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Optimising Pre-Packaging Cycle-Times of LEGO Elements

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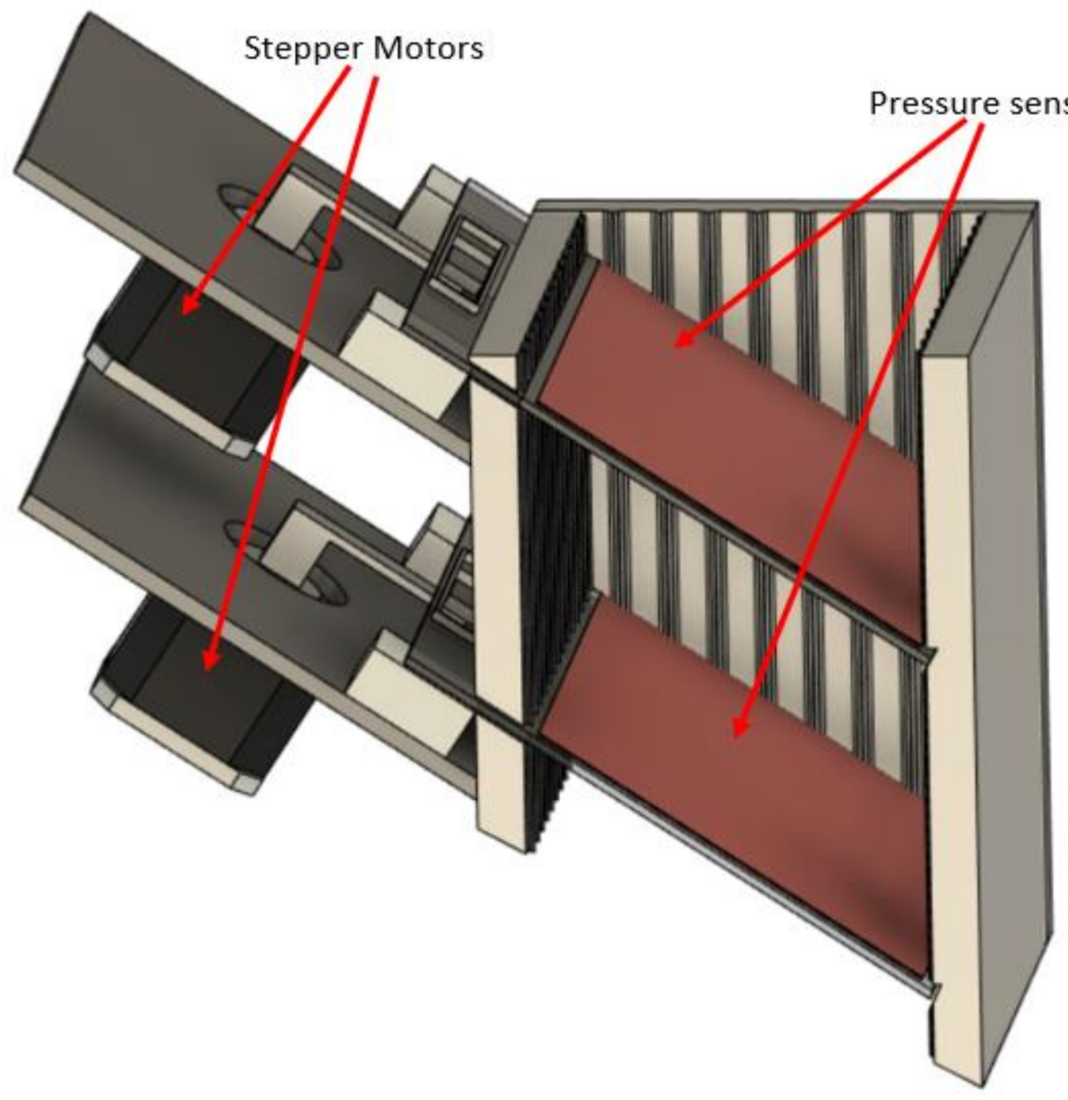
1. Introduction

LEGO uses wing unit machines, as shown to count the amount of LEGO elements that are packaged into plastic bags. However, LEGO describes the elements need to settle before the gates can open, to let the elements fall through it.

2. Presentation of the Wing Unit

The wing unit consists of two different compartment channels, each with two gates, a top gate and a bottom gate, which can open and close. These compartment channels are split into two different compartments by the gates. In each of these compartments channels a specific LEGO element can be sorted ranging from one to four elements in each dose. The figure shows the optimised compartment.



The main features of the wing unit compartment consist of the following:

Stepper motors:
LEGO are already in the process of adapting stepper motors to their current wing units, so it becomes an easy adaptation process, as most of the work has already been done. The advantage of a stepper motor is the more accurate control compared to other electric motors.

Dimensions and Gate angle:
Currently the dimensions and gate angle are potentially sub-optimal. To optimise this, an optimisation problem can be set up to find the different factors. These factors consists of height, width and depth, where the last factor to consider is the gate angle. The advantage of optimising the model is to get the optimal conditions for the compartments resulting in a desirable settling time.

Pressure sensor:
Currently, the gates are opened by a pre-defined time interval, which is set by the machine operator. By implementing a pressure sensor the gate would open at different times for each individual LEGO element, by determining whether there is a load applied to the sensor. This will reduce the cycling-time of the wing unit.

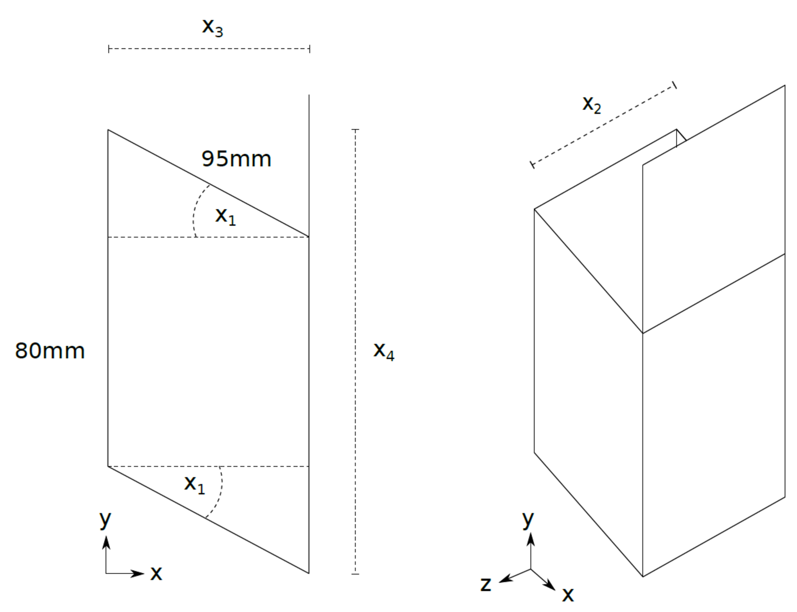
3. Optimisation of the Dimensions

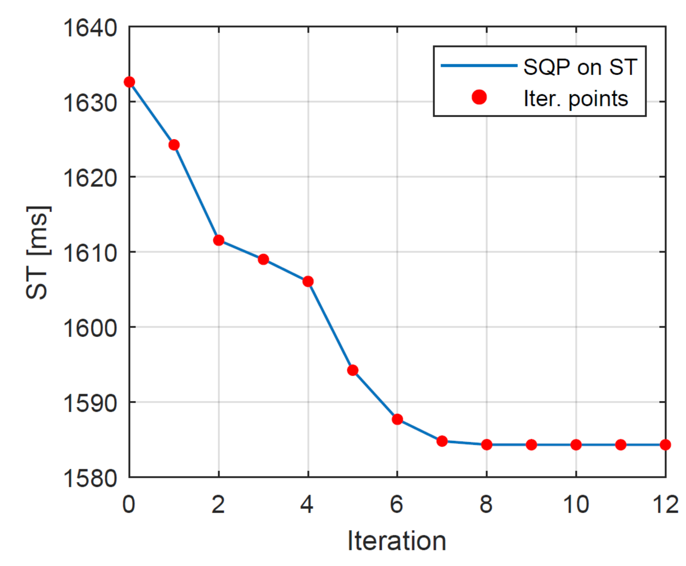
The objective function to be minimised is defined below:

$$ST(x_1, x_2) = \frac{1}{4} \cdot \sum_{i=1}^{4} f(x_i) \quad \text{S.T.} \quad \begin{array}{l} 0 \leq x_1 \leq 65 \\ 40 \leq x_2 \leq 140 \end{array}$$

The variables to be minimised are listed below:

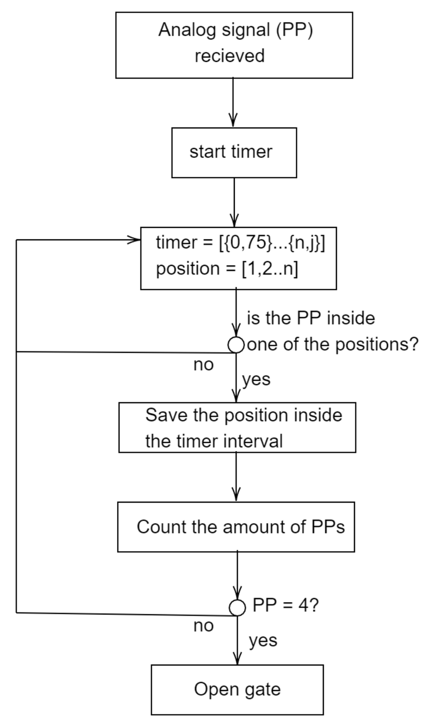
x_1 = The gate angle
x_2 = The depth of the compartment
x_3 = The width of the compartment
x_4 = The height of the compartment
d_1 = Predefined distance between the tip points of the gates, set to 80mm
d_2 = The length of the gate, set to 95mm

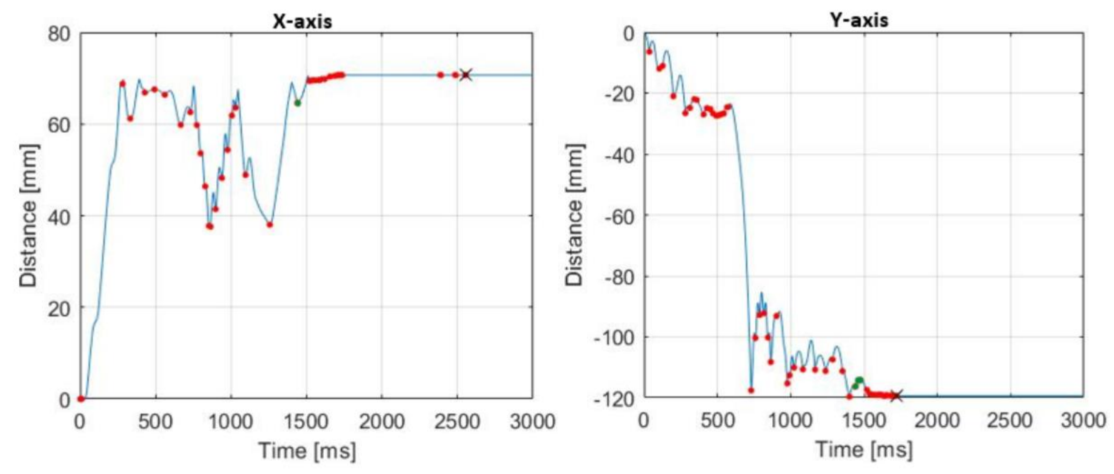




5. Pressure Sensor System

To determine if a pressure sensor would reduce the cycle-time of the wing unit, a code was written, and visualised as a pseudo-code in the figure





6. Results and conclusion

The final model, consisted of combining a stepper motor with a pressure sensor system and dimension changes of the original compartment. The pressure sensor system was developed based on practical experiments and simulations. The dimensions of the compartment were optimised, by applying sequential quadratic programming. From optimisations made on the original design, the LEGO element now settles at 524 ms and the gate opens at the same time, by using the pressure sensor system. This is a reduction of 83 ms from the validated model of the original design.

Acknowledgement

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