atomic Sync for frame fetching [done]
 - f. Atomic Sync for display update [done, and apparently faster! Yey]

[There's something wrong though, since the frame jitters like a bad codec.]
[resolved]
 - g. Double Buffer for display [skipped]
5. Hardware Interface
 - a. Modify the CLI to include menus [done]
 - b. Fagocytosis of USB demo program [done]
 - c. Working on the Proof of Concept for temperature
 - i. Velocity calculation [done]
 - ii. Realtime graphs [library installed; plplot; basic functionality tested]
 - I. Test separate [Done]
 - II. Fagocytosis [Done]
 - d. Find the axis of the lattice to find the coil angle [after experimentation, discontinued]
6. Finalizing
 - a. Temperature Interface generic
 - i. Proof of concept [Done]
 - ii. Import configurations from file [Done]
 - iii. Test proper firing [Done]
 - iv. Algorithm to find the best candidate for pumping energy [Done]
 - v. Test the algorithm with 2 dipoles (not even a lattice :) [Done]
 - vi. Ensure the temperature communication doesn't make the program wait [Done]
 - vii. Test with a 2x2 lattice [Done]
 - b. Improved colour filter based on HSV
 - i. implement [Done]

```

        ii. allow colour picking (debug existing problem) [Done]
        c. Stricter ellipse detection (rejects most unwanted ellipses) [Done]
        d. Temperature Calculation and corresponding proof of concept trigger [Done]

    */

#include "opencv2/highgui/highgui.hpp"
#include "opencv2/imgproc/imgproc.hpp"
#include <iostream>
#include <stdio.h>
#include <stdlib.h>
#include <thread>
#include <mutex>
#include <chrono>
#include <string>

#include <atomic>

using namespace cv;
using namespace std;

// #include <string.h>
// #include <array>

#define GRAPHS_ENABLED

#ifndef GRAPHS_ENABLED
    #include <plplot/plplot.h>
    #include <plplot/plstream.h>
    plstream *pls=new plstream();
    const char *legline[4];
    int colline[4],styline[4];
    int id1;
    bool plotSqKE=true;
#endif

//Configuration
//#define ATOMIC
// #define MULTI_THREAD_DISPLAY
// #define ATOMIC_DISPLAY
// #define MULTI_THREAD_CAMERA_UPDATE

#define TEMPERATURE_ENABLED

```

```

//TODO: Either calculate it at runtime, or allow the user to
    input
//This is the detected angle of the dipole when it is aligned
    with the coil (least energy configuration)
// #define COILANGLE 0
float coilAngle = 90;
#define preciseAngleTol 20
    //This is slightly twisted to explain; it is the difference
        allowed between the atan2 angle and the ellipse angle to
            resolve the mod, if this is not clear, refer to the code
const double version=0.6;
// #define MINANGULARVELOCITY 10000000
int minAngularVelocity=100;

int tempCandidate=0; //This is the dipole that is accelerated
bool blind=false;      //This is the blind option, meaning
    hardware tracking is turned off
bool invertPush=false; //This is to invert the moment of
    pushing
bool useCalibration=true;
#ifndef TEMPERATURE_ENABLED
    #ifdef TEMPERATURE_SINGLDIPOLE
        inline void fireElectro(long frame, int id);
    #else
        void fireElectro(int id, int intensity);
    #endif

    // for USB interface
    extern "C"
    {
        #include "DataTypes.h"
        #include "usbIO.h"
    }
    //
    vector<char> dipolePort;
    vector<char> dipoleBit;
#endif

#ifndef ATOMIC_DISPLAY
    #ifndef MULTI_THREAD_DISPLAY
        #define MULTI_THREAD_DISPLAY
    #endif
#endif

//#if (defined(ATOMIC) || defined(ATOMIC_DISPLAY) || defined(
//    MULTI_THREAD_DISPLAY) || defined(MULTI_THREAD_CAMERA_UPDATE))
//#include<atomic>
//#endif

#define CALIBRATION_ENABLED

```

```

#ifndef CALIBRATION_ENABLED
    Mat cameraMatrix;
    // = Mat(3,3,CV_32FC1);
    Mat distCoeffs;
    // = Mat(5,1,CV_32FC1);
#endif

#ifndef ATOMIC
    //##include <atomic>
    atomic<bool> threadsEnabled=false;
#else
    bool threadsEnabled=false;
#endif


#ifndef MULTI_THREAD_DISPLAY
#ifndef ATOMIC_DISPLAY
    mutex drawnow;
#endif
#endif

#ifndef ATOMIC_DISPLAY
    atomic<bool> updateDisplayRequested;
    atomic<bool> updateDisplayCompleted;
#endif

mutex processingImage;
mutex grabbingFrame;

//For computation time
double tCstart,tCdelta,tCend; //time for computation
vector <double> computationTime;

vector <Mat> buf;
// /////////////
//     Mat<double> cameraMatrix(3,3), distCoeffs(5,1);
//     cameraMatrix =[ 5.6712925674714052e+02, 0.,
//     3.1716566879559707e+02, 0., 5.6556813512152769e+02,
//     2.1037221807058236e+02, 0., 0., 1. ];
// /////////////

Mat grabbedFrame;
#ifndef MULTI_THREAD_CAMERA_UPDATE
    atomic<bool> frameGrabbed,frameRequested;
#else
    bool frameGrabbed=false,frameRequested=false;
#endif

#ifndef CALIBRATION_ENABLED
    void getCameraCalibrationParameters()
    {

```

```

char calibrationFile[]="configurations/logitech2";
FileStorage fs2(calibrationFile, FileStorage::READ);

// first method: use (type) operator on FileNode.
// int frameCount = (int)fs2["frameCount"];

// std::string date;
// second method: use FileNode::operator >>
// fs2["calibrationDate"] >> date;

// Mat cameraMatrix2, distCoeffs2;

fs2["camera_matrix"] >> cameraMatrix;
fs2["distortion_coefficients"] >> distCoeffs;

// cameraMatrix = Mat(3,3,CV_32FC1);
// distCoeffs = Mat(5,1,CV_32FC1);
// //TODO: Input them off of a file instead..
// //Not very certain how the pointer thing is working..found
// this on an implementation on the net
// cameraMatrix.ptr<float>(0)[0] = 5.6712925674714052e+02;
// cameraMatrix.ptr<float>(0)[1] = 0;
// cameraMatrix.ptr<float>(0)[2] = 3.1716566879559707e+02;
// cameraMatrix.ptr<float>(1)[0] = 0;
// cameraMatrix.ptr<float>(1)[1] = 5.6556813512152769e+02;
// cameraMatrix.ptr<float>(1)[2] = 2.1037221807058236e+02;
// cameraMatrix.ptr<float>(2)[0] = 0;
// cameraMatrix.ptr<float>(2)[1] = 0;
// cameraMatrix.ptr<float>(2)[2] = 1;

// distCoeffs.ptr<float>(0)[0]=1.0093652191470437e-01;
// distCoeffs.ptr<float>(1)[0]=-3.9155163783030478e-01;
// distCoeffs.ptr<float>(2)[0]=-8.1203753896884399e-04;
// distCoeffs.ptr<float>(3)[0]=4.7881016467320944e-03;
// distCoeffs.ptr<float>(4)[0]=2.8593695994355700e-01;
cout<<"Camera Calibration Enabled"<<endl<<"Using file: "<<
    calibrationFile<<endl;
cout<<cameraMatrix<<endl<<distCoeffs<<endl;
}

#endif
void initializeMultithreadResources()
{
#ifdef MULTI_THREAD_CAMERA_UPDATE
    frameGrabbed=false, frameRequested=false;
#endif

#ifdef ATOMIC_DISPLAY
    updateDisplayRequested=true;
    updateDisplayCompleted=false;
#endif
}

```

```

#define ATOMIC
//#include <atomic>
threadsEnabled=false;
#endif
}

Mat srcPreCrop; Mat cimg; Mat src; Mat src_gray; Mat
srcColorFilter; Mat src_process; Mat srcColorA; Mat srcColorB
;Mat drawing;
///////////
// bool isGood(float val,float expected,float tol)
// {
//   if(abs(val-expected)
// }
///////////
//the following two functions are from http://www.cs.rit.edu/~ncs
//color/t_convert.html
//0-360 and 0-1 (originally)
//r g b is also from zero to one
void RGBtoHSV( double r, double g, double b, double *h, double *s
, double *v )
{
r/=255;
g/=255;
b/=255;

double min, max, delta;

min = MIN( r, MIN(g, b) );
max = MAX( r, MAX(g, b) );
*v = max;      // v

delta = max - min;

if( max != 0 )
  *s = delta / max;    // s
else {
  // r = g = b = 0    // s = 0, v is undefined
  *s = 0;
  *h = -1;
  return;
}

if( r == max )
  *h = ( g - b ) / delta;    // between yellow & magenta
else if( g == max )
  *h = 2 + ( b - r ) / delta; // between cyan & yellow
else
  *h = 4 + ( r - g ) / delta; // between magenta & cyan

*h *= 60;      // degrees
if( *h < 0 )

```

```

*h += 360;

(*h) *= (180.0/360.0);
(*s) *= 255.0;
(*v) *= 255.0;
}

void HSVtoRGB( double *r, double *g, double *b, double h, double
    s, double v )
{
    h *= (360.0/180.0);
    s /= 255.0;
    v /= 255.0;

    int i;
    double f, p, q, t;

    if( s == 0 ) {
        // achromatic (grey)
        *r = *g = *b = v;
        return;
    }

    h /= 60;      // sector 0 to 5
    i = floor( h );
    f = h - i;    // factorial part of h
    p = v * ( 1 - s );
    q = v * ( 1 - s * f );
    t = v * ( 1 - s * ( 1 - f ) );

    switch( i ) {
        case 0:
            *r = v;
            *g = t;
            *b = p;
            break;
        case 1:
            *r = q;
            *g = v;
            *b = p;
            break;
        case 2:
            *r = p;
            *g = v;
            *b = t;
            break;
        case 3:
            *r = p;
            *g = q;
            *b = v;
            break;
        case 4:
    }
}

```

```

        *r = t;
        *g = p;
        *b = v;
        break;
    default: // case 5:
        *r = v;
        *g = p;
        *b = q;
        break;
    }

    (*r)*=255;
    (*g)*=255;
    (*b)*=255;
}
///////////
float findPrinciple(float val, float modVal)
{
    while(val<0)
        val-=modVal;
    return val;
}

//Think of a clock. I give you two positions on the clock. You've
//      to tell me which ones ahead
//basically modular arithmetic in some sense
bool IsClockwise(float final, float initial, float modVal)
{
    float delta,deltaA,deltaB;
    delta=final-initial;

    deltaA=delta;
    while(deltaA<0)
        deltaA+=modVal;

    deltaB=-delta;
    while(deltaB<0)
        deltaB+=modVal;

    if(deltaA<deltaB)
        return true;
    else
        return false;
}
//This is to find the shortest distance in two numbers in a
//      modular arithmetic system
float shortestDistance(float final, float initial, float modVal)
{
    float delta,deltaA,deltaB;
    delta=final-initial;

    deltaA=delta;

```

```

    while(deltaA<0)
        deltaA+=modVal;

    deltaB=-delta;
    while(deltaB<0)
        deltaB+=modVal;

    return (deltaA<deltaB) ? deltaA: deltaB;
}

// int lastBuf=1;
//for the cropping
int cropped = 0;
Point origin;
Rect selection;
bool selectRegion;

// Mat cimg;
Mat<Vec3b> srcTemp = src;
int thresh = 100;
int max_thresh = 255;
int canny=100;
int centre=30;

int minorAxis=7;
int majorAxis=35;
int radius=15;
int ellipseTolerance=8;

int mode=0;
double theta=3.14159;

//mode
//0 is screen select
//1 is colour select

RNG rng(12345);

///////////DIPOLE DETECTION

class dipole
{
public:
    double angle,order; //angle is the angle, order gives a rough
                        //size of the dipole detected
    int x,y,id; //centre, id tells where its mapped
    int e1,e2; //index number of ellipse
    static int count[2]; //double buffer
    static int current;
};

```

```

int dipole::count[2] = {0};
int dipole::current=0;

//Not using a dynamic array, doesn't matter for now
//TODO: Use a dynamic array
// array<dipole,500> dipoles;
// array<dipole,500> lastDipoles;
#define DmaxDipoleCount 1000
#define DtemperatureAverageOverPeriod 1
dipole dipoles[2][DmaxDipoleCount];
// Colour read
// Point origin;

//////////////////DIPOLE INFORMATION STORAGE IN RAM
bool dipoleRec=false;

class dipoleSkel
{
public:
    double angle;
    int id; //For the dipoleData, this refers to the id of
            seedDipole
    //in seedDipole, this should refer to the hardware ID
    vector<int> neighbour;
    vector<double> neAngle;
    int x,y;
    double instAngularVelocity;
    bool detected; //stores whether the dipole was detected at
                    all
};

//This class is for storing dipole data of a given frame
class dipoleFrame
{
public:
    double time; //time elapsed since the seed frame
    double order; //gives the rough size of the dipoles
    int count,velValidCount; //number of dipole detected in the
                            frame, number of dipoles for which inst angular
                            velocity could be calculated (essentially, that it was detected in
                            two consecutive frames)
    double meanSquaredAngularVelocity,temperature; //mean of
                                                    squares of angular velocities of each of the dipoles
    vector<dipoleSkel> data;
};

// #define DframeBufferLen 5000
dipoleFrame seedDipole;
//NOTE: You have to fix the numbering problem right here.

```

```

vector <dipoleFrame> dipoleData;

#define DframeBufferLen 5000
////THIS IS FOR STORING IN FILE
FILE * pFile;
char fileName[50];
///////////////////////////////
#ifndef TEMPERATURE_ENABLED
void getTemperaturePins()
{
    char temperaturePinsFile[]="configurations/temperaturePins";
    FileStorage fs2(temperaturePinsFile, FileStorage::READ);
    cout<<endl<<"Temperature Enabled, using file: "<<
    temperaturePinsFile<<endl;

    char tempString[5];
    string extractedString;
    dipolePort.clear();
    dipoleBit.clear();

    int iMax;
    fs2["count"]>>iMax;

    // FileNodeIterator it = fs2.begin(), it_end = fs2.end();
    // int idx = 0;
    // std::vector<uchar> lbpval;

    // // iterate through a sequence using FileNodeIterator
    // for( ; it != it_end; ++it, idx++ )
    // {
    //     // cout << "feature #" << idx << ": ";
    //     cout << "x=" << (int)(*it)["x"] << ", y=" << (int)(*it
    //     )["y"] << ", lbp: (";
    //     // you can also easily read numerical arrays using
    //     // FileNode >> std::vector operator.
    //     (*it)["lbp"] >> lbpval;
    //     for( int i = 0; i < (int)lbpval.size(); i++ )
    //         cout << " " << (int)lbpval[i];
    //     cout << ")" << endl;
    // }

    for(int i=0;i<iMax;i++)
    {
        sprintf(tempString,"p%d",i);
        fs2[tempString] >> extractedString;
        // cout<<tempString<<" "<<extractedString<<endl;
        if(extractedString.size()>1)
        {
            dipolePort.push_back(extractedString[0]);
            dipoleBit.push_back((extractedString[1]-'0'));
        }
    }
}

```

```

        //Not using dipole pin because obviously char
        //corresponding to 0 is not '0'
        cout<<"Dipole "<<i<<" \t — \t"<<dipolePort[i]<<
            extractedString[1]<<" (Port"<<dipolePort[i]<<" Bit"<<
            extractedString[1]<<")"<<endl;
    }
    else
    {
        dipolePort.push_back('Z');
        dipoleBit.push_back(9);
    }
}

}

#endif

/////////////////////////////
float candidateAptitude( int id)
{
    // int candidate=posPhysicalToDetected(id);
    int cf=dipoleData.size()-1;
    int candidate=id;
    float distanceFromCoil=shortestDistance(dipoleData[cf].data[
        candidate].angle,coilAngle,360);
    // if((dipoleData[cf].data[tempCandidate].angle - COILANGLE) >
    // 0)
    if(IsClockwise(dipoleData[cf].data[candidate].angle,coilAngle
        ,360))
    {
        if (dipoleData[cf].data[candidate].instAngularVelocity>0) ////
            if it is going in the opposite direction
        {
            if (invertPush)
                // fireElectro(cf,tempCandidate);
                return distanceFromCoil;
        }
        else
        {
            if(!invertPush)
                // fireElectro(cf,tempCandidate); //to increase speed,
                // because the force will be towards the coil
                return distanceFromCoil;
        }
    }

    else //if the angle is negative, then
    {
        if (dipoleData[cf].data[candidate].instAngularVelocity<0) ////
            if it is going towards the coil
    }
}

```

```

    {
        if(invertPush)
            // fireElectro(cf,tempCandidate);
            return distanceFromCoil;
    }
    else
    {
        if(!invertPush)
            // fireElectro(cf,tempCandidate);
            return distanceFromCoil;
    }
    // fireElectro(cf);
}
return 0; //this means the given dipole can't be used to pump
in energy
}

///////////

int posPhysicalToDetected(int phyID)
{
    for(int i=0;i<seedDipole.data.size();i++)
    {
        if(seedDipole.data[i].id==phyID)
            return i;
    }
    cout<<endl<<"INVALID physical ID";
    return 0;
}

// This is a colour filter for improving accuracy
// 20, 28, 41 [dark]
// TODO: Allow the user to select the colour
// Scalar colorB=Scalar(245,245,10);
// Scalar colorB=Scalar(126,88,47);
// Scalar colorA=Scalar(10,245,245);

// HSV

//This is experimental :P
Scalar colorA((float)103.953, (float)151.59, (float)217);

//The following's from GIMP
// Scalar colorA((float)206*(360/180),74*(255/100),83*(255/100)
// );

// int colorATol=30;
// int colorBTol=35;

```

```

    // int brightInv=10; //this is to increase the brightness
    // after processing
    // H: 0 - 180, S: 0 - 255, V: 0 - 255

    int hueTol=20;
    int valueTol=193;
    int saturationTol=85;

    int colorATol=255;
    int colorBTol=255;
    int brightInv=74; //this is to increase the brightness after
    // processing

    //

    const char* source_window = "Source";
    const char* filter_window = "Color Filter";
    const char* settings_window="Settings";

    ////////////TIMING
    long t,tLast,tickWhenGrabbed;
    double deltaT;
    static void onMouse( int event, int x, int y, int, void* )
    {
        if(mode==0)
        {
            if( selectRegion )
            {
                selection.x = MIN(x, origin.x);
                selection.y = MIN(y, origin.y);
                selection.width = std::abs(x - origin.x);
                selection.height = std::abs(y - origin.y);

                selection &= Rect(0, 0, src.cols, src.rows);
            }

            switch( event )
            {
                case CV_EVENT_LBUTTONDOWN:
                    cropped=0;
                    origin = Point(x,y);
                    selection = Rect(x,y,0,0);
                    selectRegion = true;
                    break;
                case CV_EVENT_LBUTTONUP:
                    cropped=0;
                    selectRegion = false;
                    if( selection.width > 0 && selection.height > 0 )
                        cropped = -1;
                    break;
            }
        }
    }
}

```

```

else if(mode==1)
{
    switch( event )
    {
        case CV_EVENT_LBUTTONDOWN:
            cout<<"Color A is currently (HSV) "<<endl<<(float)colorA.
                val[0]<<endl<<(float)colorA.val[1]<<endl<<(float)
                colorA.val[2]<<endl;
            cout<<endl<<"x=<<x<<" ,y=<<y<<endl;
            // colorA=Scalar(srcPreCrop.at<Vec3b>(y,x)[0],srcPreCrop.
            // at<Vec3b>(y,x)[1],srcPreCrop.at<Vec3b>(y,x)[2]);
            //THIS IS RIGHT, it had to be y,x and not x,y!!! damn..
            RGBtoHSV((int)srcPreCrop.at<Vec3b>(y,x)[2],(int)
                srcPreCrop.at<Vec3b>(y,x)[1],(int)srcPreCrop.at<Vec3b
                >(y,x)[0],&(colorA.val[0]),&(colorA.val[1]),&(colorA.
                val[2]));
            cout<<"BGR colours are "<<(int)srcPreCrop.at<Vec3b>(y,x)
                [2]<<,"<<(int)srcPreCrop.at<Vec3b>(y,x)[1]<<,"<<
                int)srcPreCrop.at<Vec3b>(y,x)[0]<<endl;
            // printf("RGB colours are %f %f %f",srcPreCrop.at<Vec3b
            // >(y,x)[0],srcPreCrop.at<Vec3b>(y,x)[1],srcPreCrop.at<
            // Vec3b>(y,x)[2]);
            cout<<"Color A's been changed to "<<endl<<(float)colorA.
                val[0]<<endl<<(float)colorA.val[1]<<endl<<(float)
                colorA.val[2]<<endl;
            break;
        // case CV_EVENT_RBUTTONDOWN:
        //     cout<<x<<" ,<<y<<endl;
        //     colorB=Scalar(src.at<Vec3b>(y,x)[0],src.at<Vec3b>(y,x)
        // [1],src.at<Vec3b>(y,x)[2]);
        //     cout<<"Color B's been changed to "<<endl<<colorB.val
        // [0]<<endl<<colorB.val[1]<<endl<<colorB.val[2]<<endl;
        //     break;
    }
}
#endif __GNUC__
void tGrabFrame(VideoCapture&& capture)
#else
void tGrabFrame(VideoCapture& capture)
#endif
{
    while(threadsEnabled)
    {

        capture>>grabbedFrame;
        if(frameRequested)
        {
            tickWhenGrabbed=getTickCount();
            grabbedFrame.copyTo(srcPreCrop);
            frameGrabbed=true;
    }
}

```

```

        }

        //buf.push_back(frameGrabbed);

        // if(processingImage.try_lock())
        // {
        //   buf.copyTo(srcPreCrop);
        //   processingImage.unlock();
        // }
    }

}

void updateDisplay()
{
    if(!drawing.empty())
        imshow("Contours", drawing );
    if(!cimg.empty())
        imshow("Debug", cimg);
    if(!src_gray.empty())
        imshow( filter_window, src_gray);
    if(!srcPreCrop.empty())
        imshow( source_window, srcPreCrop );

}

#ifndef MULTI_THREAD_DISPLAY
#ifndef ATOMIC_DISPLAY
    void tUpdateDisplay()
    {
        while(threadsEnabled)
        {
            drawnow.lock(); //this is to ensure it updates only once
                            // the processing has been done and not repetatively the
                            // same frame
            drawnow.unlock();

            updateDisplay();

        }
    }
#else
    void tAtomicDisplay()
    {
        while(threadsEnabled)
        {

            // && updateDisplayCompleted==false)
            if(updateDisplayRequested)
            {
                updateDisplay();
                // this_thread::sleep_for(chrono::milliseconds(10));
            }
        }
    }
#endif
}

```

```

        // updateDisplayCompleted=true;
        updateDisplayRequested=false;
    }
    // else
    // this_thread::sleep_for(chrono::milliseconds (1));
    // this_thread::yield();

}
#endif
#endif GRAPHICS_ENABLED

void clearGraph()
{
    pls->col0(1);
    // cout<<"1"<<endl;
    double xmin2d = -2.5;
    double xmax2d = 2.5;
    double ymin2d = -2.5;
    double ymax2d = 4.0;
    // pls->wind( 0.0, 1.0, 0.0, 1.0 );
    // pls->env(xmin2d, xmax2d, ymin2d, ymax2d, 0, -2);
    pls->adv(1);
    pls->clear();
    pls->vpor( 0.0, 1.0, 0.0, 1.0 );
    pls->wind( -2.5, 2.5, -3.0, 3.0 );

    double basex = 2.0;
    double basey = 4.0;
    double height = 3.0;
    double xmin = 0.0;
    double xmax = 10.0;
    double ymin = 0.0;
    double ymax = 1000.0;
    double zmin = 0.0;
    double zmax = 360.0;
    double alt = 45.0;
    double az = 30.0;
    double side = 1;
    pls->w3d(basex, basey, height, xmin, xmax, ymin, ymax, zmin
              , zmax, alt, az);
    pls->box3( "bnstu", "Dipole Count", 0.0, 0,
               "bnstu", "Frame Count", 0.0, 0,
               "bcdmnstuv", "Angular Position", 0.0, 4 );

// This is for selecting the second view
// Following are to get the points in the right location!
pls->adv(2);

```

```

    pls->clear();
    pls->vpqr( 0.0, 1.0, 0.0, 1.0 );
    pls->wind( -2.5, 2.5, -3.0, 3.0 );
    // pls->env(xmin2d, xmax2d, ymin2d, ymax2d, 0, -2);
    // pls->wind( 0.0, 1.0, 0.0, 1.0 );
    zmin=-360;
    zmax=360;
    pls->w3d(basex, basey, height, xmin, xmax, ymin, ymax, zmin
              , zmax, alt, az);
    pls->box3( "bnstu", "Dipole Count", 0.0, 0,
               "bnstu", "Frame Count", 0.0, 0,
               "bcdmnstuv", "Angular Velocity", 0.0, 4 );

    pls->adv(3);

    //the second false is the one!

    legline[0] = "total energy";                                // pens
    legend
    legline[1] = "not assigned";
    legline[2] = "not assigned";
    legline[3] = "not assigned";

    pls->stripc( &idl, "bcnst", "bcnsth",
                  0, 100, 0.3, 0, 10,
                  0, 0,
                  true, false,
                  1, 3,
                  colline, styline, legline,
                  "t", "", "Average Kinetic Energy" );
}
#endif

int process(VideoCapture& capture)
{
    #ifdef GRAPHS_ENABLED
    styline[0] = colline[0] = 2;      // pens color and line
    style
    styline[1] = colline[1] = 3;
    styline[2] = colline[2] = 4;
    styline[3] = colline[3] = 5;

    pls->init();
    pls->ssub( 1, 3 );
    // pls->adv(1);
    cout<<endl<<"Initializing the interface for graphing"<<endl;
    clearGraph();

#endif
}

```

```

#ifndef TEMPERATURE_ENABLED
    vInitUSB();
#endif

/// Create Window
namedWindow( source_window, WINDOW_AUTOSIZE );
setMouseCallback( "Source", onMouse, 0 );
//Show the filtered image too

namedWindow( filter_window, WINDOW_AUTOSIZE );

//Show the settings window

namedWindow(settings_window,WINDOW_AUTOSIZE | CV_GUI_NORMAL);
createTrackbar( "Min Ang Vel Sq", settings_window, &
    minAngularVelocity, 1000000, 0 );
// H: 0 - 180, S: 0 - 255, V: 0 - 255
createTrackbar( "Hue Tolerance", settings_window, &hueTol, 180,
    0 );
createTrackbar( "Saturation Tolerance", settings_window, &
    saturationTol, 255, 0 );
createTrackbar( "Value Tolerance", settings_window, &valueTol,
    255,0 );

// createTrackbar( "ColorB Tolerance", settings_window, &
//     colorBTol, 256, 0 );
createTrackbar( "Minor Axis", settings_window, &minorAxis, 100,
    0 );
createTrackbar( "Major Axis", settings_window, &majorAxis, 200,
    0 );
createTrackbar( "Radius", settings_window, &radius, 200, 0 );
createTrackbar( "Ellipse Tolerance", settings_window, &
    ellipseTolerance, 200, 0 );

createTrackbar( "Brightness Inverse",settings_window, &
    brightInv, 255, 0 );
createTrackbar( "Canny (Hough)", settings_window, &canny, 200,
    0 );
createTrackbar( "Centre (Hough)", settings_window, &centre,
    200, 0 );
// createTrackbar( "Theta", settings_window, &thetaD, 3.141591,
//     0 );

/// Show in a window
namedWindow( "Contours", WINDOW_AUTOSIZE );
namedWindow( "Debug", WINDOW_AUTOSIZE );

////Voodoo intializations
// dipoles[0][0].current=0;
// dipoles[0][0].count[0]=0;

```

```

    // dipoles[0][0].count[1]=0;
    /// Load source image
    // src = imread( argv[1], 1 );

    // std::string arg = argv[1];
///////////

    // cout<<capture.get(CV_CAP_PROP_FRAME_HEIGHT);
    // capture.set(CV_CAP_PROP_FRAME_HEIGHT,1080);
    // capture.set(CV_CAP_PROP_FRAME_WIDTH,1920);

    // capture.set(CV_CAP_PROP_FRAME_HEIGHT,720);
    // capture.set(CV_CAP_PROP_FRAME_WIDTH,1280);

    capture.set(CV_CAP_PROP_FRAME_HEIGHT,480);
    capture.set(CV_CAP_PROP_FRAME_WIDTH,640);

    thread t1(tGrabFrame,capture);
    #ifdef MULTI_THREAD_DISPLAY
        #ifndef ATOMIC_DISPLAY
            thread t2(tUpdateDisplay);
        #else
            thread t2(tAtomicDisplay);
        #endif
    #endif
    #endif

for(;;)
{
    // processingImage.lock();
    //if the video feed has over 1 frame

    // if(buf.size()>1)
    // {
    //     buf.erase(buf.begin()); //remove the oldest frame
    //     srcPreCrop=buf[buf.size()-1]; //grab the latest frame
    // }

    // frameGrabbed.copyTo(srcPreCrop);
    frameRequested=true;

    if(frameGrabbed==true && !srcPreCrop.empty())
        // #ifdef ATOMIC_DISPLAY
        //     // if(updateDisplayCompleted)
        // #endif

    {
        frameRequested=false;      //this is so that the frame is
                                //not processed unless required
    }
}

```

```

frameGrabbed=false; //this is so that we know the
next time a frame is grabbed

#ifndef MULTI_THREAD_DISPLAY
// drawnow=true;
#ifndef ATOMIC_DISPLAY
drawnow.lock();
#endif
#endif

{ //IMAGE CAPTURE and CROP
// capture>>srcPreCrop;
//////////////////COMPUTATION TIME CALCULATION
tCstart=getTickCount();
///////////
tLast=t;
// t=getTickCount()/getTickFrequency(); //This is give
// time in seconds
// t=getTickCount();
t=tickWhenGrabbed;
deltaT=(t-tLast)/getTickFrequency();

if(dipoleRec)
{
    //if this is not the last frame, add a frame
    dipoleData.push_back(seedDipole);
    //This is to avoid overflows
    // if (dipoleData.size()>DframeBufferLen)
    //     dipoleData.erase(dipoleData.begin());
    //for the last frame
    dipoleData[dipoleData.size()-1].time=dipoleData[
        dipoleData.size()-2].time+deltaT;
    dipoleData[dipoleData.size()-1].count=0; //No dipoles
    // found before analysis!
    dipoleData[dipoleData.size()-1].
        meanSquaredAngularVelocity=0; //Initially zero
    dipoleData[dipoleData.size()-1].velValidCount=0;
        //This is to set the number of dipoles
        // for which velocity was calculated to zero. Very
        // important
}

// long cfInit=dipoleData.size()-1; //last frame

// //test for current frame
// if(dipoleData[cfInit].time!=t)
// {
//     //if this is not the last frame, add a frame
//     dipoleData.push_back(seedDipole);
//     //This is to avoid overflows
//     if (dipoleData.size()>DframeBufferLen)
//         dipoleData.erase(dipoleData.begin());
}

```

```

        //  //for the last frame
        // cfInit=dipoleData.size()-1;
        // dipoleData[cfInit].time=t;
        // }

if(srcPreCrop.empty())
{
    cout<<"Didn't get an image";
    break;
}
if(!cropped==0)
{
    src=srcPreCrop(selection);
}
else
    src=srcPreCrop;

#ifndef CALIBRATION_ENABLED
if(useCalibration)
{
    Mat temp=src.clone();
    undistort(temp, src, cameraMatrix, distCoeffs);
}
#endif
// imshow( source_window, srcPreCrop );

}

///////////////////////////////
{//COLOR FILTER
//Input src, output src_gray
Scalar lowerBound;
Scalar upperBound;
Mat srcCloneTemp=src.clone();

cvtColor(src,src,CV_BGR2HSV);
// lowerBound = colorA-Scalar::all(colorATol);
// upperBound = colorA+Scalar::all(colorATol);
upperBound=colorA+Scalar((float)hueTol,(float)
    saturationTol,(float)valueTol);
lowerBound=colorA-Scalar((float)hueTol,(float)
    saturationTol,(float)valueTol);

// Now we want a mask for the these ranges
inRange(src,lowerBound,upperBound, srcColorA);

// lowerBound = colorB-Scalar::all(colorBTol);
// upperBound = colorB+Scalar::all(colorBTol);
// We do it for both the colours
}

```

```

// cvtColor(src,)
inRange(src,lowerBound,upperBound, srcColorB);

// Now we create a combined filter for them
// addWeighted(srcColorA, 1, srcColorB, 1, 0,
// srcColorFilter);
addWeighted(srcColorA, 1, srcColorB, 0, 0, srcColorFilter
);

cvtColor(src,src,CV_HSV2BGR);
// cvtColor(srcColorA,srcColorA,CV_HSV2BGR);
/// Convert image to gray
cvtColor( src, src_process, COLOR_BGR2GRAY );

/// Now keep only the required areas in the image
// // // multiply(src_process,srcColorFilter,src_gray,1);

//Change the following to use greyscaled output
src_gray=srcColorFilter.mul(src_process/brightInv);
// src_gray=srcColorFilter;

// // // src_gray=srcColorFilter;

// Now blur it
blur( src_gray, src_gray, Size(3,3) );

// imshow( filter_window, src_gray );
}

////////////

// BLANK PROCESSING
// medianBlur( src, src, 5 );
// cvtColor( src, src_gray, COLOR_BGR2GRAY );

// // // blur( src_gray, src_gray, Size(3,3) );

////////////
// This is contour Detection
////////////
Mat threshold_output;
vector<vector<Point>> contours;
vector<Vec4i> hierarchy;

/// Detect edges using Threshold
threshold( src_gray, threshold_output, thresh, 255,
THRESH_BINARY );
/// Find contours
findContours( threshold_output, contours, hierarchy,
RETR_TREE, CHAIN_APPROX_SIMPLE, Point(0, 0) );

```

```

/// Find the rotated rectangles and ellipses for each
contour
vector<RotatedRect> minRect( contours.size() );
vector<RotatedRect> minEllipse( contours.size() );

for( size_t i = 0; i < contours.size(); i++ )
{ minRect[i] = minAreaRect( Mat(contours[i]) );
if( contours[i].size() > 5 )
{ minEllipse[i] = fitEllipse( Mat(contours[i]) ); }
}

for( size_t i = 0; i< minEllipse.size(); i++ )
{
//You can add aditional conditions to eliminate
detected ellipses
float minor = (minEllipse[i].size.height<minEllipse[i].
size.width)?minEllipse[i].size.height:minEllipse[i].
size.width;
float major = (minEllipse[i].size.height>minEllipse[i].
size.width)?minEllipse[i].size.height:minEllipse[i].
size.width;
bool good=false;

if(minor/major<1.3 && minor/major>0.7) //if close
enough to a circle
{
if((abs(minor-radius)<ellipseTolerance) && (abs(major-
radius)<ellipseTolerance))
good=true; //VALID CIRCLE DETECTED
}
else //IF its an ellipse then
{
if(abs(minor-minorAxis)<ellipseTolerance && abs(major-
majorAxis)<ellipseTolerance)
good=true; //VALID ELLIPSE FOUND
}
// if(
//   !((
//     (minEllipse[i].size.height>minMinorAxis &&
minEllipse[i].size.width>minMinorAxis)
//     &&
//     (minEllipse[i].size.height<maxMajorAxis &&
minEllipse[i].size.width<maxMajorAxis)
//   )
// )

// )
if(!good)
{

```

```

        // minEllipse[i]=RotatedRect(Point2f(0,0),Point2f
        // (0,0),0);
        minEllipse.erase(minEllipse.begin()+i--);
    }
}

/////////////////////////////
// Dipole Detection Algorithm
/////////////////////////////
// This detects form the ellipses detected, the dipoles!!
// This doesn't act on the dipoles itself!!!
// You yourself got confused about this :D
/////////////////////////////
vector<bool> detected (minEllipse.size(),false);

int k = !(dipoles[0][0].current);
dipoles[0][0].current=k;
dipoles[0][0].count[k]=0; //this count is different from
    that used in frames, they correspond to a subset of
    these which are position wise close enough to the seed
    frame

// dipolesA[0].lastcount=0;
for (int i=0; i<minEllipse.size();i++)
{
    if(detected[i]==false) //This detected corresponds to
        having been paired earlier
    {
        for (int j=0; j<minEllipse.size();j++)
        {
            if((i!=j) && detected[j]==false) //This is so that
                you don't test with yourself and with others that
                got paired
            {
                // if(abs(minEllipse[i].angle-minEllipse[j].angle
                // )< 15) //if the orientation matches (less
                // than 5 degrees), then
                {
                    //Find the distance between minEllipses

                    Point differenceVector=Point(minEllipse[i].
                        center.x - minEllipse[j].center.x,
                        minEllipse[i].center.y - minEllipse[j].
                        center.y); //find the difference vector
                    double distanceSquared=differenceVector.x*
                        differenceVector.x + differenceVector.y*
                        differenceVector.y; //find the distance
                        squared

                    //Find the major axis length

```

```

        double majorAxis=MAX( MAX(minEllipse[i].size.
            width, minEllipse[i].size.height) , MAX(
            minEllipse[j].size.width, minEllipse[j].
            size.height)); //find the max dimension

        //The ratio is the ratio between the distance
        //between the ellipse and the small circle
        //and the length of the major axis
        double errorPlusOne = distanceSquared /
            ((11.348/30)*(11.348/30)*majorAxis*
            majorAxis) ; //now to compare, just divide
            and see if it's close enough to one

        if (errorPlusOne>0.5 && errorPlusOne<2) //if
            the error is small enough, then its a match
        {
            // This is to ensure these don't get paired
            detected[i]=true;
            detected[j]=true;

            // this is collection of the final result
            int c=dipoles[k][0].count[k]++; //dont get
                confused, count is static, so even
                dipoles[0][0] would've worked, so for
                that matter, any valid index
            // Note the ++ is after because the count
            // is always one greater than the index of
            // the last element!

            // dipoles[k][c].angle=(minEllipse[i].angle
            // + minEllipse[j].angle)/2.0;
            // dipoles[k][c].angle=(minEllipse[i].angle
            // );

            //We're using two shapes, one ellipse and
            //one circle.
            RotatedRect largerEllipse = ( MAX(
                minEllipse[i].size.width, minEllipse[i].
                size.height) > MAX(minEllipse[j].size.
                width, minEllipse[j].size.height) )?
                minEllipse[i]:minEllipse[j];
            RotatedRect smallerEllipse = ( MAX(
                minEllipse[i].size.width, minEllipse[i].
                size.height) <= MAX(minEllipse[j].
                size.width, minEllipse[j].size.height)
                )?minEllipse[i]:minEllipse[j];

            //CENTRE BASED ANGLE ESTIMATION
            // double dCenterX=largerEllipse.center.x-
            // smallerEllipse.center.x;

```

```

// double dCenterY=largerEllipse.center.y-
// smallerEllipse.center.y;

// dipoles[k][c].angle=((180/3.1415926535)*
// atan2(dCenterY,dCenterX)) + 180;
///////////

//UNCOMMENT THIS PART FOR THE OLD ANGLE
// ESTIMATOR
// dipoles[k][c].angle=(largerEllipse.angle
// );

//Now we use the circle to remove the mod
// 180 problem and get the complete 360
// degree position
// if((smallerEllipse.center.y -
// largerEllipse.center.y) < 0)
// dipoles[k][c].angle+=180;
///////////

///////////

//THIS IS ATAN ASSISTED RESOLVING ELLIPSE
//ANGLE
//This is because the dipole angle is more
// accurate!
double preciseAngle=(largerEllipse.angle);

//This is calculated using the centres of
// the ellipse and circle

double dCenterX=largerEllipse.center.x-
// smallerEllipse.center.x;
double dCenterY=largerEllipse.center.y-
// smallerEllipse.center.y;

//IN CODE NOTES:
//ELLIPSE is zero/180 when straight
//atan2 gives slope of the line, above the
// axis is positive, below is negative

//The first + 180 is because atan2 returns
// between plus and minus pi,
// //and the minus ninety is because the
// ellipse is perpendicular to the line
// joining centres of the two ellipses (
// ellipse and circle)
double roughAngle=((((180/3.1415926535)*
atan2(dCenterY,dCenterX)) + 180);

//THIS DOESN'T GIVE PROPER RESULTS!!

```

```

        // //THIS IS INTERESTING..
        // // if (roughAngle>0 && roughAngle<180)
        // if(roughAngle>350 && preciseAngle<10)
        // {
        //   // preciseAngle+=180;
        //   ;
        //   //do NOTHING!
        //   //don't remove this because there are
        //   else cases also!
        // }
        // else if(roughAngle<10 && preciseAngle
        // >170)
        // {
        //   preciseAngle+=180;
        // }
        // else
        // {
        //   double equivalentAngle=roughAngle; // will always be between 0 and 180
        //   //if the precise angle is anyway close enough then dont do anything, else
        //   //The commented didn't work
        //   // if(( ((int)abs(preciseAngle-equivalentAngle)) % 360)>
        //   //preciseAngleTol && ( ((int) abs((preciseAngle+180)-equivalentAngle)) %
        //   //360)<preciseAngleTol)
        //   if(abs(preciseAngle-equivalentAngle)>
        //   preciseAngleTol && abs((preciseAngle+180)-equivalentAngle)<=preciseAngleTol
        //   )
        //   {
        //     preciseAngle += 180;
        //   }
        // }
        //THIS IS MATH POWER (actually minuscule manifestation of math's power)
if((shortestDistance(roughAngle,
    preciseAngle,360)-shortestDistance(
    roughAngle,preciseAngle+180,360))>5)
preciseAngle+=180;

dipoles[k][c].angle=findPrinciple(
    preciseAngle,360);
// dipoles[k][c].angle=roughAngle;
////////////////////

// dipoles[k][c].x=(minEllipse[i].center.x
// + minEllipse[j].center.x)/2.0;
// dipoles[k][c].y=(minEllipse[i].center.y
// + minEllipse[j].center.y)/2.0;

```

```

dipoles[k][c].order=MAX(largerEllipse.size.
    height, largerEllipse.size.width);

dipoles[k][c].x=largerEllipse.center.x; //(
    minEllipse[i].center.x + minEllipse[j].
    center.x)/2.0;
dipoles[k][c].y=largerEllipse.center.y; //(
    minEllipse[i].center.y + minEllipse[j].
    center.y)/2.0;

dipoles[k][c].e1=i; //don't know why this
    is required
dipoles[k][c].e2=j;

// A NEW DIPOLE HAS BEEN DETECTED (
    HOPEFULLY)
// TIME TO PUT IT IN PLACE (IF ASKED TO)
////////////////THIS IS FOR RECORDING/SAVING
    THE DIPOLE MOVEMENT///////////
if (dipoleRec==true)
{
    long cf=dipoleData.size()-1; //last
        frame

    for(int q=0;q<seedDipole.data.size();q++)
    {
        //This is to test which dipole belongs
            where in accordance with the
            seedDipole frame
        // if(MAX(abs(seedDipole.data[q].x -
            dipoles[k][c].x), abs(seedDipole.
            data[q].y - dipoles[k][c].y)) < (
            seedDipole.order/2.0) )
        //Or you could use the last fraame for
            this
        //CAVEAT: YOU MAY THINK WITH THE LAST
            FRAME, THERE MIGHT ALREADY HAVE
            BEEN MISSES!! BUT THAT'S ALRIGHT,
            EVERY LAST FRAME COMES FORM THE
            SEED FRAME, SO AT WORST, IT WILL BE
            //MATCHED TO THE DIPOLE IN THE SEED
            FRAME
        if(
            (MAX(abs(dipoleData[cf-1].data[q].x -
                dipoles[k][c].x), abs(dipoleData

```

```

        [cf-1].data[q].y - dipoles[k][c].
        y)) < (dipoleData[cf-1].order
        /4.0) )
&&
(dipoleData[cf].data[q].detected==
    false)
)
{
dipoles[k][c].id=q;
// dipoleData.data[q] = dipoles[k][c]
//TODO: Make a function for
    converting
dipoleData[cf].data[q].id=q;
dipoleData[cf].data[q].x=dipoles[k][c
    ].x; //Copy the relavent data
    from the dipole data collected
    into the temp dipole
dipoleData[cf].data[q].y=dipoles[k][c
    ].y;
dipoleData[cf].data[q].angle=dipoles[
    k][c].angle;
dipoleData[cf].count+=1;
if(cf==0)
    dipoleData[cf].data[q].
        instAngularVelocity=0;
else
{
    if(dipoleData[cf-1].data[q].
        detected==true)
    {
        double deltaAngle=(dipoleData[cf
            ].data[q].angle - dipoleData[
            cf-1].data[q].angle);
        if(abs(deltaAngle)>300) //eg.
            359 - 2
        {
            if(dipoleData[cf].data[q].angle
                <30) //roughly speaking, it
                    couldn't have
                    crossed 20!
            {
                deltaAngle=(dipoleData[cf].
                    data[q].angle+360)-
                    dipoleData[cf-1].data[q].
                    angle;
            }
            else //the other one must be
                close to zero!
            {
                deltaAngle=dipoleData[cf].
                    data[q].angle-(dipoleData

```

```

        [cf-1].data[q].angle+360)
        ;
    }
}
dipoleData[cf].data[q].
    instAngularVelocity=
    deltaAngle/deltaT;
dipoleData[cf].velValidCount+=1;
}
else
{
    dipoleData[cf].data[q].
        instAngularVelocity=0; //this
        is NOT TRUE! but doen't
        matter, because the usual
        analysis will use angle vs
        time
    //this is used for angular
    //velocity caclulation, in
    which it will be added, but
    not counted while dividing...
    so it is harmless
}
}

// if(cf>1)
// if(dipoleData[cf-1].data[q].
//     detected)
dipoleData[cf].
    meanSquaredAngularVelocity += (
    dipoleData[cf].data[q].
    instAngularVelocity*dipoleData[cf
    ].data[q].instAngularVelocity) ;
    //Add the sqr of inst angular
    //velocity, averaging is done later

dipoleData[cf].data[q].detected=true;
    //This is true only when the
    dipole's

dipoleData[cf].order=dipoles[k][c].
    order; //This is bad programming
    ..i should average, but doens't
    matter
//Now that it has matched, terminate
    the loop
q=seedDipole.data.size();
}
}

```

```

        }
        // magnitude(differenceVector.x,
        // differenceVector.y,distance);

        // point positionVector ((minEllipse[i].x +
        minEllipse[j].x)/2.0,(minEllipse[i].y +
        minEllipse[j].y)/2.0);

    }

}

}

}

//////////////AFter the frame has been processed, evaluate
// physical quantities of interest
f(dipoleRec==true)

long cf=dipoleData.size()-1; //last frame
if(dipoleData[cf].velValidCount>0)
    dipoleData[cf].meanSquaredAngularVelocity/=dipoleData[
        cf].velValidCount;
//else it would be zero, the meanSquaredAngularVelocity
// dipoleData[cf].meanSquaredAngularVelocity=sqrt(
    dipoleData[cf].meanSquaredAngularVelocity);

int temperatureFrameCount=0;
double temperatureFrame=0;
for(int k=cf;k>0;k--)
{
    double dTime=(dipoleData[cf].time-dipoleData[k].time);
    // cout<<dTime;
    if(dTime>=0 && dTime<DtemperatureAverageOverPeriod)
    {
        temperatureFrame+=dipoleData[k].
            meanSquaredAngularVelocity;
        // cout<<temperatureFrame;
        temperatureFrameCount++;
    }
    else
        k=0; //terminate the loop
}
if(temperatureFrameCount>0)
    temperatureFrame/=temperatureFrameCount;
else
    temperatureFrame=0;
dipoleData[cf].temperature=temperatureFrame;

#ifndef TEMPERATURE_ENABLE

```

```

//If you want to put pid, put it here..
#ifndef TEMPERATURE_SINGLDIPOLE
if(dipoleData[cf].temperature<(minAngularVelocity))
{
    static int lastFireIntensity=0;
    static long lastFireTime=0;
    int bestCandidate=0;      //Gotta pump some dipole! :P
    float lastMinDist=360;   //This is the how far it is
                             from the coil, can't be greater than 180
    for(int i=0;i<dipoleData[cf].data.size();i++)
    {
        float minDist=candidateAptitude(i);
        if(minDist<lastMinDist)
        {
            lastMinDist=minDist;
            bestCandidate=i;
        }
    }

    int dipoleToFire=seedDipole.data[ dipoleData[cf].data
        [bestCandidate].id ].id;
    // fireElectro(dipoleToFire,abs(dipoleData[cf].data[
    // bestCandidate].instAngularVelocity/10));
    cout<<( (tickWhenGrabbed - lastFireTime )/
        getTickFrequency() ) <<","<<((float)
        lastFireIntensity)/1000)<<endl;
    if( ( (tickWhenGrabbed - lastFireTime )/
        getTickFrequency() ) > ((float)
        lastFireIntensity)/1000) )

    {
        lastFireIntensity=30;
        fireElectro(dipoleToFire,lastFireIntensity);
        lastFireTime=tickWhenGrabbed;
    }
}
#endif

#endif TEMPERATURE_SINGLDIPOLE
//THE SINGLE DIPOLE ALGORITHM
if(!blind)
{
    if(dipoleData[cf].temperature<(minAngularVelocity))
    {
        int candidate=posPhysicalToDetected(tempCandidate);

        // if((dipoleData[cf].data[tempCandidate].angle -
        // COILANGLE) > 0)
        if(IsClockwise(dipoleData[cf].data[candidate].angle
            ,coilAngle,360))
    }
}

```

```

        if (dipoleData[cf].data[candidate].
            instAngularVelocity>=0) //if it is going in
            the opposite direction
        {
            if (invertPush)
                fireElectro(cf,tempCandidate);
            }
            else
            {
                if(!invertPush)
                    fireElectro(cf,tempCandidate); //to
                    increase speed, because the force will
                    be towards the coil
                }
            }

        }
        else //if the angle is negative, then
        {
            if (dipoleData[cf].data[candidate].
                instAngularVelocity<=0) //if it is going
                towards the coil
            {
                if(invertPush)
                    fireElectro(cf,tempCandidate);
                }
                else
                {
                    if(!invertPush)
                        fireElectro(cf,tempCandidate);
                    }
                    // fireElectro(cf);
                }
                // fireElectro();
            }
        }
        else
            fireElectro(cf,tempCandidate);
        #endif
        #endif
    }
    /////////////
#endif GRAPHICS_ENABLED
    if(dipoleRec==true)
    {
        // cout<<endl<<"DID SOMETHING";
        static long cfRe=0;
        long cf=dipoleData.size()-1; //last frame
        long t=(cf-cfRe);
        if(t>=1000)
        {
            cfRe=cf;
        }
    }
}

```

```

    clearGraph();
    t=0;
    // pls->bop();
    // pls->adv(1);
    // pls->clear();
    // pls->adv(2);
    // pls->clear();
}

for(int i=0;i<dipoleData[cf].count;i++)
{
    if(dipoleData[cf].data[i].detected)
    {
        pls->adv(1);

        pls->vpqr( 0.0, 1.0, 0.0, 1.0 );
        pls->wind( -2.5, 2.5, -3.0, 3.0 );
        pls->w3d(2,4,3,0,10,0,1000,0,360,45,30);
        double x = dipoleData[cf].data[i].id;
        double z = dipoleData[cf].data[i].angle;
        // double x = i;
        // double z=i;
        double y = t;
        pls->col0((i+1)%10);
        pls->poin3(1,&x, &y, &z,1);

        pls->adv(2);
        pls->vpqr( 0.0, 1.0, 0.0, 1.0 );
        pls->wind( -2.5, 2.5, -3.0, 3.0 );
        pls->w3d(2,4,3,0,10,0,1000,-360,360,45,30);
        // x = dipoleData[cf].data[i].id;
        z = dipoleData[cf].data[i].instAngularVelocity;
        // double x = i;
        // double z=i;
        // y = cf;
        pls->col0((i+1)%10);
        pls->poin3(1,&x, &y, &z,1);
    }
}

pls->adv(3);
pls->stripa(id1,0,cf,minAngularVelocity);
//NOTE: The library apparently has issues if you stop
//      printing both! it crashes at runtime :(
if(plotSqKE)
    pls->stripa(id1,1,cf,(dipoleData[cf].
        meanSquaredAngularVelocity));
else
    pls->stripa(id1,1,cf,(dipoleData[cf].temperature));

```

```

        }
#endif

//////////DRAWING THE CONTOUR AND DIPOLE
/// Draw contours + rotated rects + ellipses
drawing = Mat::zeros( threshold_output.size(), CV_8UC3 );
for( size_t i = 0; i< contours.size(); i++ )
{
    // Scalar color = Scalar( rng.uniform(0, 255), rng.
    // uniform(0,255), rng.uniform(0,255) );
    Scalar color = Scalar(0,0,255 );
    // contour
    drawContours( drawing, contours, (int)i, color, 1, 8,
                  vector<Vec4i>(), 0, Point() );

    // ellipse
    if(i<minEllipse.size())
        ellipse( drawing, minEllipse[i],
                 color, 2, 8 );

    // rotated rectangle
    // Point2f rect_points[4]; minRect[i].points(
    //     rect_points );
    // for( int j = 0; j < 4; j++ )
    //     line( drawing, rect_points[j], rect_points[(j+1)
    // %4], color, 1, 8 );
    // }

    // int xx=dipoles[k][i].x;
    // int yy=dipoles[k][i].y;
    // int theta=dipoles[k][i].angle;

    // line(drawing, Point2f(xx,yy),Point2f(xx + 5*cos(
    // theta), yy + 5*sin(theta)), Scalar(0,0,255),1,8);

}

for( int i=0;i<dipoles[0][0].count[k];i++)
{
    int xx=dipoles[k][i].x;
    int yy=dipoles[k][i].y;
    double theta = (3.1415926535/180) * dipoles[k][i].angle;

    line(drawing, Point2f(xx - 5*cos(theta), yy - 5*sin(theta)
    )),Point2f(xx + 5*cos(theta), yy + 5*sin(theta)),
          Scalar(0,255,255),5,8);

    // Use "y" to show that the baseLine is about
}

```

```

char text[30];
// dipoles[0][0].count[0]=1;
// sprintf(text,"%f",dipoles[0][dipoles[0][0].count[k
]-1].angle);
// sprintf(text,"%f",dipoleData[dipoleData.size()-1].
meanSquaredAngularVelocity);
int fontFace = FONT_HERSHEY_SCRIPT_SIMPLEX;
double fontScale = 0.5;
int thickness = 1;

int baseline=0;
Size textSize = getTextSize(text, fontFace,
                           fontScale, thickness, &
                           baseline);
baseline += thickness;

// center the text
Point textOrg((drawing.cols - textSize.width)/2,
               (drawing.rows + textSize.height)/2);
// // draw the box
// rectangle(drawing, textOrg + Point(0, baseline),
//            textOrg + Point(textSize.width, -textSize.
height),
//            Scalar(0,0,255));
// // ... and the baseline first
// line(drawing, textOrg + Point(0, thickness),
//       textOrg + Point(textSize.width, thickness),
//       Scalar(0, 0, 255));

// then put the text itself
// putText(drawing, text, textOrg, fontFace, fontScale,
//          Scalar::all(255), thickness, 8);
sprintf(text,"%1.1f",dipoles[k][i].angle);
putText(drawing, text, Point(dipoles[k][i].x,dipoles[k][i
].y), fontFace, fontScale, Scalar::all(0), thickness
*3, 8);
putText(drawing, text, Point(dipoles[k][i].x,dipoles[k][i
].y), fontFace, fontScale, Scalar::all(255),
thickness, 8);

sprintf(text,"%d%d",dipoles[k][i].id,i);

if(dipoleRec==true)
{
    if(dipoles[k][i].id < seedDipole.data.size())
        sprintf(text,"%d",seedDipole.data[dipoles[k][i].
id].id,i);
}

```

```

        putText(drawing, text, Point(dipoles[k][i].x,dipoles[k][i]
            ].y-10), fontFace, fontScale, Scalar::all(0),
            thickness*3, 8);
        putText(drawing, text, Point(dipoles[k][i].x,dipoles[k][i]
            ].y-10), fontFace, fontScale, Scalar(255,255,0),
            thickness, 8);

    //DEBUG ONLY
    if(i==0)
    {
        cimg = Mat(src.rows,src.cols+500, CV_8UC3, Scalar
            (0,0,0));
        // sprintf(text,"%1.1f",dipoles[k][i].angle);
        sprintf(text,"Press p to seed");
        // sprintf(text,"%1.1f",dipoleData[dipoleData.size()
            -1].data[0].instAngularVelocity);

        // if(dipoleData[dipoleData.size()-1]..
            meanSquaredAngularVelocity >0)
        if(dipoleRec==true)
            sprintf(text,"%1.1f",dipoleData[dipoleData.size()-1].
                meanSquaredAngularVelocity);
        putText(cimg, text, Point(src.rows/4,src.cols/4),
            fontFace, fontScale*12, Scalar::all(255), thickness
            *4, 8);
    }
}

///////////////////////////////
// THIS IS HOUGH
/////////////////////////////
// // cvtColor(img, cimg, CV_GRAY2BGR);
// // cimg=src_gray;
// // Mat cimg();
// Mat cimg(src.rows,src.cols, CV_8UC3, Scalar(255,255,255)
// );

// vector<Vec3f> circles;
// HoughCircles(src_gray, circles, CV_HOUGH_GRADIENT, 1,
// 10,
// // canny, centre, minMinorAxis, maxMajorAxis
// // change the last two parameters
// // // (min_radius & max_radius)
// // to detect larger circles
// // );

// // src_gray:s Input image (grayscale)
// // circles: A vector that stores sets of 3 values: x_{c
// }, y_{c}, r for each detected circle.
// // CV_HOUGH_GRADIENT: Define the detection method.
// Currently this is the only one available in OpenCV

```

```

// // dp = 1: The inverse ratio of resolution
// // min_dist = src_gray.rows/8: Minimum distance between
// // detected centers
// // param_1 = 200: Upper threshold for the internal Canny
// // edge detector
// // param_2 = 100*: Threshold for center detection.
// // min_radius = 0: Minimum radio to be detected. If
// // unknown, put zero as default.
// // max_radius = 0: Maximum radius to be detected. If
// // unknown, put zero as default

// for( size_t i = 0; i < circles.size(); i++ )
// {
//     Vec3i c = circles[i];
//     // Scalar color = Scalar( rng.uniform(0, 255), rng.
//     uniform(0,255), rng.uniform(0,255) );
//     Scalar color = Scalar( 255,255,0 );
//     circle( cimg, Point(c[0], c[1]), c[2], color, 3,
//     CV_AA);
//     circle( cimg, Point(c[0], c[1]), 2, color, 3, CV_AA)
// ;
// }

// imshow("Debug", cimg);

#ifndef MULTI_THREAD_DISPLAY
    updateDisplay();
#endif

#ifdef MULTI_THREAD_DISPLAY
    // drawnow=true;
    #ifndef ATOMIC_DISPLAY
        drawnow.unlock();
    #else
        updateDisplayRequested=true; //Both are required to
        trigger an update
        // updateDisplayCompleted=false; //The request flag is
        used to indicate processing is done, the second
        indicates the same here
        //however, once the frame has been updated, the update
        flag avoids unnecessary refreshing of the frames.
    #endif
#endif

/////////////////
// CLI
/////////////
char key = (char) waitKey(5); //delay N millis, usually
    long enough to display and capture input

```

```

    int kMax; //sorry, bad programming, but relatively
              desparate for results..
switch (key)
{
    #ifdef GRAPHS_ENABLED
    case 'o':
    {
        plotSqKE=!plotSqKE;
        cout<<endl<<"Plot measure of inst. average kinetic
                     energy:"<<plotSqKE;
        break;
    }
    #endif
    case 'o':
    {
        cout<<endl<<"Input the coil angle"<<endl;
        cin>>coilAngle;
        cout<<endl<<"CoilAngle updated to "<<coilAngle;
        break;
    }
    case 'i': //Initialize the indices of the seed
    {
        //you've to use brackets in case if you want local
        //variables!
        if(dipoleRec==true)
        {
            cout<<endl<<"Input the indices in order to
                         calibrate "<<endl;
            for (int newLocation=0;newLocation<seedDipole.data.
                size();newLocation++)
            {
                int val;
                cin>>val;
                seedDipole.data[val].id=newLocation;
            }
        }
        else
        {
            cout<<endl<<"Start dipole recording using the key '
                         p' and try again";
        }
        break;
    }
    case 'c':
        #ifdef GRAPHS_ENABLED
        clearGraph();
        #endif
        break;
    case 'C':
        mode=1;
}

```

```

cout<<"Mouse will capture color now. Right click for
      one, left for the other"<<endl;
break;
case 'S':
mode=0;
cout<<"Screen crop mode selected. Mouse will capture
      start point at left click and the other point at
      right click"<<endl;
break;
case 'p':
{
    cout<<"Look what you've done!"<<endl<<"Just kidding
          : This frame will be used as a seed"<<endl;
    dipoleRec=true; //Enable dipole recording
    seedDipole.data.clear(); //clear the data
    dipoleSkel tempDipole; //create a temporary dipole
                           skeleton
    k=dipoles[0][0].current; //find the current buffer
                           of dipoles detected (double buffered for
                           possible multithreading)
    kMax=dipoles[0][0].count[k]; //find the number of
                           dipoles detected in the last scan

    for(int c=0;c<kMax;c++)
    {
        tempDipole.x=dipoles[k][c].x; //Copy the relevant
                                       data from the dipole data collected into the
                                       temp dipole
        tempDipole.y=dipoles[k][c].y;
        tempDipole.angle=dipoles[k][c].angle;
        tempDipole.instAngularVelocity=0;
        tempDipole.detected=false; //This is to ensure
                                   the dipole was detected, but for the seed
                                   frame, it is left false.
        tempDipole.id=c;
        seedDipole.data.push_back(tempDipole); //Add the
                                       data in the seedframe's data stream

        seedDipole.order+=dipoles[k][c].order; //to get
                                       the average order
        if(c>0)
        {
            seedDipole.order/=2.0;
        }
    }
    seedDipole.time=0; //Initial time is to be stored
                       as zero
    dipoleData.push_back(seedDipole);
    break;
}
case 'w':
{

```

```

        cout<<endl<<"Writing angle vs time for the first
              dipole to file"<<endl;
        if(dipoleRec==true)
        {
            sprintf(fileName,"latticeAnalyserBeta_%d",
                   getTickCount());
            pFile = fopen (fileName,"w");

            //Loop through all the frames
            for (vector<dipoleFrame>::iterator dD =
                  dipoleData.begin() ; dD != dipoleData.end();
                  ++dD)
            {
                //Within each frame, loop through all dipoles?
                // for(vector<dipoleSkel>::iterator dS = dD.
                //       data.begin() ; dS!=dD.data.end() ; ++dS)
                // {

                // }
                //or just print the first dipole
                if(dD->data[0].detected)
                    fprintf (pFile, "%f,%f,%f\n",dD->data[0].
                        angle,dD->time,dD->
                        meanSquaredAngularVelocity);
                    //->data[0].instAngularVelocity);
                // fprintf (pFile, "%d,%d\n",dD->data[0].angle,
                //           dD->time);
            }

            // for (int p=0;p<dipoleData.size();p++)
            // {
            //   fprintf(pFile,"%d,%d\n",dipoleData[p].data.
            //           size(),dipoleData[p].time);
            // }
            fclose (pFile);
            // fprintf (pFile, "Name %d [%-10.10s]\n",n,name)
            //

        }
        break;
    }
case 'F':
{
    // Table Description
    // Time      Dipole 0      Dipole 1      Dipole 2 ...
    // cout<<endl<<"Writing angle of all dipoles for the
    // given frame"

    if(dipoleRec==true)
    {

```

```

cout<<endl<<"Writing all the data collected so far
      into a file";
sprintf(fileName,"latticeAnalyserRENAMEorLOSEme");
pFile=fopen(fileName,'w');
//Write the column names (very important to figure
//out which dipole corresponds to which spatial
//location)
fprintf(pFile,"Time");
for(int fi=0;fi<seedDipole.data.size();fi++)
{
    fprintf(pFile,"\t Dipole %d",seedDipole.data[fi].
             id);
}
fprintf(pFile,"\n");

//Now write the data
for (vector<dipoleFrame>::iterator dD=dipoleData.
     begin(); dD!=dipoleData.end();dD++)
{
    //The first entry is time
    fprintf(pFile,"%f",dD->time);
    for(vector<dipoleSkel>::iterator dData=dD->data.
         begin(); dData!=dD->data.end(); dData++)
    {
        //Second entry onwrds, we have the dipole
        //angles
        if(dData->detected==true)
            fprintf(pFile,"\t %f",dData->angle);
        else
            fprintf(pFile,"\t");
    }
    fprintf(pFile,"\n");
}
fclose (pFile);
cout<<endl<<"Written! Unless something broke..";
}
else
    cout<<endl<<"Data recording is off. Turn it on
                  using 'p'.";
break;
}
case 'b':
//This is to make blind
blind=!blind;
cout<<"Blind:"<<blind<<endl;
break;
case 'd':
useCalibration=!useCalibration;
cout<<endl<<"Calibration Use:"<<useCalibration<<endl;
break;
case 'I':
//invert push

```

```

        invertPush=!invertPush;
        cout<<"Push"<<invertPush<<endl;
        break;
    case 'W':
    {
        pFile=fopen("TestComputation","w");
        for(vector<double>::iterator d=computationTime.
            begin();d!=computationTime.end();++d)
        {
            fprintf(pFile,"%f\n",*d);
        }
        fclose(pFile);
        break;
    }
    case 'q':
    case 'Q':
    case 27: //escape key
        destroyWindow(source_window);
        destroyWindow(filter_window);
        destroyWindow(settings_window);
        destroyWindow("Contours");
        destroyWindow("Debug");

        #ifdef TEMPERATURE_ENABLED
        vCloseUSB();
        #endif
        threadsEnabled=false;
        t1.join();
        #ifdef MULTI_THREAD_DISPLAY
        t2.join();
        #endif
        // destroyAllWindows();
        // this_thread::sleep_for( chrono::milliseconds
        (5000) );
        // waitKey(1000);
        return 0;
    // case ' ': //Save an image
    //     sprintf(filename, "filename%.3d.jpg", n++);
    //     imwrite(filename, frame);
    //     cout << "Saved " << filename << endl;
    //     break;
    default:
        break;
    }
    tCend=getTickCount();
    tCdelta=tCend-tCstart;
    computationTime.push_back(tCdelta/getTickFrequency());
}
// processingImage.unlock();
}
#endif GRAPHS_ENABLED
delete pls;

```

```

#endif
return 0;

}

// double distSq(int x1,int y1,int x2,int y2)
// {
//   return (pow(x1-x2,2) + pow(y1-y2,2));
// }
// void latticeAxis(vector<dipoleSkel>& data,vector<double>&
// angles)
// {
//   int lastDistance=10000;
//   // Calculating the shortest distance squared, between the
//   first point and all other points
//   for(int i=1;i<data.size();i++)
//   {
//     int distance=pow((data[0].x-data[i].x),2) + pow((data[0].y
// -data[i].y),2);
//     lastDistance=MIN(distance,lastDistance);
//   }

//   double tolLower=0.5;
//   double tolHigher=1.5;
//   for(int i=0;i<data.size();i++)
//   {
//     for(int j=0;j<data.size();j++)
//     {
//       if(i!=j)
//       {
//         double neiDist=distSq(data[i].x,data[i].y,data[j].x,
// data[j].y)/(lastDistance)
//         if( neiDist > tolLower && neiDist<tolHigher ) //Yup,
// found a neighbour!
//         {
//           double angleFound=atan2( (data[i].y - data[j].y) / (
// data[i].x - data[j].x) );
//           angles.push_back(angleFound); //Added the angle
// found to an array
//         }
//       }
//     }
//   }

// inline void latticeAxisTest()
// {
//   // Calculate shortest distance squared between the first
//   point and all other pointss

```

```

//    // for each point, find all neighbours, store the angle
//    determined in an array
//    // TODO: In the previous step, add a method to avoid
//    incorrect counting

// }

// void latticeAxis(vector<dipoleSkel>& data)
// {
//Find neighbours
//Find the ones with only 3 neighbours
//Within these, find the ones with a particular slope missing

// double a=3.14; // The value you seek
// std::find_if(v.begin(),v.end(),[a](double b) { return a>b-
//    epsilon && a<b+epsilon; });

// }
#ifndef TEMPERATURE_ENABLED
#ifndef TEMPERATURE_SINGLDIPOLE
inline void fireElectro(long frame,int id)
{
    //this is to avoid too many fires within a short time
    static long lastFrame=0;
    // static bool alternate=false;
    if(frame-lastFrame>3)
    {
        // alternate=!alternate;
        // if(alternate)
        // {
            char usbBuf[REPORT_LEN]={dipolePort[id],dipoleBit[id]
                ],0,200};

            nWriteUSB((unsigned char*)usbBuf,14);
            lastFrame=frame;
            cout<<endl<<">> Temperature: Electro Fired for dipole "<<
                id;

        // }
    }
}
#else
void fireElectro(int id, int intensity)
{
    char usbBuf[REPORT_LEN]={dipolePort[id],dipoleBit[id],0,
        intensity};

    nWriteUSB((unsigned char*)usbBuf,14);
    // lastFrame=frame;
    cout<<endl<<">> Temperature: Electro Fired for dipole "<<
        id<<" with intensity "<<intensity<<" ";
}

```

```

    }

#endif
#endif

void temperatureTest()
{
#ifdef TEMPERATURE_ENABLED
    cout<<"Which dipole to fire?";
    int i=0;
    cin>>i;

    char usbBuf[REPORT_LEN];
    for(int q=0;q<REPORT_LEN;q++)
    {
        usbBuf[q]=0;
    }

    // usbBuf[0]='B';
    // usbBuf[1]=5;
    usbBuf[0]=dipolePort[i];
    usbBuf[1]=dipoleBit[i];
    usbBuf[2]=255;
    usbBuf[3]=255;

    cout<<"temperature Test"<<endl<<endl;
    cout<<"Initializing Hardware"<<endl;
    vInitUSB();
    cout<<endl;
    // cout<<"Initialization Successful"<<endl<<endl;

    cout<<"Writing to hardware:"<<usbBuf<<endl;
    int usbLen;
    if( (usbLen=nWriteUSB( (unsigned char *) usbBuf,14)) )
    {
        cout<<"Writing Successful"<<endl<<endl;
    }

    cout<<"Reading from hardware"<<endl;
    usbLen=nReadUSB( (unsigned char*) usbBuf);
    if(usbLen==0)
        cout<<"Failed!"<<endl<<endl;
    else
    {
        usbBuf[usbLen]= '\o';
        cout<<"Data Read: "<<usbBuf<<endl;
        for(int i=0;i<usbLen;i++)
            printf("%d",usbBuf[i]);
        cout<<endl<<endl;
    }
    vCloseUSB();
}

```

```

#else
    cout<<"Temperature Support not enabled";
#endif
}

/** 
 * @function main
 */
int main( int ac, char** argv )
{
    initializeMultithreadResources();
#ifdef TEMPERATURE_ENABLED
    getTemperaturePins();
#endif

    cout<<"Loading";
    cout<<endl<<endl
        <<"Lattice Analyser | version "<<version<<endl
        <<"_____"\<<endl
        <<"Created at the National Physical Laboratory, New Delhi
            "\<<endl
        <<endl
        <<"Project Repository Folder: github.com/toAtulArora/
            IISER_repo/Summers_2013/NPL"\<<endl
        <<endl
        <<"For help type"\<<endl
        <<"help"\<<endl
        <<"(Like you couldn't guess!)"<<endl<<endl
        <<"\t now what?  ";
}

for(;;)
{
    string a;
    cin>>a;

    if(!a.compare("help"))
    {
        cout<<endl; //for multi line, beauty stuff

        cout<<"Command \t Description"\<<endl
        <<"_____ \t _____"\<<endl
        <<"temp    \t Launches hardware test"\<<endl
        <<"temperature \t same as temp"\<<endl
        <<"<number> \t Initiates analysis of dipoles using the
                    corresponding camera"\<<endl
        <<"q        \t exit or quit"\<<endl;

        cout<<endl; //again for multi line console outputs, to
                    maintain beauty
    }
}

```

```

else if(!a.compare("exit") || !a.compare("quit") || !a.
    compare("q"))
{
    break;
}
else if(!a.compare("temperature") || !a.compare("temp"))
{
    temperatureTest();
}
else
{
    // if(atoi(a.c_str())!=0 || !a.compare("0"))
    cout<<"Commands for this mode:<<endl
    <<"c \t Will clear the graphs"<<endl
    <<"C \t Enable mouse capture of colour"<<endl
    <<"S \t Screen crop is selected, viz Drag with left click
        to select a sub window"<<endl
    <<"p \t This frame will be selected as the seed frame"<<
        endl
    <<"w \t Write the angles and dipoles, of the first dipole
        to file"<<endl
    <<"W \t Write computation times to file"<<endl<<endl;

    threadsEnabled=true;
    getCameraCalibrationParameters();
    VideoCapture capture; //try to open string, this will
        attempt to open it as a video file
    // if (!capture.isOpened()) //if this fails, try to open as
        a video camera, through the use of an integer param

    capture.open(a);
    if(!capture.isOpened())
    {
        capture.open(atoi(a.c_str()));
    }

    if (capture.isOpened())
    {
        process(capture);

    }
    else
    {
        cerr << "Failed to open the video device specified" <<
            endl;
        // return 1;
    }
}
// else if(!a.compare("latticeAxis"))
// {
//     latticeAxisTest();
// }

```

```

        cout<<endl<<"\t now what? ";
    }

    return 0;
}

```

2.2.5 temperature; the rise

'temperature' was built around the Atmega8 processor to start with. Its task was to energize the coils of the dipoles, when instructed by the Lattice Analyser. Its source code was written in C, compiled with the free AVR-GCC compiler using some other sister tools of it. Atmega's interface to the computer was built from Dr. Ravi Mehrotra's library, which was built to simplify the existing ob-dev's virtual USB libraries. The coils are powered directly using the chip for the 2×2 setup. For larger matrices, a multiplexer will be required and built suitably.

The current that was roughly enough to align the dipole to the coil was (after experiments with a 6 Volt battery and resistance of coil measurement, viz. 7 ohms) found to be about 1 ampere. The microcontroller can sync at most 20 mA of current at a given pin. Further for the USB interface, the system was set to run at 3.3 V (this can be pushed up to 5V also, but that would've required redesigning the circuit) and the current limiting resistor was correspondingly chosen to be about 150 ohms. This was put in series with the coil and tested. It was found that the dipole wouldn't, for even a second long pulse, align itself to the coil, starting from some initial angle. However, when further experiments were done for pumping in energy using the algorithms developed for the Lattice Analyser, this push was found to be enough, even with a few milliseconds long pulse. This version of temperature has been given in [Figure 15](#)

The main file for the temperature has been listed herewith.

tempererture.c

```

/*
filename: temperature
description: This is the firmware of the hardware that
            simulates temperature on the dipole lattice

baby steps(TM):
1. Bare Minimum Tests: Communication Test with
   the lattice analyser      [done]
2. Proof of Concept:
   The target of this would be to keep a
   dipole continuously rotating

```

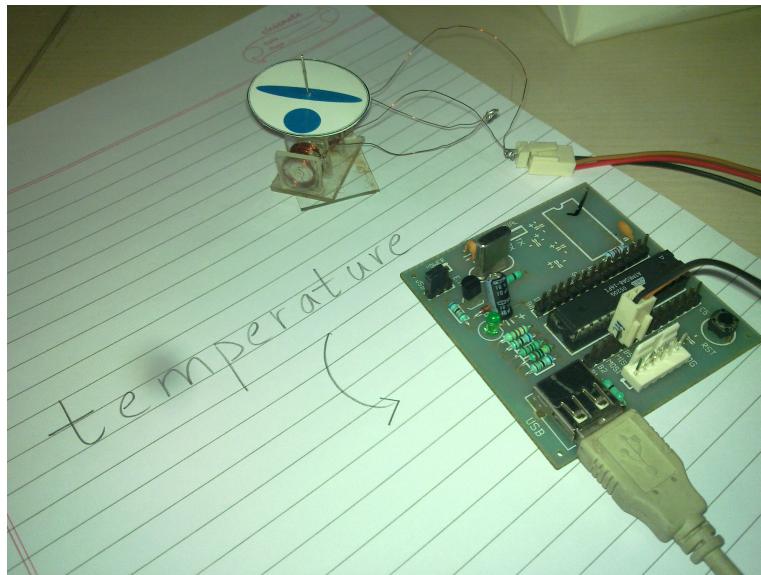


Figure 15: First Version of Temperature

- a. Test the kind of currents and voltages required to fire up the magnet
- b. Make a program and fire up the magnet from the lattic analyser

```

communication protocol [clear text]
fixed length, 10 characters (8 bit each)

xxxxx xxxx
\---/ \---/
|      |
|      +----- Field Intensity
+-----Dipole ID

for
Binary Protocol for testing
fixed length, 10 charactes, 8 bit each
0 1 2 3 4   5 6 7 8 9
x x x x x   x x x x x
| | | |     \ - - - /
| | | |           |
| | \ |           +-----Undefined for now
\ | -|-----Dipole Intensity
(65536 max)
-|-----Dipole ID (65536 max)
Binary Protocol V0.2
fixed length, 4 characters for now
0 1 2 3 4
x x x x x
| | | |
| | | |
| | \ |

```

```
\ | -----Dipole Intensity
  (65536 max)
  -| -----Dipole ID
                                         Port
                                         Bit

*/
#include "usbIO.h"
#include "avriomacros.h"
// #include "temperatureConfig.h"
// #define DEBUG_STAGE_ZERO

// This is to ease programming, reduce codesize
// #define port(x) port##x
// #define bit(x) bit##x
#define fireElectro(port,bit,duration) \
{ \
    out(bit,port); \
    off(bit,port); \
    for(U16Bit j=0;j<duration;j++) \
        _delay_us(1); \
    in(bit,port); \
    on(bit,port); \
}
#endif DEBUG_STAGE_ZERO
// U16Bit acknowledge[10]="Ok";
U16Bit* dipoleID;
U16Bit* intensity;
U8Bit   len;
U8Bit*  data=0;
#endif

int main(void)
{
    #ifdef DEBUG_STAGE_ZERO
        U8Bit   i;
        U8Bit   ucInDataLen;
        U8Bit   *pucInData = 0;
    #endif

        usbInit();
```

```

// ----- enforce re-enumeration.
usbDeviceDisconnect(); // enforce re-enumeration
, do this while interrupts are disabled!
i = 255;
while(--i)
    // fake USB disconnect for > 250 ms
    _delay_ms(1);
usbDeviceConnect();

sei();
for(;;)
{
    usbPoll();
    ucInDataLen = ucGetUSBData( &pucInData );
    if ( ucInDataLen > INBUFFER_LEN )
        ucInDataLen = INBUFFER_LEN;
    if ( ucInDataLen )
    {
        // copy indata and send back
        ascii values incremented by 1
        //
        // also
        ,
        make
        the
        first
        value
        ,
        the
        length
        of
        data
        received

        pucOutBuf[0] = ucInDataLen;
        for ( i = 0; i < ucInDataLen; i++)
            )
            pucOutBuf[i+1] =
                pucInData[i] + 1;
        vSendUSBData( ucInDataLen+1 );
    }
}

```

also
,

make
the
first
value
,

the
length
of
data
received

```

        }
        return 0;
    #else
        // for(;;)
        // {
        //     DDRB |= (1<<5);
        //     PORTB |= (1<<5);
        //     _delay_ms(1000);
        //     PORTB &= ~(1<<5);
        //     _delay_ms(1000);

        //     // DDRB=0xff;
        //     // // DDRC=0xff;
        //     // // PORTD=0xff;
        //     // // PORTB=0xff;
        //     // // _delay_ms(1000);
        //     // // // DDRB=0x0;
        //     // // // DDRC=0x0;
        //     // // // PORTD=0x0;
        //     // // PORTB=0x0;
        //     // // _delay_ms(1000);
        // }

        DDRB=0;
        DDRB &= ~(1<<5);
        //Make it high impedance again
        PORTB |= (1<<5);
        //

        usbInit();                                //Initialize USB
        usbDeviceDisconnect();                     //Disconnect and re-connect
        _delay_ms(255);
        usbDeviceConnect();

        sei();                                     //Enable Interrupts
        for(;;)
        {
            usbPoll();                            //
            // This has to be called frequently
            // enough
            len=ucGetUSBData(&data);             //Get data
            if(len>INBUFFER_LEN)
                len=INBUFFER_LEN;
            // truncate if overflow
            if(len)                               //Got
                data?                           //

```

```
{  
    dipoleID=(U16Bit*)&data[0];  
        //point the  
        dipoleID to its location in  
        the data  
  
    intensity=(U16Bit*)&data[2];  
        //point the intensity  
        pointer to its location  
  
    if(*dipoleID==256)  
        //if  
        the id is for the zeroth  
        dipole (testing)  
    {  
        pucOutBuf[0]=(U8Bit) (*  
            intensity);  
        // pucOutBuf[0]=(U8Bit)  
        //(*(intensity[0]))  
        vSendUSBDData(1);  
  
            //Acknowledge  
            receiving data  
  
        //TODO: ADD PORT CODE  
        //  
        Fire up the magnet  
        for a time  
        proportional to the  
        intensity  
  
        DDRB |= (1<<5);  
  
            //Define as  
            output  
PORTB &= ~(1<<5);  
  
            //Make port D  
.4 low, to fire the  
magnet
```

```

        for(U16Bit j=0;j<(*
            intensity);j++)
            _delay_us(1);
    DDRB &= ~(1<<5);

            //Make it
            high impedance again
    PORTB |= (1<<5);

            //

            // _delay_us((U8Bit) (*
            intensity/2) );
            // _delay_us((U8Bit) (*
            intensity/2) );
            //TODO: ADD CODE TO TURN
            OFF
}
else
{
    char pin=data[1];

    pucOutBuf[0]=':';
    pucOutBuf[1]='(';

    // if(data[0]=='A')
    //     fireElectro(A,
    //                 pin,
    //                 *intensity)
    if(data[0]=='B')
    {
        fireElectro(B,pin
                    ,*intensity)
    }
    else if(data[0]=='C')
    {
        fireElectro(C,pin
                    ,*intensity)
        pucOutBuf[0]='C';
        pucOutBuf[1]=data
                    [1];
    }
    else if(data[0]=='D')
        fireElectro(D,pin
                    ,*intensity)
    // don't even think of
    // missing the brackets,
    // the macro is a set
    // of statements!

    vSendUSBData(2);
}

```

```

        //Acknowledge
        receiving data

    }

}

return 0;
#endif

}

```

```

commit 8e385842ed187496bb320697afceea6ac735183f
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Thu Jul 18 22:23:15 2013 +0530

    Updating the documentation

commit 3fd0c2734e2cb00eaf4e036dee732ff0c38dfca7
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 16 17:28:58 2013 +0530

    Minor change, major fix (hopefully) fixed the modding problem
    (after rediscovery:P)

commit 6e6bf4f59a34b0e14246fd8e28845bdc2de401df
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 16 17:09:45 2013 +0530

    Converted colour detection to HSV from BGR

commit ce55da42951066b207320efe944169b50b82ab08
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 16 11:40:47 2013 +0530

    Slight failures in the modding problem also resolved..finally
    based on equivalent classes from math

commit a974f4c3b2aa02e06c3f7df8a6fad2fdd0f66223
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 16 11:02:29 2013 +0530

    Temperature: Solved the modding problem for the axis

commit 33fda35ce344b612b786853b044e2229811fefcf
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu Jul 11 15:44:37 2013 +0530

    Completed addition of distortion correction and it has worked
    well, but hasn't solved the problem

commit 7ad448b39f301eceb69a8bdb1206c67f8f8196ca

```

```
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu Jul 11 12:48:02 2013 +0530

Documentation: README updated

commit 3efc849a25294a881bf05e99af4afa02d6031e2c
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 10 18:05:57 2013 +0530

More error analysis and found an error in the error analysis

commit 25debdf7a1a06aeab24b14f66eb597eda39ff7d9
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 9 17:39:49 2013 +0530

Doing error analysis on the observations from the software to
figure out what to optimize next

commit e2e8270db661e3e902626f188f32d1950445b404
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 9 12:01:56 2013 +0530

Ready for error analysis, recorded all the data into a data
file

commit 0f8893ca05b450d67c3a23ade21c6d74c693149a
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jul 8 17:42:23 2013 +0530

minor or no change

commit 5c26dd130980019fa34f5700cc5512ddb80d60c7
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jul 8 15:24:19 2013 +0530

latticeAnalyser: Functionality for re-assigning dipole
numbers made functional :P

commit 55ea71e74a5416dd7f7417acf7eald1ff48d754
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jul 8 14:09:03 2013 +0530

latticeAnalyser: Another finer improvement on the inst vel
calculation

commit 6ed09058eb15263ae4ba74775f9b4cafaf9bc83
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jul 8 11:23:12 2013 +0530

Documentation: README updated

commit 1c822e7fe983d18e84be3e3ebe9a8c084ab72f16
```

Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 17:49:41 2013 +0530

Angle modding problem finally resolved for the greater good :
P

commit f83f81c76577417bef7725a040eb638f66a7906d
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 17:12:24 2013 +0530

Error message in graph; its cause has been resolved and
consequently they've been suppressed

commit 35fde5f24b524bc4bcb5ccbd9ad6a72608ed7f54
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 17:38:25 2013 +0530

Multi threading now functional, though unstable, angle
estimator still troublesome, blips

commit 9bda4ff89f6c343609f7a9be0a95d784a8b021c2
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 15:16:45 2013 +0530

Control for min Angular velocity (for use with temperature)
added. Angle estimator now even more stable. No glitches
so far

commit 03154549ee38e6b4421f0a27797c4c00dc9626e7
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 14:27:20 2013 +0530

Angle estimator now more stable, though still gives
fluctuations

commit aa67fe4b451af9af9a12acb899e6d28c2e1359cc
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 14:05:55 2013 +0530

Angle estimator now much more stable, but still peaks out

commit a0dfdae7cda0a9e35b90632d3513ab5a293be6fe
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jul 5 13:49:14 2013 +0530

Angle estimator tested, poor precision with atan2, now using
atan2 assisted modding to ellipse based angle detection

commit c515d301935b620fcc2004f5057c63a9881e1974
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu Jul 4 18:23:17 2013 +0530

```
Documentation: Screenshot was missed out

commit 9f0faf13c588cbd325a2067f0c54005bdb9f0fe7
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu Jul 4 18:21:42 2013 +0530

Documentation: README updated

commit a5880c4b1185ed0e5557d51181e3165e8345a7ce
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu Jul 4 18:14:21 2013 +0530

Kinetic Energy graph added, problem located and calculation
corrected

commit 10d125df11fdb250ee3a04e2d51a8bde97cd3f87
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 17:07:57 2013 +0530

Documentation: Readme updated

commit 3b8a0fcbb44b4be72622fb8bff6d7c226a60da80f
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 16:21:51 2013 +0530

Documentation: READMEs updated

commit 16438bd90783665801e5f334421863af78544773
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 16:19:25 2013 +0530

Added auto clear on overflow for the graphs

commit a37c4fdb0fce9d140c7ab2e169270392b46daf26
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 15:19:39 2013 +0530

atan2 used for angles; problem of outlying angles solved

commit 132b1d4b32c794b9bca31ff575521290e30f67fd
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 15:00:05 2013 +0530

2 graphs in one created, one for velocity, one for position

commit 282c04b3bd3824e77e6d57dcac5f393f2adbf988
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed Jul 3 11:48:52 2013 +0530

3D graph plotting, updated to show angles

commit 8dedf79959fcb26c39e1ff7c0ec334fc8bf65732
```

```

Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 2 17:07:12 2013 +0530

    Fagocytosis successful: Graphing including within the program

commit 5dee7e255f4ac1f281399937619af5db8c012a80
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 2 16:59:56 2013 +0530

    Fygocytosis done, implementing the rest of it

commit be11592758b03ab9487ffe985ee8de45005db691
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 2 15:47:53 2013 +0530

    Realtime update finally done for 3d graphics

commit a91a624ccfe896b9acfddd2efbeb24fc5b5d3b24
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 2 13:59:37 2013 +0530

    Now stable

commit bdcc662088707dd91789a53748d49feelbef1d76
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jul 2 13:52:33 2013 +0530

    Working on using plplot and tried to write an algorithm to
        support auto grid numbering; but doomed

commit 7c8f275d2e1059b25e33fc34d381a74ed54a3e8e
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon Jul 1 11:28:29 2013 +0530

    After summer school

commit 4b1a5a3758caa379c2cdbca7e9e657953b5757a
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Sat Jun 8 00:00:05 2013 +0530

    Documentation: code listings updated

commit 261de8437cf18f8f11d61964343d8529603aa1c
Merge: 803d298 502f050
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Fri Jun 7 23:57:40 2013 +0530

    Merge branch 'master' of https://github.com/toAtulArora/IISER
        _repo

commit 803d2984bea33f8fb0e206a2f378638048ec90b6
Author: Atul Sinh Aurora <toatularora@gmail.com>
```

```
Date: Fri Jun 7 23:57:06 2013 +0530

Documentation: Progress for the week added, including the
milestone event

commit 502f050adf2d40f697e70b318a8f3705e8837020
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri Jun 7 18:02:18 2013 +0530

[MileStone commit] latticeAnalyser and temperature: Sight
based energy pumping into the dipole successfull

commit 2a24425f8af44d372d9a5b3887c0db0b7aa9989b
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Fri Jun 7 09:00:04 2013 +0530

latticeAnalyser: trying to compile on windows

commit ae2c44716c144a80ce276959cd8e2df1a92856bf
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu Jun 6 16:24:23 2013 +0530

sachetIO: buffer function fixed and tested ok

commit efa7bdded264e2aeb81945a807e975637ae8e47a
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu Jun 6 15:32:22 2013 +0530

sachetIO: added the buffered read function

commit 22b0d4a24d5281dd1753aba4ab1b6a71b341bf7d
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu Jun 6 13:21:03 2013 +0530

Documentation: Readme Updated with Wednesday's progress

commit ffcc38dff780bb33e426f323e42626cd5db1f6b
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Wed Jun 5 22:42:27 2013 +0530

sachetIO: bare minimum fixed and tested

commit ea3e045f05988e42d9eb2dd884a3ceff949e4abc
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Wed Jun 5 21:45:36 2013 +0530

sachetIO: Fixing recieving

commit 07b8135ddee04430704625bc95cc3091d2098a
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Wed Jun 5 21:13:32 2013 +0530
```

```

sachetIO: Sending tested

commit 0cb0ee0d725288a914cdc7327b7d8271a4545a13
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Wed Jun 5 20:46:09 2013 +0530

    Debugging sachetIO

commit a0e26da38bc55571ae426e30f820aa3b83c0aa8a
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Wed Jun 5 18:55:06 2013 +0530

    lattice and temperature: sachetIO added, not tested

commit 91ad9c62158050abf17d2845df6a73e459bd6dc6
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Wed Jun 5 11:13:13 2013 +0530

    Windows thumbnail updated, bad gitting

commit 971107d27875483c7da099fbc919bb3ff6e10cbc
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue Jun 4 17:38:28 2013 +0530

    Documentation: Readme updated

commit 1ae6231a7947ff2dfb60cde8c5ff6f04126fe6dd
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue Jun 4 17:17:29 2013 +0530

    latticeAnalyser: Brightness level added amongst other mods

commit 66e0a71c8883402d9f417ceee81fd90aae6b3978
Merge: 5197b0e f74225f
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue Jun 4 16:29:11 2013 +0530

    Sync between i7 and the laptop i3.

commit f74225f45621d6787eabb6aa8f1a6b8b2a2ed838
Merge: a9e3f77 0acd87a
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Tue Jun 4 16:25:39 2013 +0530

    Merge branch 'master' of https://github.com/toAtulArora/IISER
        _repo

commit a9e3f773ce60d4d2208df7916ded4eb265dc3374
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Tue Jun 4 16:25:00 2013 +0530

    Dipoles for printing corrected

```

```
commit 5197b0e7cdf547ab1f2d0ac919d75a7374091b18
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 16:19:24 2013 +0530

    Completed Firing the electro using the console

commit 61a7d99bbaca3a1ff5bd242605a5d02931189fb1
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 12:28:48 2013 +0530

    Protocol tested | functional

commit d216f3253d72c34b41a37c3de40d3de4c7e4df61
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 12:10:52 2013 +0530

    lattice and temp, both about to be tested

commit 1c300638b1a4f72d4bd0c1adc871aa4e331f604a
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Tue Jun 4 11:44:14 2013 +0530

    Dipoles for printing prepared

commit 5716ed3aac119b7f9ed73fdf91fd3cc5d582f3ad
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 10:20:38 2013 +0530

    temperature: modifying directory structures

commit 0acd87a44061dbad55c16cdf3edeb83f0ba282e
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 10:12:00 2013 +0530

    Committing missed out changes

commit bc84259a0622c96483cd2a2e6192c64a50001387
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 10:10:06 2013 +0530

    Improving makefiles

commit 41bf3439997260e2ea985159dbeac26f3c932e09
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue Jun 4 09:59:29 2013 +0530

    latticeAnalyser and temperature: Now test built and stable
        together

commit 87e256921410d3b3dd64d3cf5c7bee2a07f2d07c
Author: Atul Singh Arora <toatularora@gmail.com>
```

```
Date: Mon Jun 3 18:25:20 2013 +0530

    Unstable: Testing temperature with latticeAnalyser

commit 414bd316aee99f833fb0990d46ed8e8e812bb431
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jun 3 16:22:39 2013 +0530

    Completed making a directory structure and compiling with a
        makefile, the original program. Plus brought the
        latticeAnalyser up to pace, ready to be tested with a
        makefile

commit 45870e0b999e2a2fb5262c1724524c32344146e0
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon Jun 3 15:11:22 2013 +0530

    temperature: Brought to life

commit 45ec731b3acdd2453b9b398f2bab241f44a1d44c
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Mon Jun 3 09:06:32 2013 +0530

    Documentation: Minor changes

commit c9dba8a5a11417bcd88e5871d21447634d8dcdf8
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Sun Jun 2 21:21:18 2013 +0530

    Documentation: Report completed for this week

commit a8caec9bc8d48e292500a67aaa4ab30307ce5f3c
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Sun Jun 2 20:23:22 2013 +0530

    Documentation: Updating the report, air levitation bit

commit 81911d7db6ad61c78adb43cdf38f923463e99ea2
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Sun Jun 2 13:59:47 2013 +0530

    Tested and functional in windows

commit 545b4b2a6f2fe5b479b2b195db3e33bf07dcfd05
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri May 31 17:49:46 2013 +0530

    Documentation: Updating the readme with todays update

commit 6ba72ab3722dde5108c24f36cf1f0b7a431a5473
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Fri May 31 17:47:33 2013 +0530
```

```
latticeAnalyser: Working on the CLI to support hardware test  
and interface  
  
commit c02f28b3cb63b80de999d6e48caf7d1c11ee134b  
Merge: e799380 4124d6f  
Author: Atul Singh Arora <toatularora@gmail.com>  
Date: Fri May 31 09:37:56 2013 +0530  
  
Merge between my laptop on the i7  
  
commit 4124d6f02088e68eee26a717a2d311d878e94e14  
Merge: e7fdc40 b9fa975  
Author: Atul Singh Aurora <toatularora@gmail.com>  
Date: Fri May 31 09:37:40 2013 +0530  
  
Merge branch 'master' of https://github.com/toAtulArora/IISER  
_repo  
  
commit e79938071a4774aead45190065d4b89ec897f172  
Author: Atul Singh Arora <toatularora@gmail.com>  
Date: Fri May 31 09:36:41 2013 +0530  
  
Documentation: Readme updated  
  
commit e7fdc40f167da5cc37e4be6d00126a16139b6392  
Author: Atul Singh Aurora <toatularora@gmail.com>  
Date: Fri May 31 09:35:45 2013 +0530  
  
latticeAnalyser: Working on adding hardware support  
  
commit b9fa9750312fb712d4f67e412c6f8fa439d2e3f  
Author: Atul Singh Arora <toatularora@gmail.com>  
Date: Thu May 30 14:48:47 2013 +0530  
  
Documentation: Updating the readme  
  
commit e5ab8b0d86d65f425b6cb8882fe2e3e217ef32f8  
Merge: 96497a8 8641fb  
Author: Atul Singh Aurora <toatularora@gmail.com>  
Date: Thu May 30 11:14:22 2013 +0530  
  
Merge branch 'master' of https://github.com/toAtulArora/IISER  
_repo  
  
commit 8641fbb08ea2310ef683cf273e246372083ca0fd  
Merge: 947f4a9 eb3aa7b  
Author: Atul Singh Arora <toatularora@gmail.com>  
Date: Thu May 30 12:03:26 2013 +0530  
  
Merge remote-tracking branch 'origin'
```

```

commit 947f4a92fdb40167b79fbcbf0703961068e9d928
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Thu May 30 12:03:04 2013 +0530

Documentation: For installing the avr tool chain added

commit 96497a8bfdaa355470b28457c0c3258e58246727
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu May 30 11:13:55 2013 +0530

Testing Air Levitation: Drawing for drilling corrected

commit eb3aa7ba02b8fe4e8fe461a1fcf3f48985637ac7
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu May 30 11:01:53 2013 +0530

Testing Air Levitation: Drawing for drilling completed

commit 88a86f88320485cf29a4bd549fc596574efb5cd7
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 29 18:18:42 2013 +0530

Compiled with linux, gcc and opencv built with openTBB and
IPP, in i7, seems to be screeching fast so far

commit 97e92d0a1c358a48f6268620e8f27550fe4df930
Merge: a06ca8c 88a86f8
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Wed May 29 17:27:41 2013 +0530

Merge branch 'master' of https://github.com/toAtulArora/IISER
_repo

commit a06ca8c3c46b595a18fd2857b67181a58d426b3c
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Wed May 29 17:27:18 2013 +0530

Adding the dipole image

commit dd49ef3da14113786804d091524dc9fe985f1ba2
Merge: 7118975 c5783f2
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Tue May 28 17:53:20 2013 +0530

Resolving conflicts

commit c5783f2c0326b6f9932a79cb1ebcb6423eb5f3f4
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Tue May 28 17:49:26 2013 +0530

Finalizing, now stable in windows, tested

```

```

commit 9094e4956634cf6552d4a13034681c9aa467ced4
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 28 17:40:52 2013 +0530

    Multi-Thread Atomic Sync Completed to satisfactory level

commit 54ef6c6562e5191d9a13fc28f4af5bb86aa0d9b8
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 28 17:12:15 2013 +0530

    Display atomic multi-thread, mysteriously functional

commit aea12d12ff7a7392a9a8aa6bfc24b9480fac2bed
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 28 16:10:41 2013 +0530

    Atomic Sync implemented for capture frame

commit 4c37bfb7a65726b0c5d4c0be78efa8adf308db20
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue May 28 15:22:27 2013 -0800

    Working on atomic aspects. Now switching to visual studio

commit ec9f99c1950c6590f14f011b5ced221a71bb44a4
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Tue May 28 11:18:46 2013 -0800

    Working on the multithreaded aspect, somehow still faster
    without multithreading

commit 7118975120137a637efbd00f4f37029dcb48f5
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 28 15:37:55 2013 +0530

    Minor changes

commit 1937a9b1a85d298adf71082c7d4d5d0b2e2459ed
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 27 16:58:04 2013 -0800

    Support for multi-threading added, also compiled with IPP

commit 634469581390949623305417360e3337e2c4b559
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 27 11:40:47 2013 -0800

    Multi threaded for reducing lag

commit 118b1118a3a9c9a2450c97857dfa1f3c7cdce17a
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Thu May 23 15:42:56 2013 +0530

```

Template Record modified and committed

```
commit b15b3b68ecf14b8f6412e68a0e32e07fafb8b320
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Thu May 23 14:17:21 2013 +0530
```

Template Record zip added

```
commit 69cc3d0baf0c5593220504d6184379cf4f1eeaac
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Thu May 23 14:16:29 2013 +0530
```

Adding the template amongst other things

```
commit 65be7489adf56a9d1ddb5429a812446b6d5a90fe
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 21 21:07:12 2013 +0530
```

Minor bug, memory leak corrected.

```
commit d491b930c62d39d8d9032d7a7361fc302fccd29e
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Tue May 21 19:25:15 2013 +0530
```

Windows Support Added, amongst other things

```
commit 76de5131ce3281f6a67c6fa4e2e04390eb9ffddf
Merge: 92b9031 5bd296f
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 17:16:48 2013 +0530
```

Merge branch 'master' of https://github.com/toAtulArora/IISER
_repo

```
commit 5bd296f6330bc6a994cdd3cb568944ddae03ddd4
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 20 17:16:10 2013 -0800
```

Corrections

```
commit 7f19fcacfdd84895a66df61918983d26b9966f5c
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 20 14:02:50 2013 -0800
```

latticeAnalyser functional again

```
commit 4720ab5b6ce0310a35c4e67392430d8248b488c4
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 20 14:02:04 2013 -0800
```

Test results for speed added

```
commit f546e50310b6a9721430739bd0d1710939d4f98e
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 20 12:48:50 2013 -0800

    Testing: Computation time

commit 92b903140f65e1a1dc13fa340d2ba60f467a907d
Merge: 6b87a0b 7f19fca
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 14:03:18 2013 +0530

    Merge branch 'master' of https://github.com/toAtulArora/IISER
        _repo

commit 6b87a0bea18e78b97272fa4d2948add994f9be0b
Merge: c18ab4f f546e50
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 12:51:15 2013 +0530

    Merge branch 'master' of https://github.com/toAtulArora/IISER
        _repo

commit c18ab4f832ab6905bd110cb35f97f462ad4d64e3
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 12:51:01 2013 +0530

    Testing Overall speed

commit d902a319f303aa07b7744b28b10c2b7f7d9d4704
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 08:49:51 2013 +0530

    Documentation: Pushing final changes

commit 3961ae759ca5d8cd49ea0fc5b1f117808af64357
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Mon May 20 00:59:40 2013 +0530

    Documentation: For this week, completed

commit 600d76a3c5a0157d2704643c7606a6f4845015a0
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Sun May 19 23:32:05 2013 +0530

    Documentation: Working on it

commit 97dfb751a1e095d12c2bd9b8bfdb692f2c7fc9f8
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date: Sun May 19 21:33:03 2013 +0530

    Latex documentation initiated
```

```
commit 965a960cc01ba8c12828c9c7184002abfa254516
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Sat May 18 21:18:13 2013 +0530
```

Documentation: Graph for the result added

```
commit 2b54dcdccda1674acd1e55b4811deef84af22bd6
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 20:05:53 2013 +0530
```

Documentation: Graphs added plus the screenshots fixed

```
commit b451f3235971d518bdb8b598d7d0617b30d1905c
Merge: 24299e9 e6992b4
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 19:49:02 2013 +0530
```

Merge branch 'master' of https://github.com/toAtulArora/IISER_repo

```
commit e6992b4d4dfdd247e13cc26792e5ae2e967b71e7
Merge: b99fa82 e6a9613
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 17:29:37 2013 -0800
```

Merge branch 'master' of [github.com:toAtulArora/IISER_repo](https://github.com/toAtulArora/IISER_repo)

```
commit b99fa823120154b9605e9c7295f7b1095788940c
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 17:28:39 2013 -0800
```

junk files removed

```
commit 2f90706321725486350bf5e5cab471880024732c
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 17:28:05 2013 -0800
```

Tested with movement, Passed so far atleast qualitatively

```
commit d0713d1bc4387bc86ffa97ffa70e7135461c1c8d
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 16:49:45 2013 -0800
```

Data readout successful

```
commit 9562182c76cdd8bd3332369b077a537979b38226
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 14:38:46 2013 -0800
```

Unstable: working on saving the data in frames

```
commit 24299e9b82d126498eb9fdb2a423b73dc10c956a
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 17:48:00 2013 +0530

    Completing documentation

commit e6a961387d67fc44b61d9d4a7ff8cdbf3c9300c8
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 17:07:59 2013 +0530

    Test animation added

commit c4b267c3aee1b4a250b35947909b9b66d840e124
Merge: 592f37f e76bdab
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 06:26:55 2013 +0100

    Merge branch 'master' of https://github.com/toAtulArora/IISER
        _repo

commit e76bdab03a3563f80b2b6a7df35a03cf5016cb08
Merge: c577396 139aa07
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 10:56:05 2013 -0800

    Merge branch 'master' of github.com:toAtulArora/IISER_repo

commit c5773969054079d95f2b6ffa6374a70bc37edae3
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 10:55:28 2013 -0800

    Stable and tested, the dipole angle measurement for each
        frame is successful

commit 1b512fc3f783b9ceab973241bac17de424fcf374
Merge: 17b9e98 7ed3367
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 10:21:26 2013 -0800

    Merge branch 'master' of github.com:toAtulArora/IISER_repo

commit 17b9e981d3d6eca9e1bcb5057c6e9223615685b0
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Fri May 17 10:21:09 2013 -0800

    Dipole detection successful and stable

commit 592f37fa548922654bfae0d0df77f873243a1501
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 06:26:44 2013 +0100

    Image Rotated
```

```
commit 139aa076a25cb555d7ea8148a5ffc5d16efac3ef
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 10:36:18 2013 +0530
```

Dipoles modified, ellipse thinner

```
commit 7ed336730f865b7fa6dd42b966062c47b12414ce
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 09:51:06 2013 +0530
```

Circle Ellipse for Dipole

```
commit a28114a6da1a2c41eea58773edbe7b36be55bfd1
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Fri May 17 09:17:00 2013 +0530
```

STABLE upto mod 180. Updated a few things

```
commit 71f70879c14c7ee04acc4967eb30efadcfb503b
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Thu May 16 20:01:51 2013 +0530
```

Dipole diagrams under development

```
commit 67091067fc83d9bd6b82435a147fa147b73a9ce
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Thu May 16 18:30:23 2013 -0800
```

Stable and angle detection, Mod PI stable

```
commit f0331273de52a2cbc08375adf828c8c19c793b5a
Merge: 0a238d6 fbf2852
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Thu May 16 17:51:57 2013 -0800
```

Merge remote branch 'origin'

```
commit 0a238d683fc9596f1f4e39b476239495fb431a0
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Thu May 16 17:50:47 2013 -0800
```

Stable but not functional, the angle detection

```
commit fbf2852326d676b5249558b81bd9fb9359f5c050
Author: Atul Sinh Aurora <toatularora@gmail.com>
Date:   Thu May 16 11:23:54 2013 +0530
```

Darker

```
commit 3e35bb152be886098e2ad3c627eb97d655ac4156
Author: Atul Sinh Aurora <toatularora@gmail.com>
```

```
Date: Thu May 16 10:54:22 2013 +0530

    Ellipses, exported

commit 8a77a1cda5fdb8a31384aba38e7f9c59822d7d9
Author: Atul Singh Aurora <toatularora@gmail.com>
Date: Thu May 16 10:34:13 2013 +0530

    Ellipses: Dipoles now have ellipses

commit 1352099dd4b874d3c40feeaf1bb60ba2ecc0e0ac
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 16:46:49 2013 -0800

    Readme fixed

commit d4dde74debd2808ed61985555efed5e3f249faa8
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 16:45:34 2013 -0800

    latticeAnalyser now Stable

commit 8185f26452a568f24436dad15d7721c6abf09507
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 15:46:39 2013 -0800

    readme fix

commit b5c2f8ef6f30b41f8922595de45b2d21078ee535
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 15:45:36 2013 -0800

    readme fix

commit a1882f5b9ca8608c5f5078959990de0f4328d0af
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 15:44:17 2013 -0800

    Proof of concept for Hough

commit c4c85189bc2a33a21fa4bd18e746d5faff8f4cc3
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 14:54:41 2013 -0800

    Proof of concept is complete

commit 7989309295af080c63d2359e228548a83df384f0
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Wed May 15 14:32:34 2013 -0800

    Test version functional with contours, for circle detection
```

```
commit 48eb9ca66cd831e7622c3411e5d772dc48861853
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Wed May 15 13:19:45 2013 -0800
```

Test with circles, using contours is fine

```
commit 38c0db3f5a80f766d6ce392874cf6dbd0c98084
Author: Atul Singh Aurora <toatularora@gmail.com>
Date:   Wed May 15 13:01:00 2013 +0530
```

Plausibly unstable, rewriting latticeAnalyser

```
commit ae3ed9a080a08f1293835340bbe27f67bb03a092
Author: Atul Singh Aurora <toatularora@gmail.com>
Date:   Wed May 15 11:51:55 2013 +0530
```

Added the dipole drawing

```
commit bbcf6834ea3ea5a8bc8beaccc111802da44ac762
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue May 14 16:39:23 2013 -0800
```

Readme final update for tuesday

```
commit 7d37eb031af55077a3406fcb8636be9ff9c50688
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue May 14 14:47:01 2013 -0800
```

Updating the readme

```
commit b468d8f06c6b1ce0a6ab8584c144766bb3c832e6
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue May 14 14:45:57 2013 -0800
```

Updating the readme

```
commit 9050ca5cf5520a743c9fd15b1c62d1a4ebda7e01
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue May 14 14:10:03 2013 -0800
```

Trying to push changes

```
commit 85749c48d6c87e4ae693daff193ff5c6682fe577
Author: root <root@ccf1.ccf.npl>
Date:   Tue May 14 12:58:47 2013 -0800
```

Up and running in the new setup

```
commit b31da232eef661b854d86ea0f495f2f491a74a58
Author: Atul Singh Arora <toatularora@gmail.com>
Date:   Tue May 14 12:51:14 2013 +0530
```

Migrating :(

```
commit a8cbef25fc90a3c878456f921b2a029dd5b0b058
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 13 12:09:08 2013 +0530
```

Basic Colour Filters up and running

```
commit 118a3519f5123a64ac8049229462213f02f6052e
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Mon May 13 11:54:40 2013 +0530
```

The lattice analyser is being built..has begun to 'see'
things

```
commit 75bd2af30f3ee056eb2b840877782803f4a8bda5
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Sat May 11 15:25:51 2013 +0530
```

Setting up the structure

```
commit f3751b794796ddb116da91dbf4d034faec6a5998
Author: Atul Singh Arora <toatularora@gmail.com>
Date: Sat May 11 13:52:10 2013 +0530
```

Readme Updated

COLOPHON

This document was typeset using the typographical look-and-feel `classicthesis` developed by André Miede, for L^AT_EX.
The style was inspired by Robert Bringhurst's seminal book on typography "*The Elements of Typographic Style*".

The latest version of this document is available online at:

https://github.com/toAtulArora/IISER_repo