The Tennis Ball Problem

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This is a problem of geometry, of sampling and of error.

Imagine that you wish to track the location of an object in 3-space. As always in the real world, you are short of resource, so you choose to use just two cameras. Each camera contains a two dimensional array. Each array produces an image, say i1(x,y), and i2(x,y). Unfortunately rather than being continuous these images are composed of discrete pixels, say 640 x 480.

These two cameras both watch the tennis ball (or the missile, or the projectile) as it leaves the ball machine. They acquire a series of frames at discrete time intervals (say 1/120th of a second for a 100 mph tennis ball). What the observer is then left with are a series of images which suggest the ultimate trajectory of the tennis ball.

Here are the problems:

The cameras all have distortion. Do we model this with Riemannian or other curved space geometry to simplify distortions and geometric effects? The mathematical formulations of general relativity are well developed and may represent a direct approach. Or, do we try to model with corrections to the distorted and angularly granularized data to take us back to our rigid Euclidian 3-dimensional world?

Because of the discrete sampling we may only have 5 - 10 images. If we had perfect calibration data we would have a perfect model. How do we calibrate this system well enough so we can fit our limited data to get a reasonable estimate of trajectory? It turns out that a one pixel error in estimating the ball's position can lead to errors in the trajectory estimate of many metres. Again the problem is one of fitting, and modeling with imperfect sampled data. The imperfections are present in both the calibration data and the real time data; they are 'amplified' because of the leverage of distance. What is surprising is that even though the physics of the projectiles is very well understood, it is often difficult to incorporate it into the model in a way which helps the data set to become more self-coherent. It is also worth remembering that real balls have spin, and therefore tend to take slight deviations from a ballistic trajectory.

We have a tennis ball machine. We have cameras. We can produce data live, or attempt to implement solutions live.