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Calibration of the Shooting Mechanism using the Kinect Camera

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Shooting mechanism

- Inputs
  - Duty cycle (K)
  - Lever position (L)
- Ball trajectory
  - Initial velocity (v_0)
  - Initial angle w.r.t the ground (α_0)
  - Initial angle w.r.t the yz plane (β_0)
- Nonlinear $v_0(K,L)$ and $\alpha_0(K,L)$

Shooting mechanism

- Two types of shots
  - Lob: L>0.05
  - Pass:L<0.05
- All tests performed on TURTLE 3

Goal

- Estimate the initial conditions of the ball using the kinect.
- Use this information to estimate the curves $v_0(K,L)$ and $\alpha_0(K,L)$

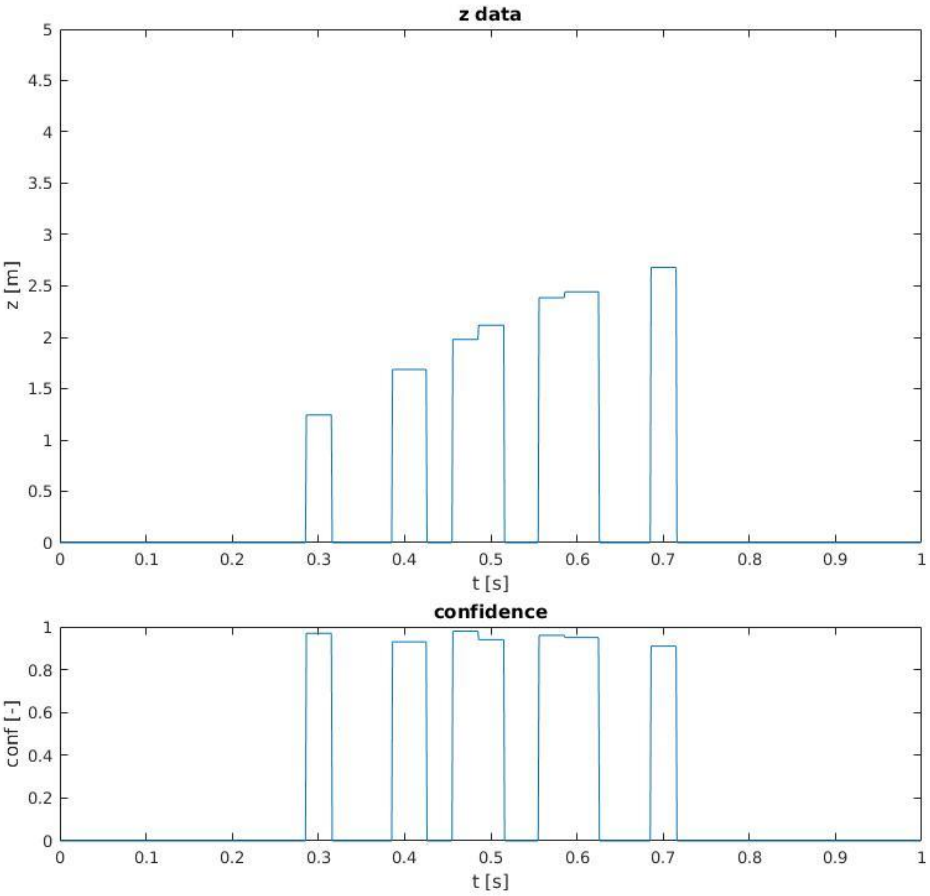
- Is the kinect a viable option to calibrate the kinect?
  - How accurate can the initial conditions be estimated?
  - How long would the calibration take to perform?

Contents

- Shot analysis algorithm
- Validation analysis method
- Number of measurement points neccessary
- Experiment

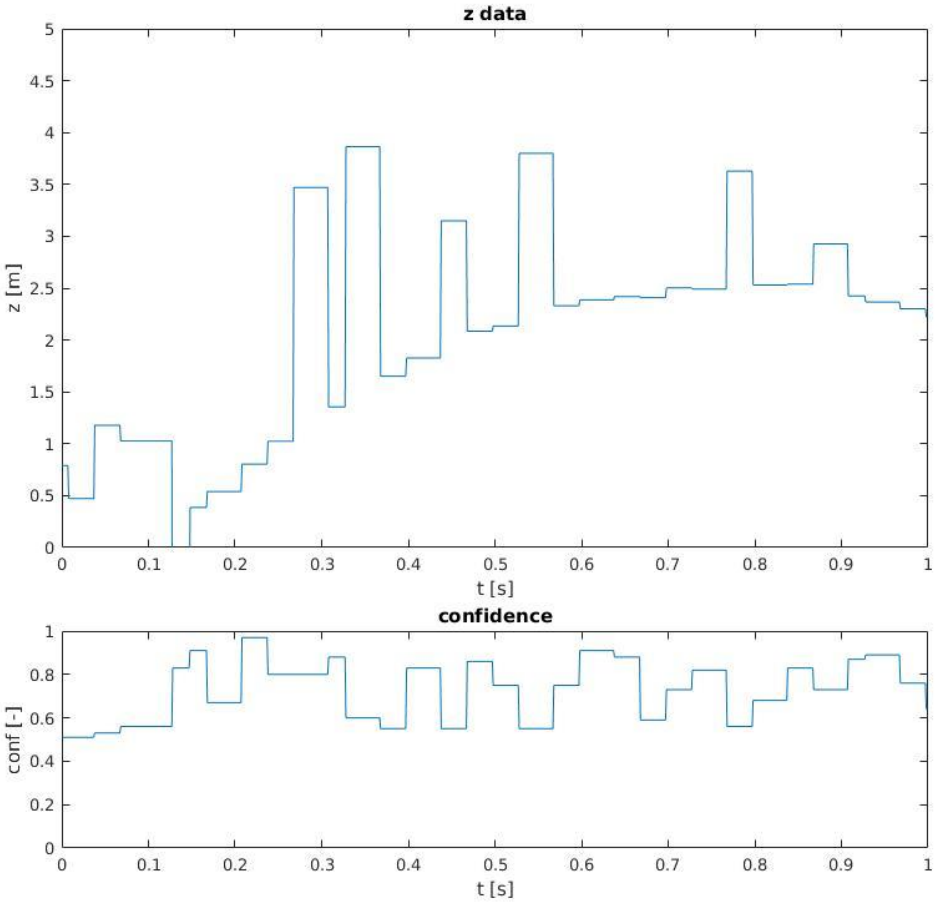
Kinect data

- Fast moving balls are hard to detect
- Low confidence value
- Confidence guard of 0.9



Kinect data

- Confidence guard changed to 0.3
- Trajectory becomes visible
- False positives



Shot analysis algorithm

- Extended Kalman filter

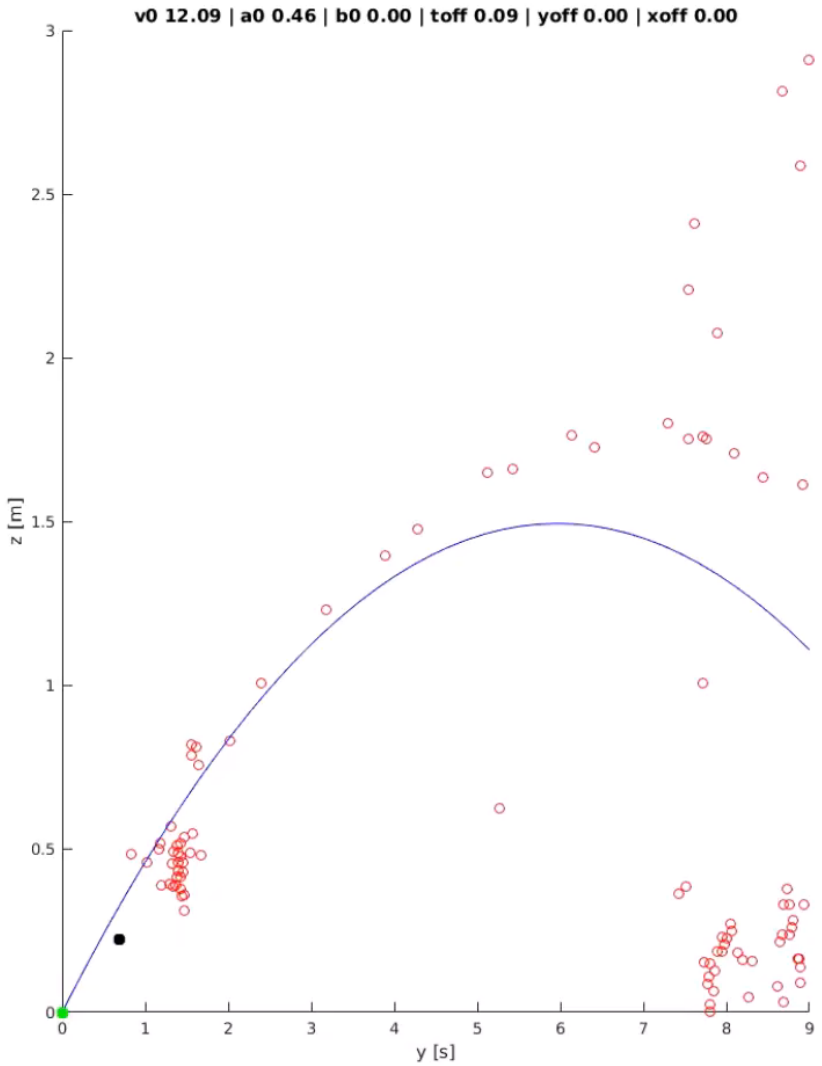
$$x = \begin{bmatrix} v_0 \\ \alpha_0 \\ \beta_0 \\ t_{offset} \\ y_{offset} \\ x_{offset} \\ t \end{bmatrix}$$

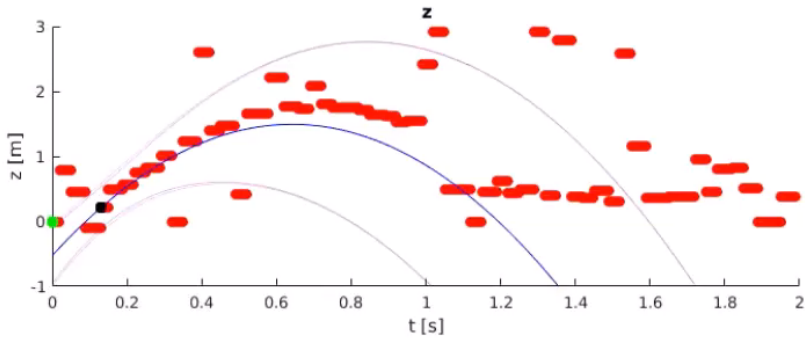
$$h(x) = \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} = \begin{bmatrix} v_0 \cos\alpha_0 \sin\beta_0 (t - t_{offset}) + x_{offset} \\ v_0 \cos\alpha_0 \cos\beta_0 (t - t_{offset}) + y_{offset} \\ v_0 \sin\alpha_0 (t - t_{offset}) - \frac{1}{2} g (t - t_{offset})^2 \end{bmatrix}$$

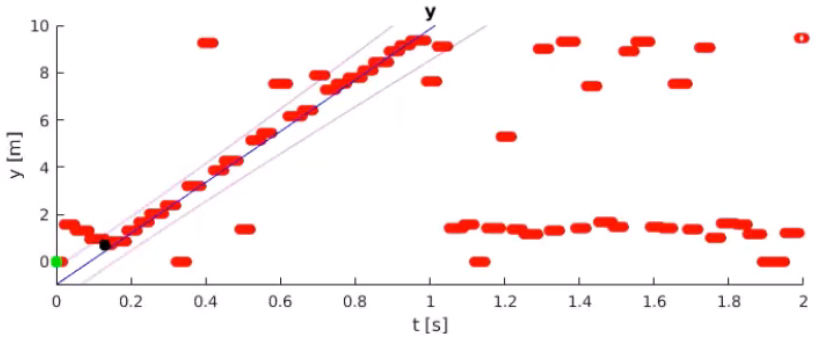
Shot analysis algorithm

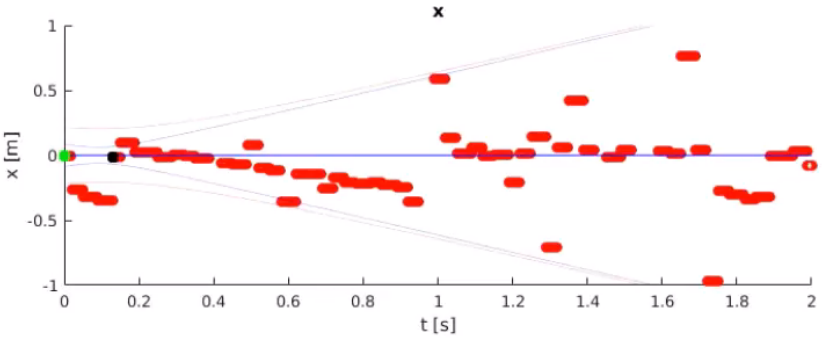
- False positives are filtered using the covariance matrix of the Kalman filter.

- Error bound consists of
  - Covariance of the estimate
  - Covariance of kinect measurements


v0 12.09 | a0 0.46 | b0 0.00 | toff 0.09 | yoff 0.00 | xoff 0.00
z [m]
y [s]


z
z [m]
t [s]

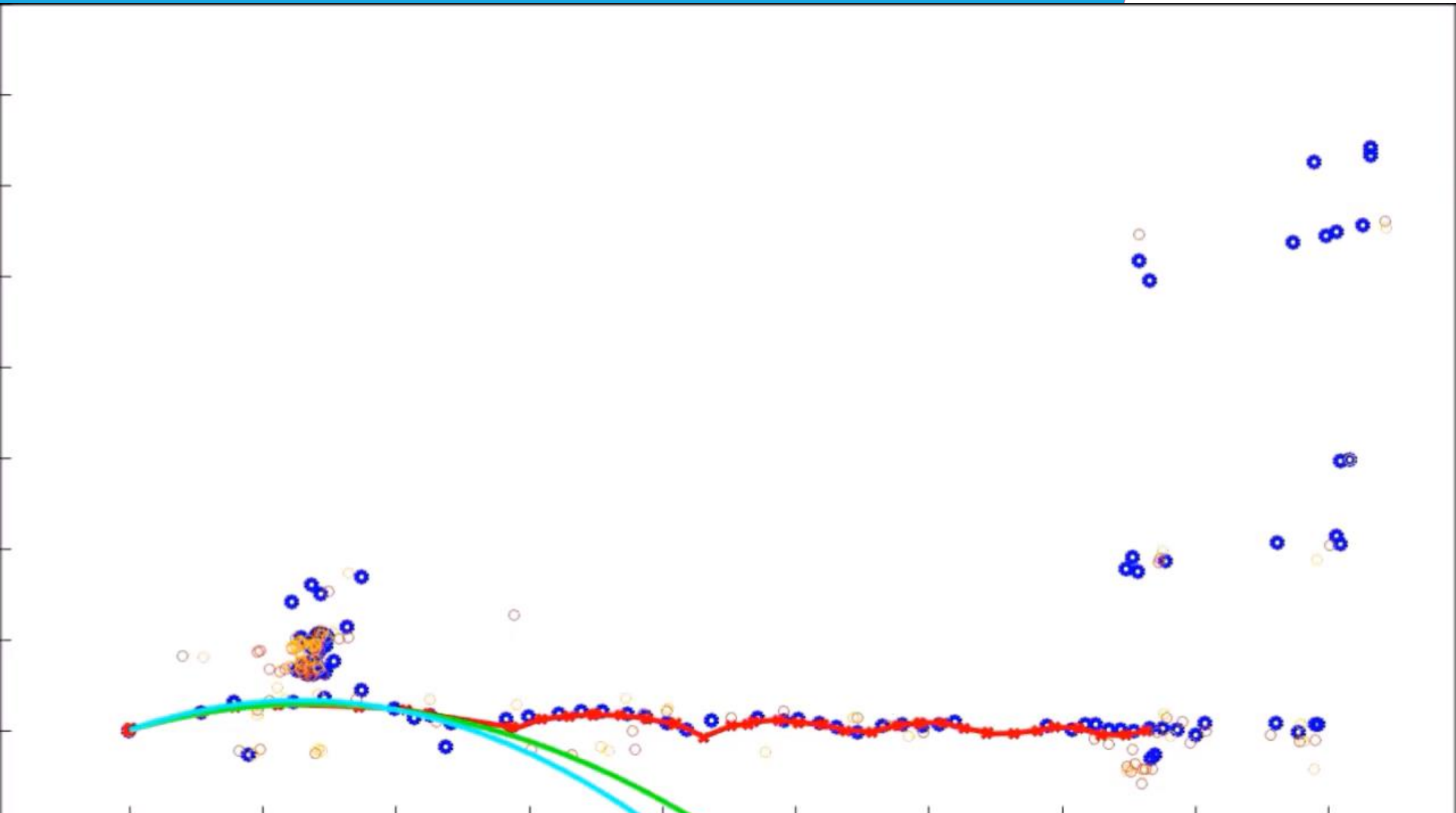

y
y [m]
t [s]


x
x [m]
t [s]

Validation shot analysis

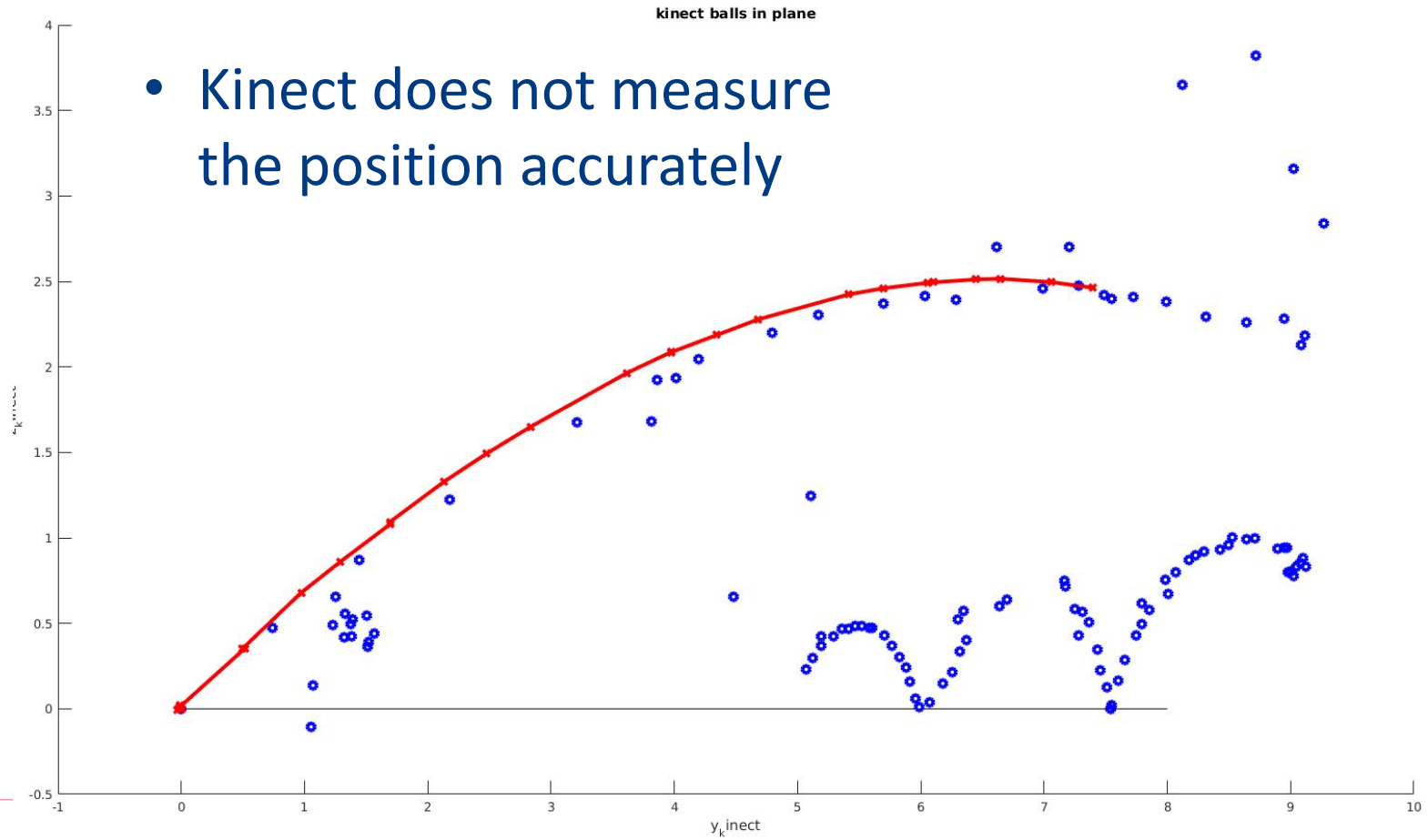
Validation shot analysis

Validation shot analysis

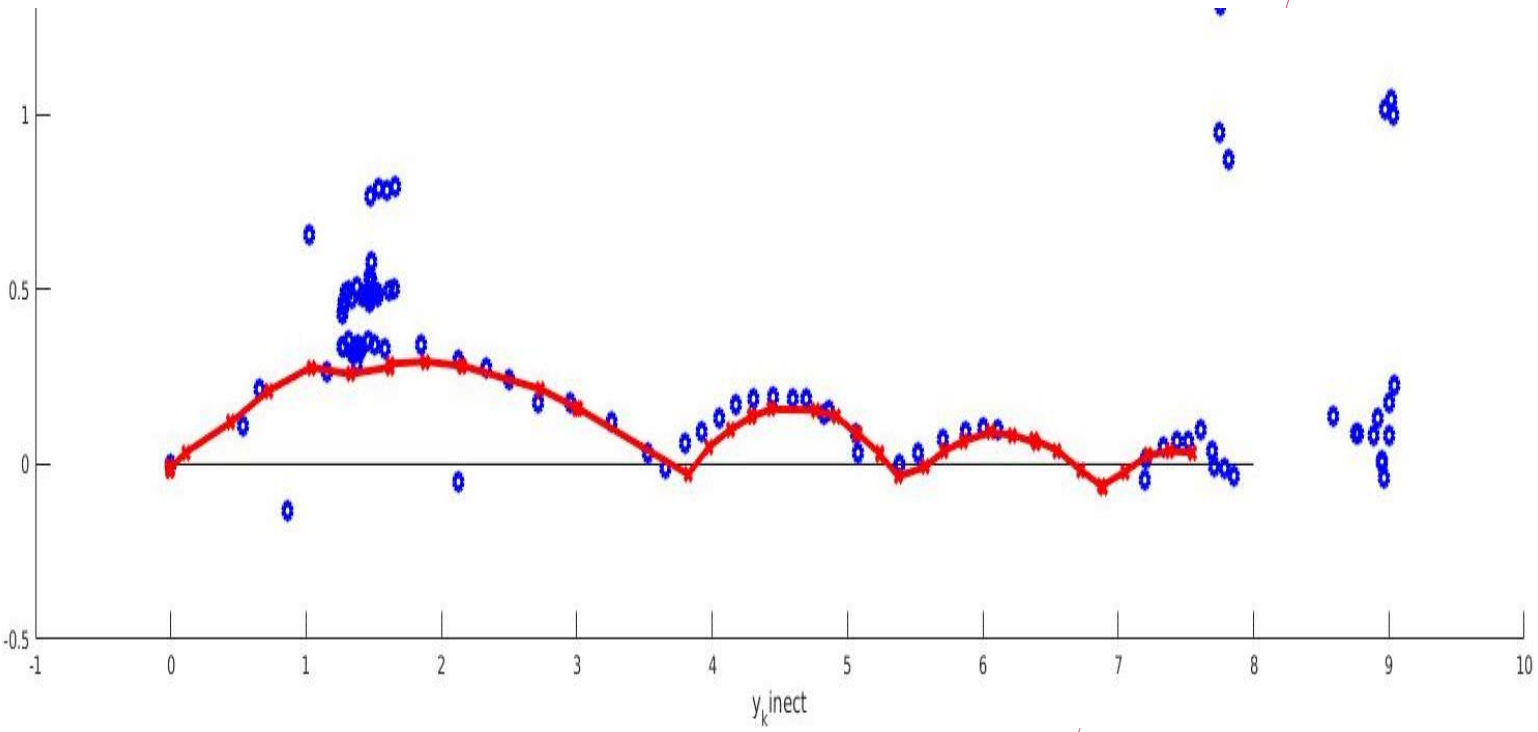


Validation shot analysis

- Kinect does not measure the position accurately



Validation shot analysis



Validation shot analysis

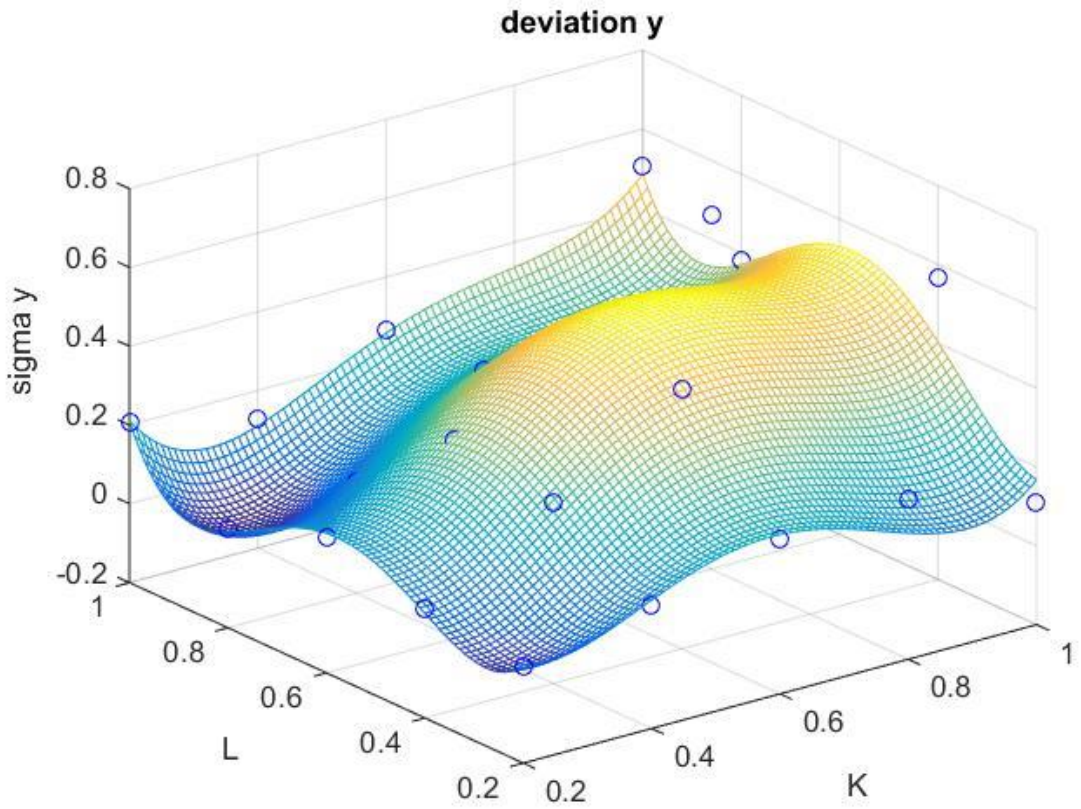
- σ_{ey} +- 30cm
- Higher than σ_y -> analysis is not accurate enough

- Main cause: accuracy of the kinect

Required measurement points

- σ_y (K,L) estimated using 5 shots for a range of K and L
- Shots analysed using the kinect
- Polynomial fit through the points

Standard deviation of shots



Placement of measurement points

- Placement of measurement points can be used to shape the deviation of the estimate
- Median estimate remains constant

Required measurement points

- Simulation of the calibration
- Tested for 25, 49, 100 measurement points
- 100 measurement points
- Median deviation y estimate < 0.1 m

Required measurement points

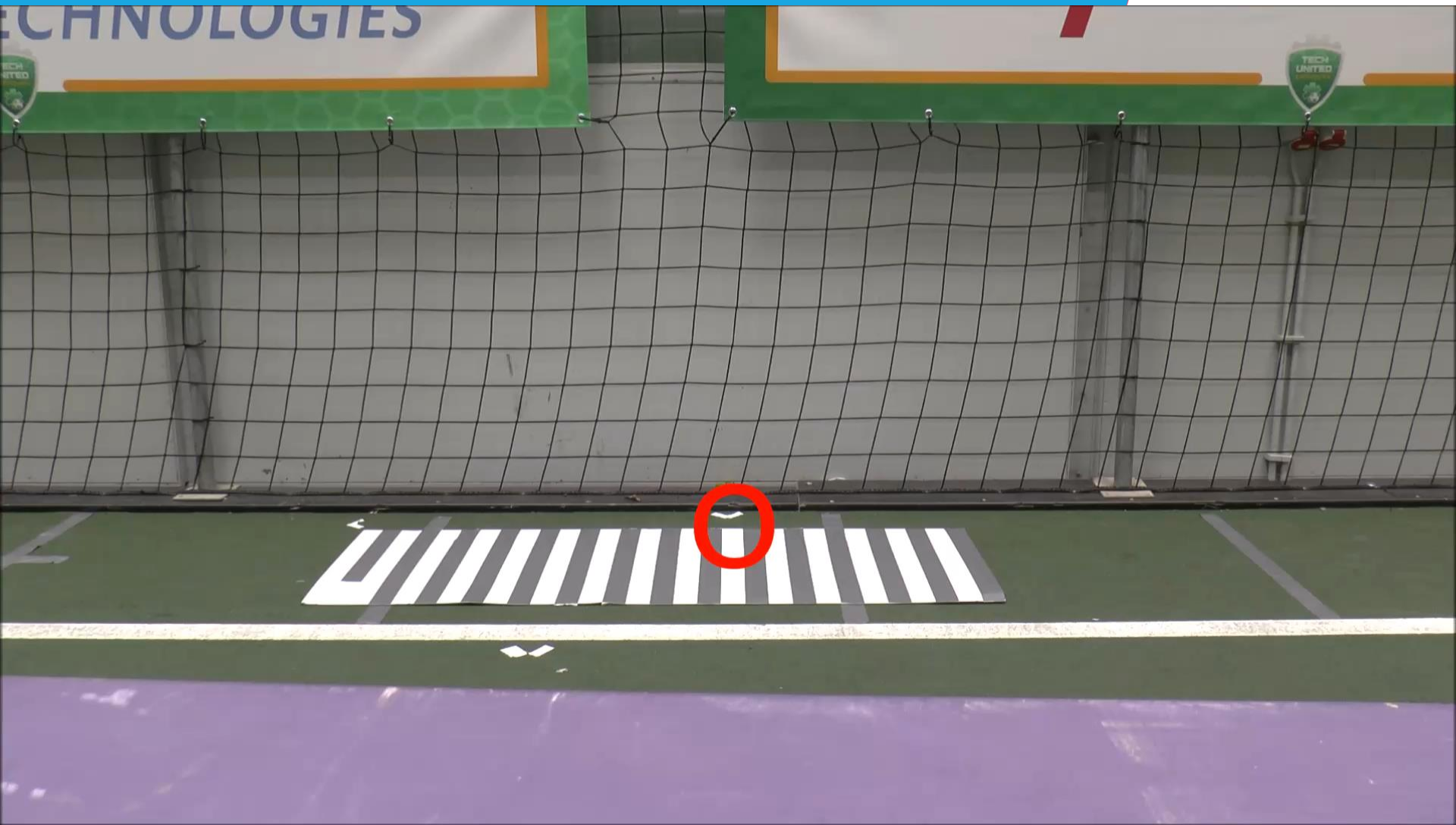
Per TURTLE

- Number of measurements required: +-100
- Time required: 60 min

Note: could be less

- Deviation of K not taken into account

Test calibration



Test calibration

Landing positions were off by 1 meter

Kinect was able to predict the landing positions with an accuracy of 20cm

Something went wrong during the experiment

Can the kinect be used to calibrate the shooting mechanism?

Not yet,

- The accuracy is too low.
- The calibration would take too long

Recommendations

- Investigate and improve the ability of the kinect to detect fast moving balls
- Improve the reproducability of the shots

Thank you

- Questions?