Back of the Envelope Estimates

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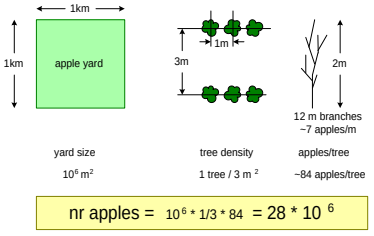
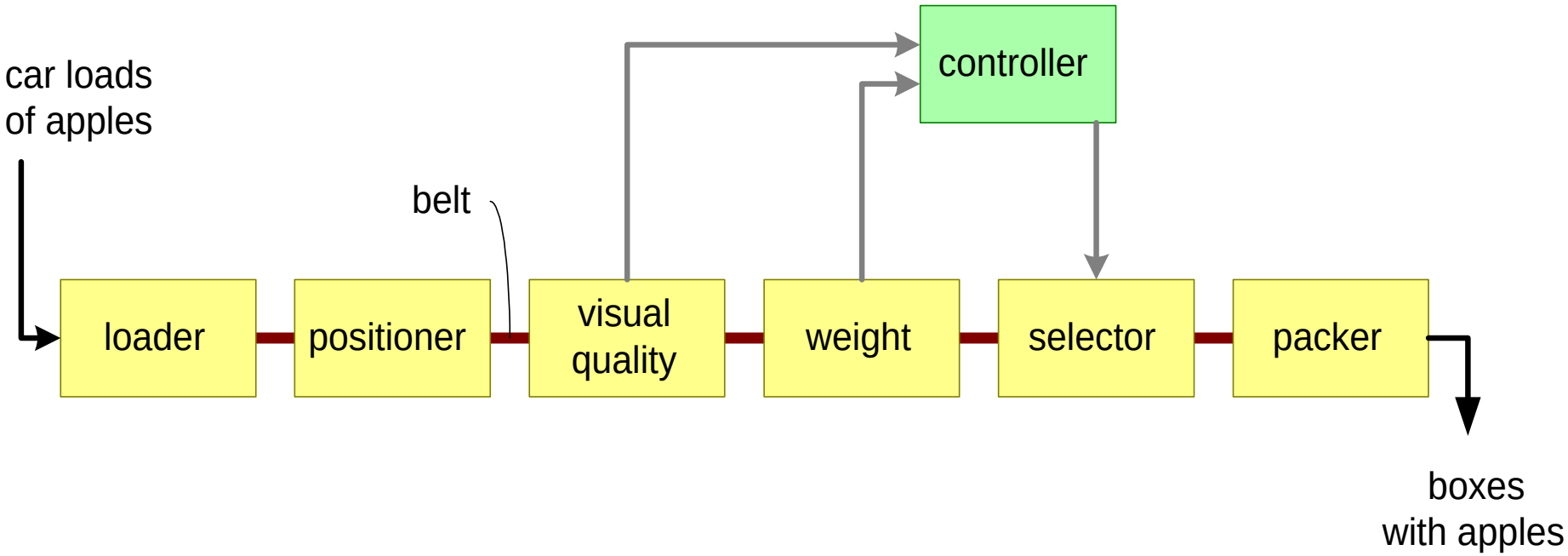
Abstract

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.

February 10, 2011
status: planned
version: 0

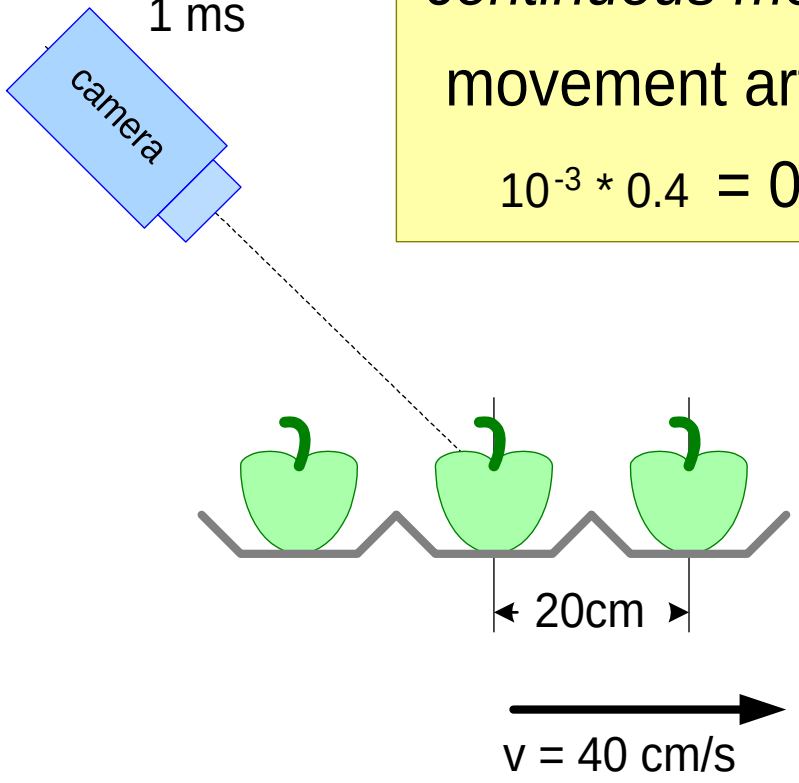


Apple Handler Functional Design



Vision Design

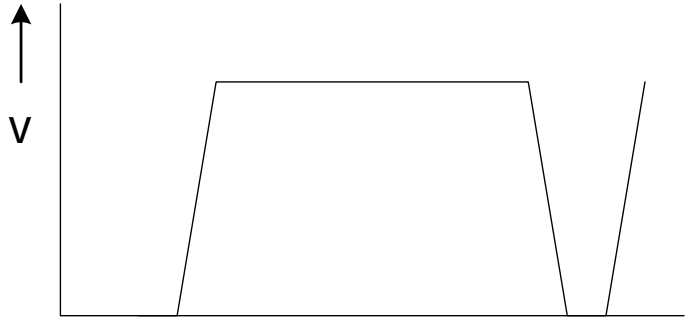
exposure time
1 ms



continuous movement

movement artefact =

$10^{-3} * 0.4 = 0.4$ mm

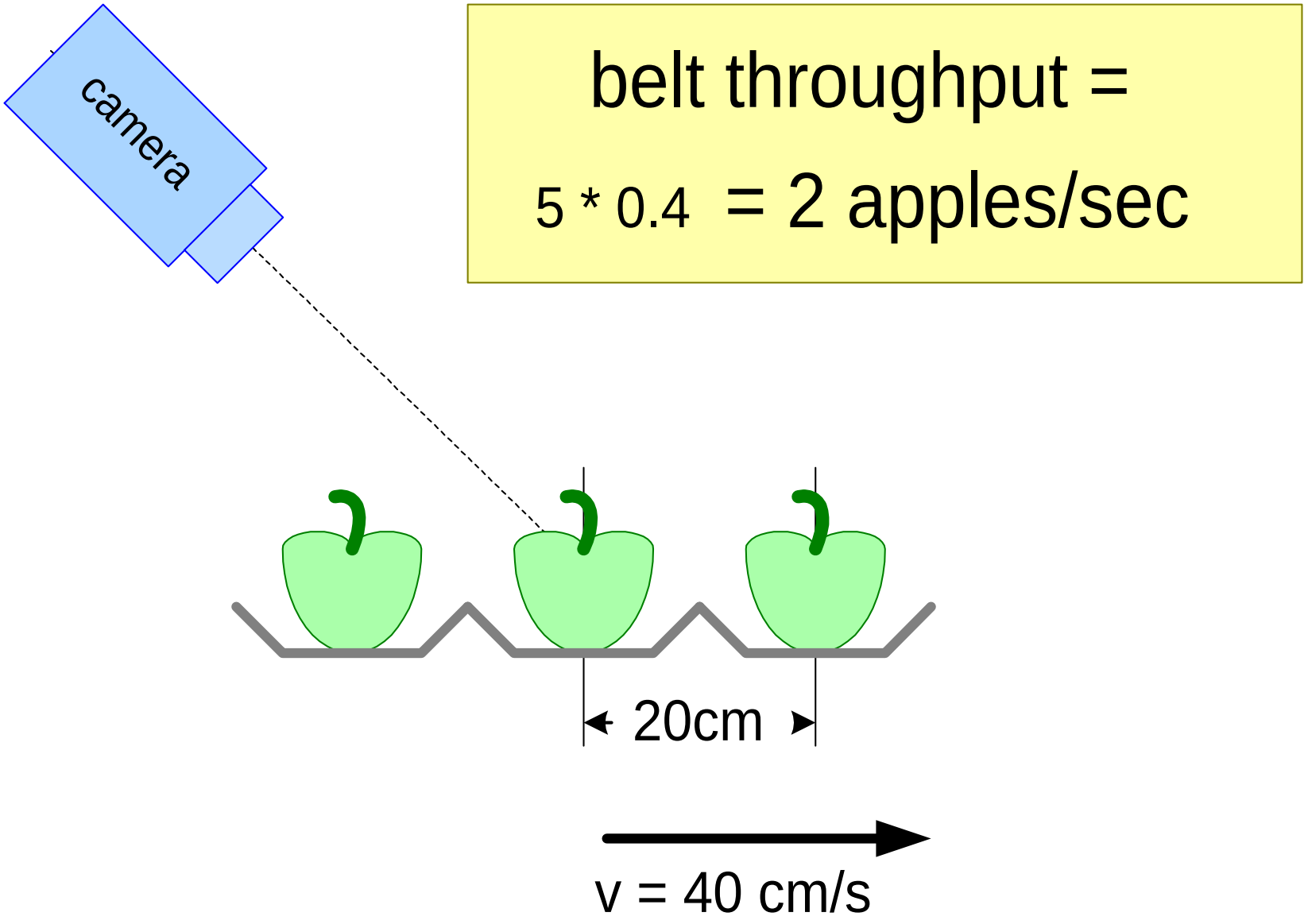


$t_{stopped} = 50$ ms
$t_{acceleration} = 50$ ms
$t_{continuous} = 400$ ms

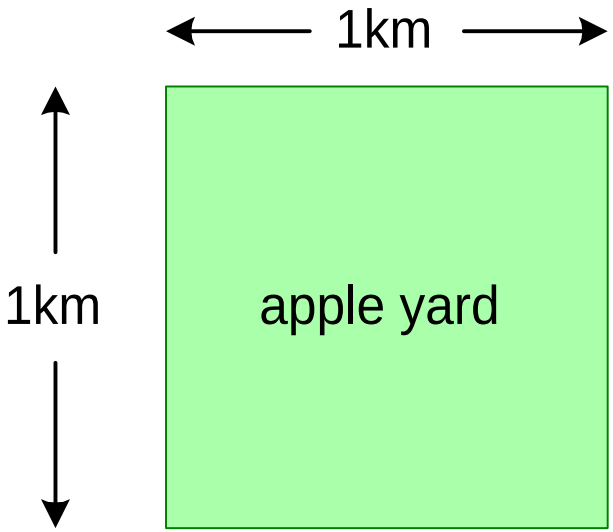
start-stop movement

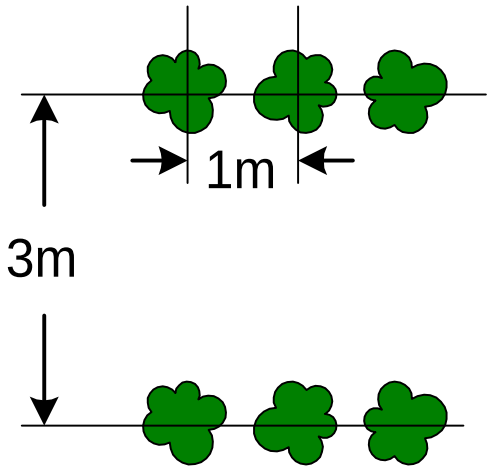
acceleration = $1.6\ m/s^2$

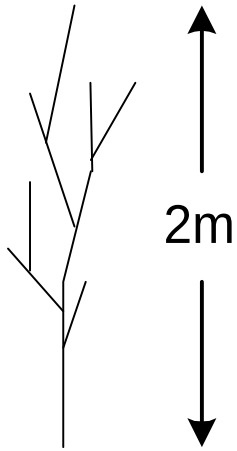
Belt Throughput (continuous movement)



Apples per Yard





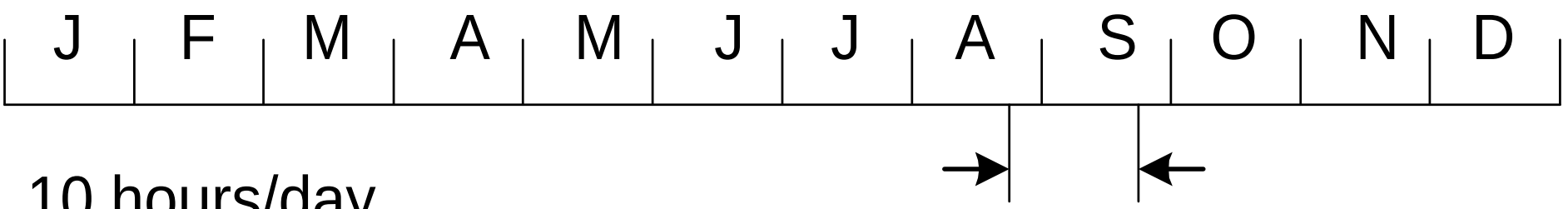


12 m branches
~7 apples/m

yard size	tree density	apples/tree
10^6 m^2	1 tree / 3 m ^{2}	~84 apples/tree

nr apples = $10^6 * 1/3 * 84 = 28 * 10^6$

Operational Hours



10 hours/day

7 days/week

4 weeks

4 weeks of harvesting

operational time =

10 * 7 * 4 = 280 hours

Throughput

nr apples = $28 * 10^6$

operational time = 280 hours

throughput =

$28 * 10^6 / 280 = 10^5$ apples/hour =

$10^5 / 3600 \sim= 28$ apples/sec

Assumptions

Every assumption deserves verification

exposure time (1 ms)

acceptable blur due to movement (0.4 mm)

acceleration (1.6 m/s ^{2})

time needed to stabilize after stopping (50 ms)

required distance between apples (20 cm)

typical area size to be served (1 km ^{2})

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