

Back of the Envelope Estimates

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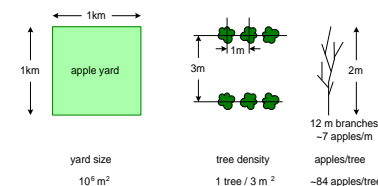
Abstract

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.

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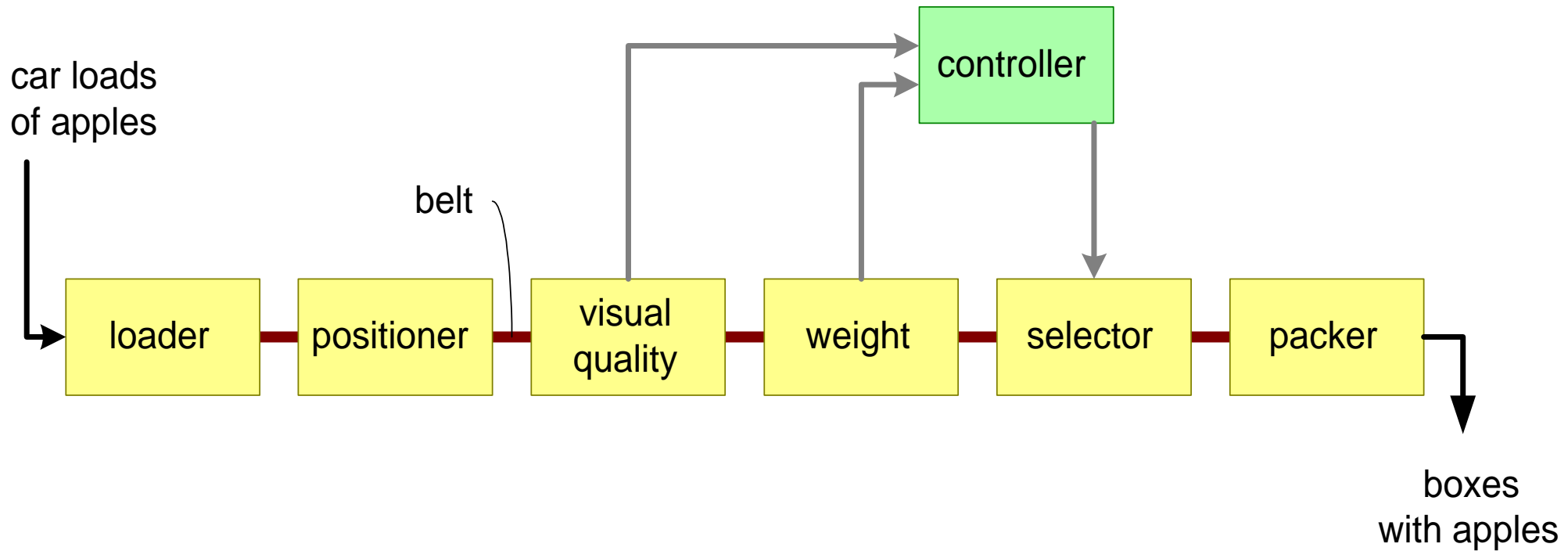
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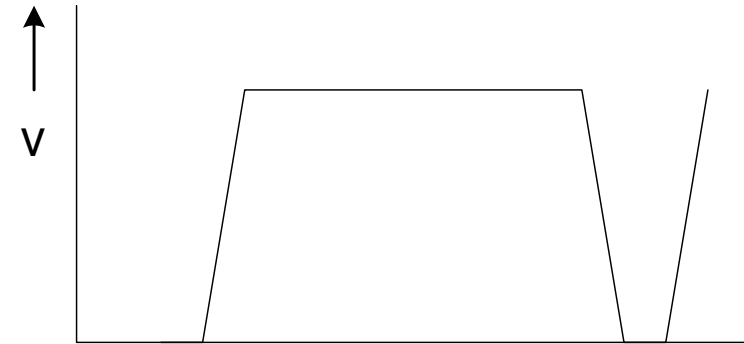
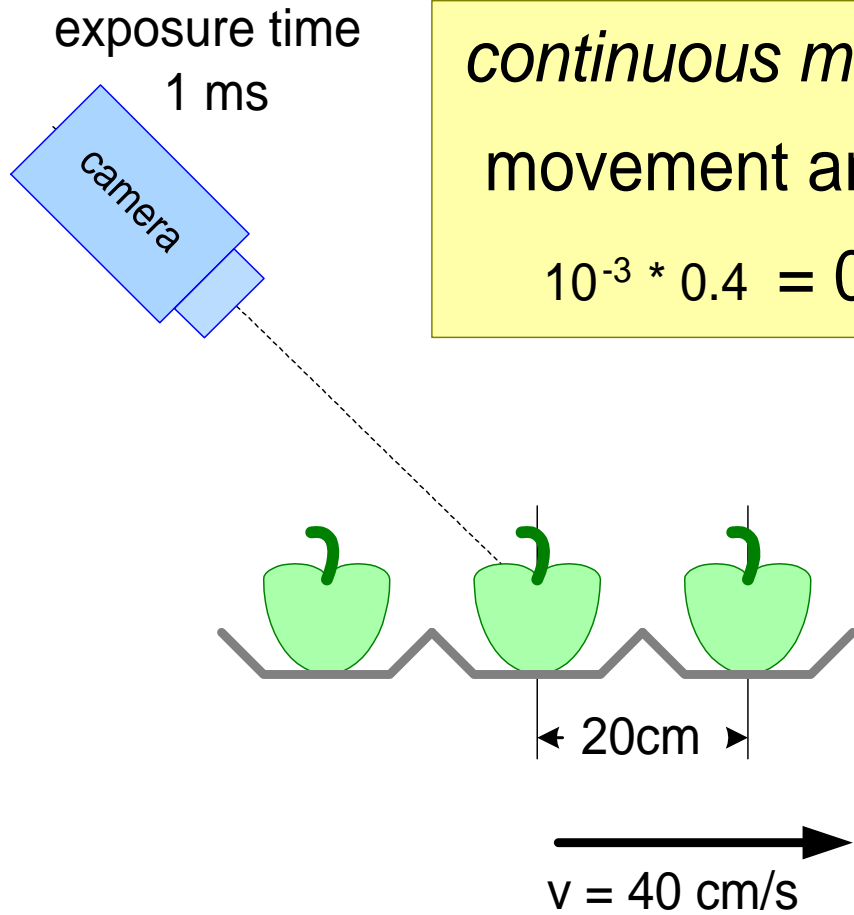


$$\text{nr apples} = 10^6 \cdot 1/3 \cdot 84 = 28 \cdot 10^6$$

Apple Handler Functional Design



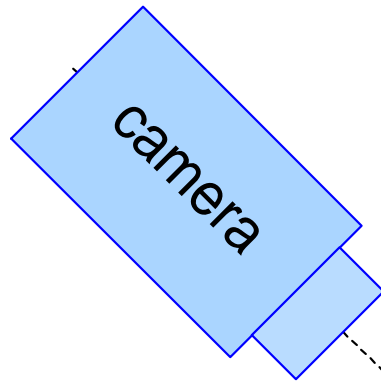
Vision Design



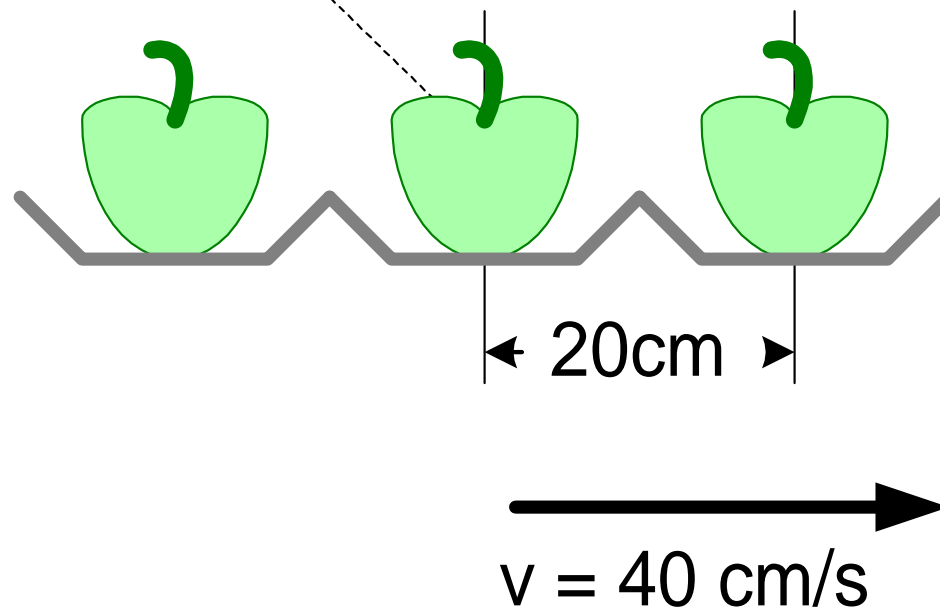
$$t_{\text{stopped}} = 50 \text{ ms}$$
$$t_{\text{acceleration}} = 50 \text{ ms}$$
$$t_{\text{continuous}} = 400 \text{ ms}$$

start-stop movement
acceleration = 1.6 m/s^2

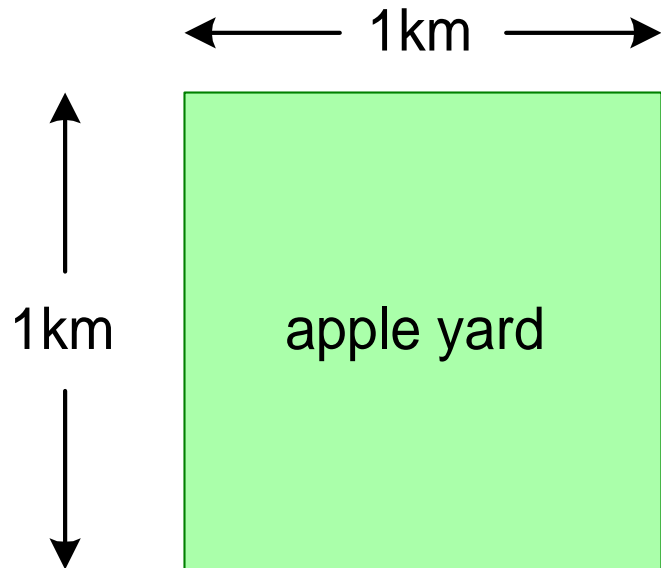
Belt Throughput (continuous movement)



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

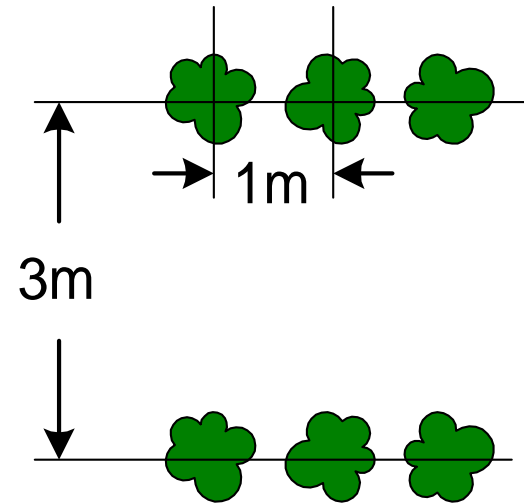


Apples per Yard



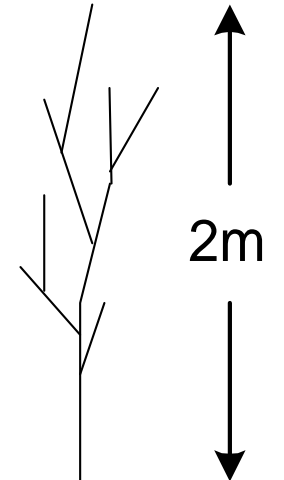
yard size

10^6 m^2



tree density

1 tree / 3 m^2



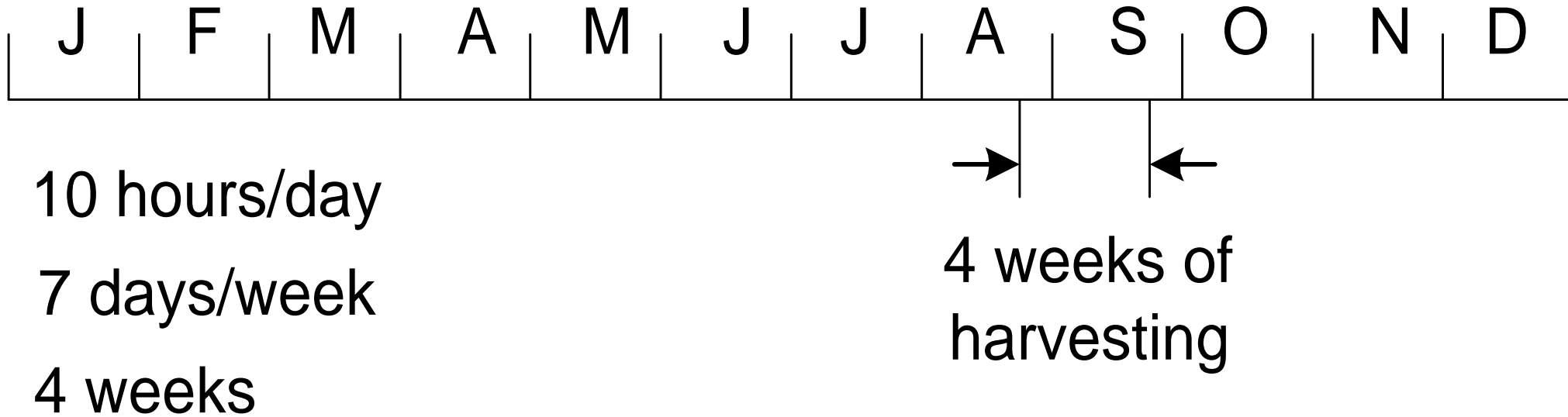
12 m branches
~7 apples/m

apples/tree

~84 apples/tree

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

Operational Hours



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

Throughput

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

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

$$\text{throughput} =$$

$$28 * 10^6 / 280 = 10^5 \text{ apples/hour} =$$

$$10^5 / 3600 \sim 28 \text{ apples/sec}$$

Assumptions

Every assumption deserves verification

exposure time (1 ms)

acceptable blur due to movement (0.4 mm)

acceleration (1.6 m/s²)

time needed to stabilize after stopping (50 ms)

required distance between apples (20 cm)

typical area size to be served (1 km²)

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*

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