Example of Kalman filter use for lorry positioning

Imagine a lorry making a long-distance trip delivering haggis from Edinburgh to Rome for a newly inaugurated Scottish Pope. True Scottish Haggis is very precious and hijacking haggis lorries is a lucrative crime, so the small highland company which makes these particular haggises wants to be sure that they know exactly where their lorry is at all times. As the lorry leaves the haggis factory, its position is obvious to the company bosses, but the further it travels from the factory the more uncertain its location becomes. The highland company bosses must ensure that the lorry is taking some kind of measurement of its own position so that they can know where it is.

The lorry is equipped with an old GPS unit which provides an estimate of its position to within a few meters. But the GPS estimate is noisy and somewhat unreliable - particularly in the mountainous Highland areas and further on in the Alps - readings jump around and can be anywhere within a kilometre of the lorry's true position.

The position of the lorry can also be estimated by integrating its velocity over time - this is called "Dead Reckoning". The velocity of the lorry is calculated by counting wheel revolutions and the angle of the steering wheel. Dead reckoning provides a very smooth estimate of the lorry's position, but it will drift over time as small errors accumulate.

But using either GPS or Dead Reckoning on their own will not give the highland haggis company bosses precisely the correct position of their valuable lorry. This is where Kalman Filtering comes in. A Kalman filter can be used to combine the GPS and the dead reckoning data to make the best estimate of the lorry's correct position:

The first step in the Kalman filtering process is to make a forecast of the lorry's position from the dead reckoning calculations. By knowing how good their dead reckoning has been in the past, the company bosses can also calculate the error bars on this position estimate - this is called the covariance. Perhaps the covariance is proportional to the speed of the lorry because the bosses are more uncertain about the accuracy of the dead reckoning estimate at high speeds but very certain about the position when it's moving slowly.

Next the lorry's approximate position is observed from the GPS unit, if this is different to the dead reckoning forecast, then the two must be combined to give a new estimate for the lorry's position somewhere between the two values. But Kalman filtering is more advanced than merely taking an average of the two values. Along with the GPS measurement comes some amount of uncertainty, and the covariance of the GPS relative to the forecast covariance determines how much certainty the bosses can have in their final calculated location measurement. If the GPS is less reliable than the dead reckoning, then the estimate given by dead reckoning will have more weight in calculating a final position.

Ideally, if the dead reckoning estimates tend to drift away from the real position, the GPS measurement should pull the position estimate back towards the real position but not disturb it to the point of becoming rapidly changing and noisy. The final position calculated by the Kalman filter will be more accurate than either the dead reckoning or the GPS reading. And what's more the Kalman filter also quantifies the uncertainty in its own estimate of the lorry's position - giving the highland company bosses a re-assuringly informative estimate of where their haggises are on their long and dangerous journey to Rome.