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
This article or presentation is written as part of the Gaudí project. The Gaudí project philosophy is to improve by obtaining frequent feedback. Frequent feedback is pursued by an open creation process. This document is published as intermediate or nearly mature version to get feedback. Further distribution is allowed as long as the document remains complete and unchanged.

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status: planned
version: 0

apple yard
1km
1km
3m
1m
2m
12 m branches
~7 apples/m
yard size
10
6

tree density
1 tree / 3 m

apples/tree
2
~84 apples/tree

nr apples =
10
6
* 1/3 * 84
= 28 * 10
6
Apple Handler Functional Design

car loads of apples

belt

controller

loader
positioner
visual
quality
weight
selector
packer

boxes with apples
**continuous movement**

movement artefact =

\[ 10^{-3} \times 0.4 = 0.4 \text{ mm} \]

exposure time

1 ms

\[ v \times t = 40 \text{ cm/s} \times 50 \text{ ms} = 50 \text{ ms} \]

acceleration

50 ms

\[ t_{\text{continuous}} = 400 \text{ ms} \]

\[ \text{start-stop movement} \]

acceleration = \[ 1.6 \text{ m/s}^2 \]
Belt Throughput (continuous movement)

belt throughput =

\[ 5 \times 0.4 = 2 \text{ apples/sec} \]
Apples per Yard

yard size
10^6 m^2
tree density
1 tree / 3 m^2
apples/tree
~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
nr apples = $28 \times 10^6$

operational time = 280 hours

throughput =

$$\frac{28 \times 10^6}{280} = 10^5$$ apples/hour =

$$\frac{10^5}{3600} \approx 28$$ 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.
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