Chicagoland Observatory for Underground Particle Physics (COUPP)

Calibration of cameras in an X, Y, and Z coordinate plane, for the surveillance of bubble chamber detection

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Astrophysicists are searching for what they believe to be a new particle, known as dark matter. What they believe makes up 85% of the matter in the universe is cold, dark and non-baryonic; they believe that the prime suspect for dark matter is a new type of matter, a weakly interacting massive particle (WIMP). Dark matter cannot be seen through telescopes, since it does not emit or absorb light. Scientists have been trying to infer of its existence by seeing its effects in the universe, such as it having an effect on the rational speeds of galaxies, showing gravitational lensing of background objects, and temperature distribution. Although the scientific community accepts the existence of dark matter, there hasn't been solid evidence of it being detected.

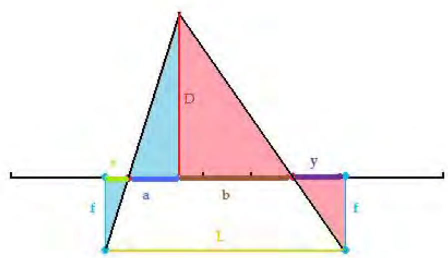
The Chicagoland Observatory for Underground Particle Physics (COUPP) has taken the job of trying to detect dark matter by using a bubble chamber. A bubble chamber is a vessel filled with superheated fluid—just below boiling point—and as particles pass through the chamber a piston on the chamber quickly decreases the pressure inside, the particle leaves a tack—which the liquid vaporizes—to form a bubble. The bubble chamber that's being used by COUPP ha a different setup from its ancient sibling; the bubble chamber has an inner vessel that contains the superheated fluid that captures the bubble—the COUPP-500 kg inner vessel has a max allowable pressure of 9.25 psi. Next it has a pressure vessel, which is connected directly to the hydraulic system that it needs to readjust the pressure inside, and this is what allows the chamber to capture the bubble inside; but differing from the old bubble chamber, the new and modified versions use an accumulator tank, consisting of a high and low pressure, where the pressure inside the chamber can be set easier and less moving parts to worry about besides the valves. And lastly the thermal controls being used are a copper coil inside and through the pressure vessel; the copper coil was originally being used for the COUPP-4 kg inner vessel. COUPP has been improving and making a bigger version of the last chamber built that started with 0.1 kg following 4 kg, 60 kg and the quickly escalated 500 kg. The 500 kg is still in process of being designed, but designed nonetheless and this one will hopefully be the main chamber that completes the project. The cameras in the chamber had to be calibrated in order to get the appropriate feedback to be able to detect bubbles in the space inside the bubble chamber.

Technical work with the calibration of cameras was a new work. I had never done work with video, photography or coding, so when trying to work with new work, very little helped except advanced algebra and trigonometry. The motivated work did not come from past context, but from the new knowledge that would be gained; since it was all a learning experience, I had to learn new subjects. Having to teach myself on my free time was the challenge in order to complete the objectives in figuring out how the cameras being used for the bubble chamber were working and to learn how to calibrate them.

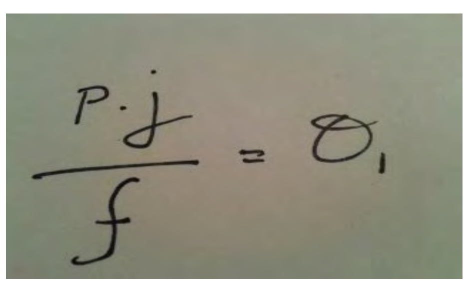
In the methodology of the technical work, we had to calibrate the Computar cameras using different methods. A signal feed had to be sent from the camera to software by National Instruments, called LabView, where source code can be constructed and altered. There were already built-in examples of some code written by National Instruments, so we used and altered the prewritten code in order to figure out certain parts of the camera.

The camera had to be at its optical center where no parallax showed; parallax is a displacement or difference in the apparent position of an object viewed along two different lines of sight. So what that means is we had to get the camera lens showing us everything, and if we were to turn the camera an object wouldn't appear to shift because of a different angle that it would be in. We figured that we had to set up an experiment where two rods were lined up on the same line one bigger than the other, and we figured that the camera had to be pulled back in order to be on the same line as the two rods where the parallax can be taken out of the field of vision. We had to pull the camera back farther than the allowable measure on the camera mount by building a mount extender and having that be the part that was made manually; since Mike Crisler is the only person allowed to operate the machinery at the Proton Assembly Building, it took consistent nagging and fighting to get him over to build the part that had been designed. And finding the optical center was crucial in order to find the right coordinate graph for the camera.

We had to then figure out where the chamber was—figuratively—if we were seeing it through the camera lens, and see how far the end of the chamber is; we had to then create an algorithm that told us the Roll, Pitch and Yaw of an object and figure out its position in the chamber. In order to do that we had to start off with doing incredibly long trigonometric algorithms in order to figure out the angles between the distances (lines) of certain objects; we tried to involve a second camera, especially since in the chamber there would be a second camera. This is how the problem was solved using this type of method.



We had to use that answer to plug into a second algorithm of the problem involving the camera in figuring out the type of lens the camera had and that involved measuring a line of pixels and the pixel pitch, which was 0.0092, divided by the focal length, which had a varying length between 4-8 mm; soon after that we would have to find three different types of answers—one involving sine of theta, tangent of theta, and theta; and the equation looked like:



Coding everything so that LabView would give off the appropriate reading of an angle on an object in the camera was the harder part. An enormous amount of time was spent on the coding in LabView. We started off an example VI that was already installed and then when we finally made our calculations, we started to add the functions that we had to put into LabView block panel; we put the different calculations that involved getting the yaw, pitch and roll in the camera so that we could add an outline structure in the form of a square and take the outline, and be able to read off the yaw of an object that had rotated on the side-to-side axis, the roll if the object had rotation on the front-to-back axis, and the pitch if the rotation appeared on the vertical axis.

Work to still be done are calibrations with the camera on top of a rotary plate where the camera will spin around and do the same things but while spinning, and the main problem that could with that is that we would have to rework certain parts of the algorithms that we had set up for when the camera was stationary. Soon it became a problem of having to get the rotary plate to function because it would be unknown what would cause the malfunction in the plate. And along with this, more work to be done with the cameras is the refraction problem because of the water filter, acrylic, second water filter, and the inner vessel. We would have to capture the edge of an object (bubble) in order to determine its placement in the vessel.

The impact that was made on the project, to start, is that it took an old idea, using a bubble chamber, a thought that had been forgotten because of its previous work, and it recycled the idea and modified it to work better and have greater consequence with results and along with that dark matter isn't an explored topic; its new to the field because it shows that the Standard Model of physics is incomplete.

ACKNOWLEDGEMENTS

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APPENDIX

The rotary plate was the newer part of the camera that had to be worked with separately because the plate came with its own software, and we did not have the opportunity to program it through LabView. The rotary plate had amplifier commission software that would get feedback from the plate to the computer to the monitor and through the computer; we could input a sequence of steps the plate could take through the CVM program in the software, where then the motion plate can take Nano-steps in degrees, which meant that if we inputted 36000000 Nano-steps, the plate would move 90 degrees in a circle. The plate had to be built a mount that involved extra outside work in the Proton Assembly Building (they don't actually assemble protons) and construct a mount made from malleable parts of aluminum so that it could be stood on right-angle brackets for the attachment of a hexapod mount.

A hexapod mount is a type of mount with six legs that would hold a camera and give every degree of freedom, so in summary one could move a camera, up, down, left, right, forwards and back. The legs all have rods that turn the top pod and moving one leg moves the mount in a different direction; so moving just one leg would never be the case, since there is a 6x6 matrix in which figuring out would give the appropriate measurements to be able to move the hexapod mount; in short, it can only move in the way and direction you want, meaning that in order to move a camera inside the hexapod, one must manually turn all six legs simultaneously in order for the mount to be positioned correctly.

REFERENCES

M. Crisler
C. E. Dahl
Fermi National Accelerator Laboratory, Batavia, Illinois

Notable outcomes

H2Z0414C-MP Computar Manual
CME 2 User Guide
National Instruments