

# Back of the Envelope Estimates

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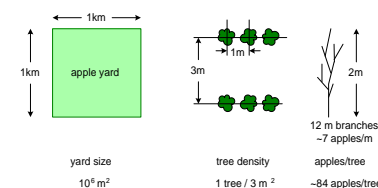
## Abstract

In system design we frequently have to bootstrap our understanding by making assumptions and estimates. An example of making assumptions and estimates is provided for an apple handler system.

### Distribution

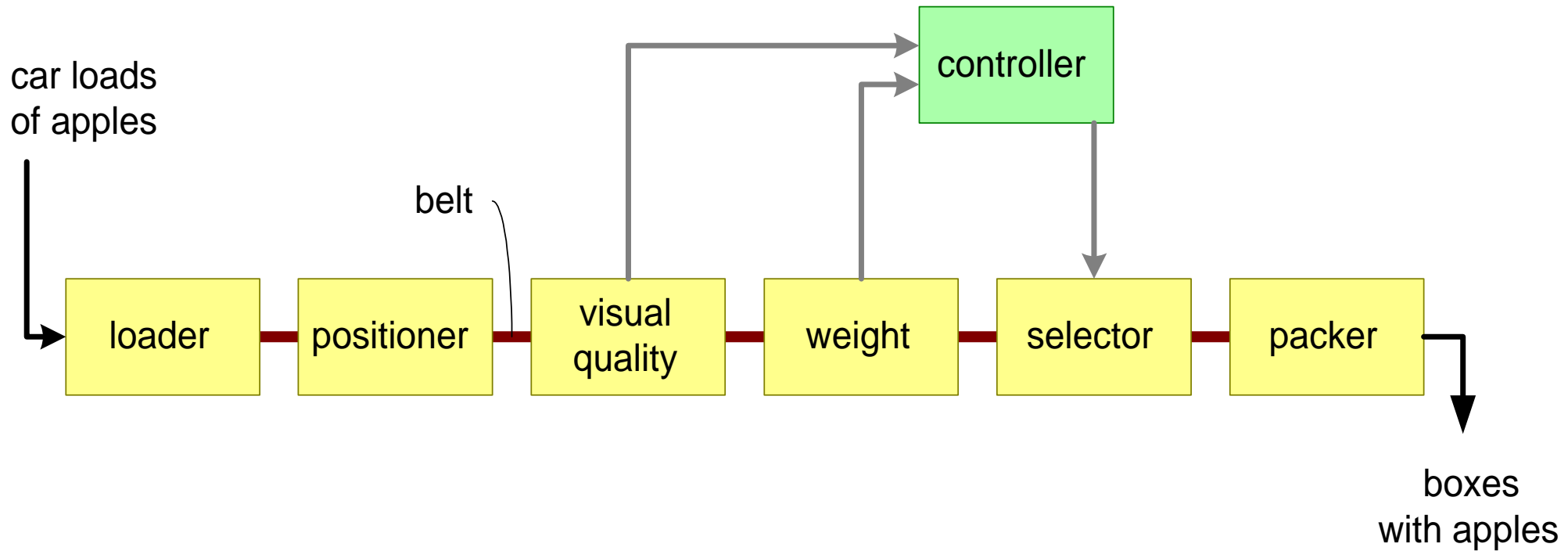
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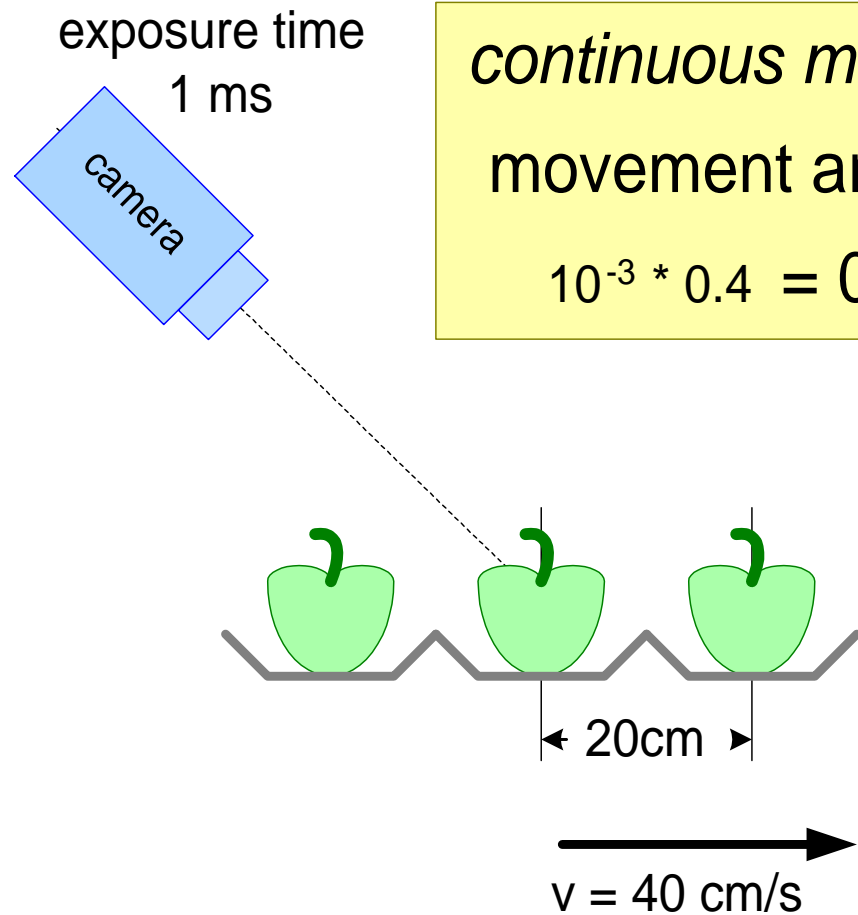


$$\text{nr apples} = 10^6 \cdot 1/3 \cdot 84 = 28 \cdot 10^6$$

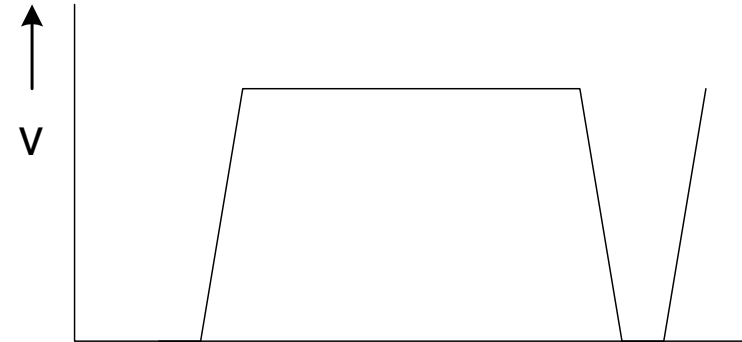
# Apple Handler Functional Design



# Vision Design



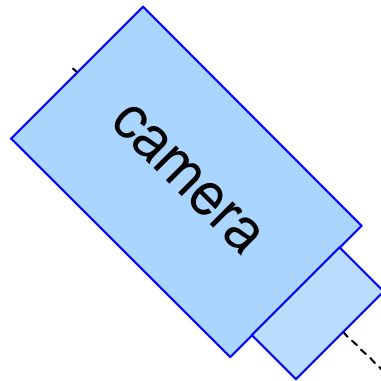
*continuous movement*  
movement artefact =  
 $10^{-3} * 0.4 = 0.4 \text{ mm}$



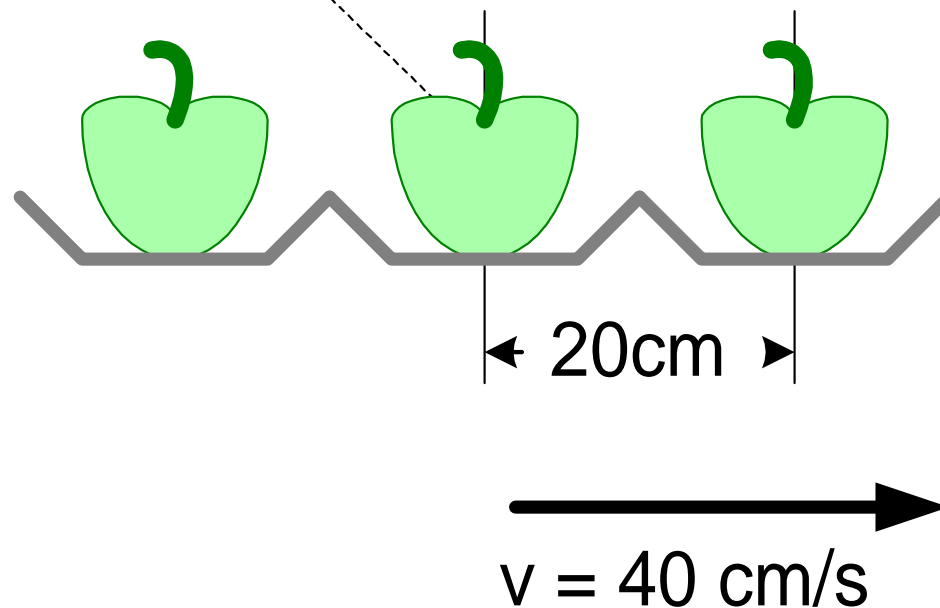
$$t_{\text{stopped}} = 50 \text{ ms}$$
$$t_{\text{acceleration}} = 50 \text{ ms}$$
$$t_{\text{continuous}} = 400 \text{ ms}$$

*start-stop movement*  
acceleration =  $1.6 \text{ m/s}^2$

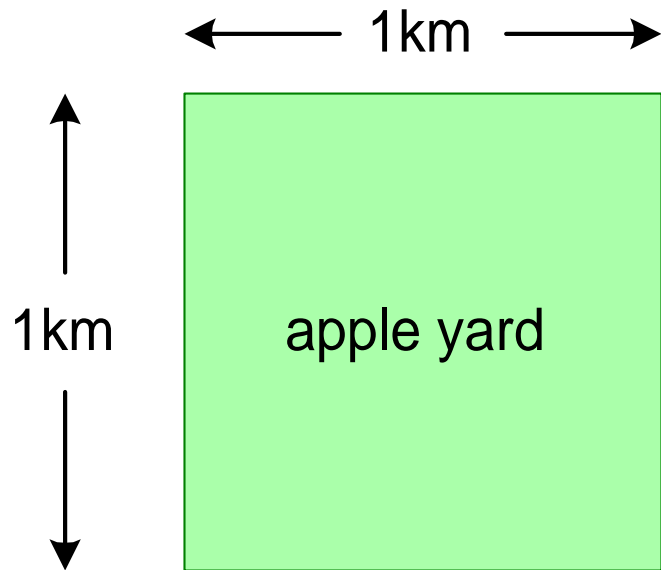
# Belt Throughput (continuous movement)



$$\text{belt throughput} = 5 * 0.4 = 2 \text{ apples/sec}$$

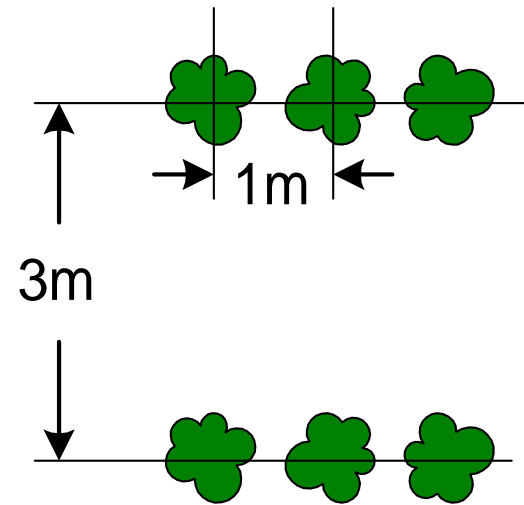


# Apples per Yard



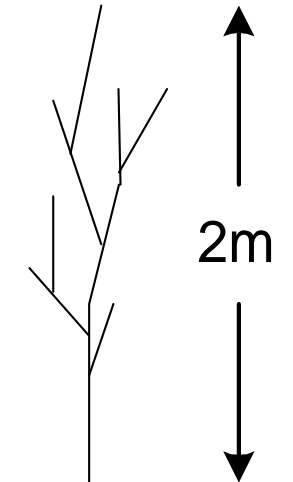
yard size

$10^6 \text{ m}^2$



tree density

1 tree /  $3 \text{ m}^2$



12 m branches  
~7 apples/m

apples/tree

~84 apples/tree

$$\text{nr apples} = 10^6 * 1/3 * 84 = 28 * 10^6$$

# Operational Hours



10 hours/day

7 days/week

4 weeks



4 weeks of  
harvesting

$$\text{operational time} =$$
$$10 * 7 * 4 = 280 \text{ hours}$$

# Throughput

$$\text{nr apples} = 28 * 10^6$$

$$\text{operational time} = 280 \text{ hours}$$

$$\begin{aligned} \text{throughput} &= \\ 28 * 10^6 / 280 &= 10^5 \text{ apples/hour} = \\ 10^5 / 3600 &\sim 28 \text{ apples/sec} \end{aligned}$$

# Assumptions

*Every assumption deserves verification*

exposure time (1 ms)

acceptable blur due to movement (0.4 mm)

acceleration (1.6 m/s<sup>2</sup>)

time needed to stabilize after stopping (50 ms)

required distance between apples (20 cm)

typical area size to be served (1 km<sup>2</sup>)

distance between trees in row (1 m)

distance between rows (3 m)

apples per tree (84)

duration of harvesting season (4 weeks)

number of operational hours (10 hours/day, 7 days/week)

*So at least we learned what questions to ask and  
we have some expectation to assess the answers we find*



# Other Considerations

## *What did we ignore?*

variation in load, peak load

disturbance of production, e.g. maintenance or break down

## *What options could we consider?*

operate the machine for 24 hours/day, requires more storage

have many parallel belts and cameras

replace camera by alternate solution

target only small apple farms