Don't throw that video away! Reference Frames can fix Video Analysis with a Moving Camera

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Abstract. One common source of error in video analysis is camera movement. The paper describes a simple frame of reference correction that students can employ to salvage otherwise corrupted video analysis data. Two examples are provided.

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1. Introduction

When the United States entered World War One one of the problems they faced was logistics. How much food do you need to ship overseas to Europe to feed a million soldiers? That early work in nutrition led to the 3000 Calorie diet many people remember from secondary Health Education class. A bit about units you might remeber: $1Calorie = 1kilo - calorie$, and a dietician might build a 3000kcal diet for a 20 year old basketball player. A *calorie* is the amount of energy it takes (typically) to heat a gram of water by a degree Celsius. There are about 4.2 Joules in a single calorie, and a Joule occurs all over introductory high-school physics. If you need to buy a new electrical furnace, the sales brochure might advertise that it is capable of delivering 100,000 BTU's of heat each hour. What's a BTU? Heat a pound of water by $1°F$. Of course Heat Pumps are far more efficient than simply burning methane or propane, but they consume kilo-watt-hours of electricity, not BTU's. What's a kWh? Run a 1000Watt toaster for an hour and you'll have pulled one off the grid, it will cost you about $0.13 in Minnesota. If you decide to put solar panels in your backyard, they will probably collect about 10% of the 3.5kWh the the sun delivers to each square meter of your lawn (in Minnesota) each day.

There are a frustratingly large number of different units in an "Energy" class. At Winona State, this 3 credit class fulfulls a "Science and Social Policy" general education requirement and is taken by students from across the university. Lots of college majors don't require a math class beyond algebra or introductory statistics and the population is largely mathaverse. You could jokingly say that one of the main things students learn in the class is unit converstion, but it isn't far off. Nearly every field finds energy a useful representation, and every profession has their own set of units and terminology that's most well suited. Would a medical lab scientist talk about an acre-foot of urine needed test kidney function? No, but someone in the central valley of California would certianly care about the acre-feet of water necessary to grow almonds! Does a gas station price their gasoline in dollars per kWh? Given the growing electrification of cars, they might soon.

Everyone eats, maybe not 3000kcals per day, but at least something every day. When I teach our energy class, I spend a few weeks talking about food energy before all other types. While food production is not central to the current struggles with climate change and wars over oil, food is essential in a way that diesel and gasoline are not. Vehicle fule makes modern life possible, but we could live, unpleasantly, without it. We can't live without fats and protein though.

2. Food Energy

3. Example: How big could Tenochtitlan have been?

4. Example: Was the Irish Potato Famine a Natural Disaster?

5. Conclusion

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References

[1] Marey M 1894 Photographs of a Tumbling Cat. *Nature* **51** 80

[2] The ISLE approach to learning physics is described in Etkina E 2015 Millikan award lecture: Students of physics—Listeners, observers, or collaborative participants in physics scientific practices? *American Journal of Physics* **83(8)** 669 and Brookes D T and Etkina E 2010 Physical Phenomena in real time *Science* **330** 605 Here is a pointer to the video archive I'm using `http://islevideos.net/` .

[3] The ball toss video used in the first part of the paper is available for download at `http://islevideos.net/experiment.php?topicid=2&exptid=95` .

[4] See the excellent introduction at `https://www.youtube.com/watch?v=QsGMKv8Lrew` .

[5] Peter Bohacek's YouTube channel contains a large number of these videos `https://www.youtube.com/user/bohacekphysics`. A nice overview of the approach he takes is given in `https://www.youtube.com/watch?v=QsGMKv8Lrew`. These videos are available as a commercial curriculum at `https://www.pivotinteractives.com/` .

[6] Tracker is a free, open-source tool that you can install on your computer or run in a web browser. It is available online at `https://physlets.org/tracker/` .

[7] Vernier's LoggerPro is typically used for lab data acquisition but it contains an excellent video analysis tool that this paper employs. `https://www.vernier.com/product/logger-pro-3/`

[8] Here is the help page for calibration sticks in Tracker `https://physlets.org/tracker/help/frameset.html`. The process in LoggerPro is similar.

[9] There are many copies of this video on the web. It seems that the original video was taken by Mark Hoyoak of KPAX News in Montana on September 9, 2003. The clip was subsequently featured on national news and comedy programs. For an overview, see `https://www.youtube.com/watch?v=jB47Vucoj2o` .

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