Capstone I - Journal 03
Project 61 · Steelcase
Reduction of Logistics and Packaging Costs

Basil R. Yap

2018 March 19

1 Summary

Predictions and outline given in prior Journal[1]:

- **Week 7:** Site visit & data cleaning
- **Week 8:** Load optimization modelling
- **Week 9:** Model implementation

Given the information collected during the site visit, I have re-evaluated the importance of load optimization in the earlier stages of ideation and redoubled my efforts to helping ideate for possible improvements for SMM's[2] current package solution.

With a greater insight of the actual manufacturing process of the three mechanism components we want to focus on, I believed it was more prudent to ideate for potential solutions as soon as possible, while the memory of our visit was still fresh. Given this shift in focus, the planned outline of the week 8 & 9 were changed to the following:

- **Week 8:** Breadth oriented ideation
- **Week 9 (Proposed):** Feasibility analysis
- **Week 9 (Actual):** Formalisation of problem scope

The overall idea was to have the group independently generate as many diverging ideas as possible. Then, slowly over the span of weeks prune the number of ideas down to manageable enough amount for deeper investigations into each respective idea.

[1] Journal 02
[2] Steelcase Manufacturing Malaysia

2 Problems Encountered

2.1 Week 7 & 8

During the site visit, the manufacturing process was extensively documented from assembly of the mechanisms to the loading of the packages. Various factors/variables were identified to be key to the design of our future solution. In the order of process stage, the problems are as follows:

- **Folding of packaging:**
  - Packaging is not pre-folded and components need to be stored in an accessible storage compartment
  - The boxes are highly compartmentalised and consists of many pieces that require assembly
  - The boxes tend to be quite low, requiring the worker to frequently bend down
- **Loading of mechanism:**
  - Mechanisms are covered with a disposable plastic prior to loading.
  - The method of loading varies widely between the three mechanisms, the complexity of how it is loaded must be taken into consideration.
  - The assembly cycle time varies widely between the three mechanisms, the loading step is a bottleneck in some cycles.
  - Depending on the weight of the mechanism, the boxes used were required to be double or triple layered in order to ensure its integrity while in transit
  - The pallets used for the packaging of all three mechanisms are the same, therefore, the footprint of every box is identical with varying heights. This constraint severely affects the packing efficiency of the V2 mechanism.
- **Loading of boxes:**
  - The number of boxes that can be stacked sequentially is limited by a prior load test. With the current paper pallets, The maximum number of each stack is 3 boxes high.
  - The loading of the mechanism boxes are done purely by forklifts, which are accurate enough to position the boxes with minimal gaps.
  - The compartmentalisation of the mechanisms and the usage of the disposable plastic is to ensure that the mechanisms do not scratch or gather dust.

2.2 Week 9

Due to an oversight on my part, the problem scope of our project was reduced too significantly with the complete removal of the logistics management[3] component of the project. In addition to that, the entirety of the problem scope was not well documented nor formalised prior to the completion of Review I. Week 9 was, therefore, spent on documenting the problem scope thoroughly and to build up a case for the re-introduction of the logistics management component and the data needed to sustain the problem. During this period, I focussed predominantly on building up the logistics management case and its incorporation into our current problem scope.

3 Actions Taken

Based on the information gathered from the site visit, the direction I believed to be the most fruitful was to redesign the external dimensions of the box, or at the very least, find a pallet size which would allow for all three mechanisms to have minimal space wastage. During week 8, my ideation and research efforts centred around finding literature and industry best practices for designing efficient packaging solutions. This knowledge was also supplemented literature on spatial packing optimization.

The list of readings, I compiled are as follows:
texts in italics, were of particular significance

- **3D packing optimization:**
  - *Mathematical model and efficient algorithms for object packing problem*
    N Chernov, Y Stoyan, T Romanova
  - The 3D-Packing by Meta Data Structure and Packing Heuristics
    H Yamazaki, K Sakanushi, S Nakatake
  - A packing algorithm for particles of arbitrary shapes
    X Jia, RA Williams
- **Package design:**
  - *Structural Packaging*
    P Jackson
  - Package Design Workbook: The Art and Science of Successful Packaging
    S DuPuls

[3] In-depth explanation regarding its removal is available in Journal 02

4 Insights Obtained

4.1 3D packing problem

[1] **Why do we need to optimize a simple block fitting problem?**
Optimizing for a 3D packing problem allows the team to consider non-conventional box shapes. i.e. non-cuboid shaped boxes

A 3D packing problem is equivalent to a 3-dimensional cutting and packing problem, where instead of extracting 2D shapes from a 2D board, we are attempting to extract 3D composite polygons (*packages*) from a 3D container (*container*). In Figure 1, an extreme case of 3D packing problem solution is demonstrated. Given the design of our box, we can breakdown/approximate the shape of the

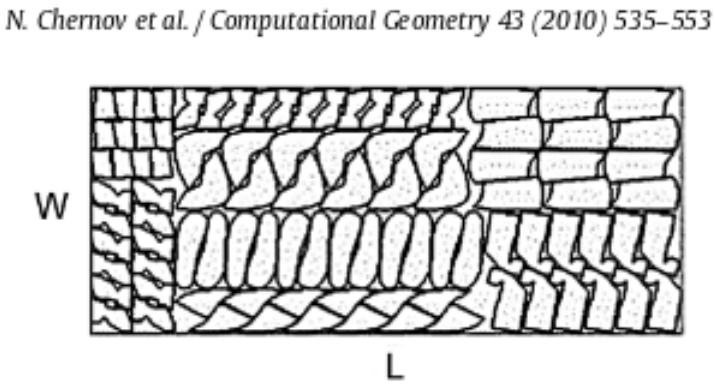

Figure 1: 2D/3D cutting and packing problems

box into a combination of 3D phi objects. Phi objects are mathematical representations of geometrical shapes we can use as variables in our 3D packing problem. In the event our boxes do not conform to a conventional shape, we can derive its phi function as a composite of simpler phi functions such as spheres, cones and cuboids. A example of a composite pi function can be seen in Figure 2. Using proposed solutions in the paper, we can derive the optimal positions and rotations of each box in the container.

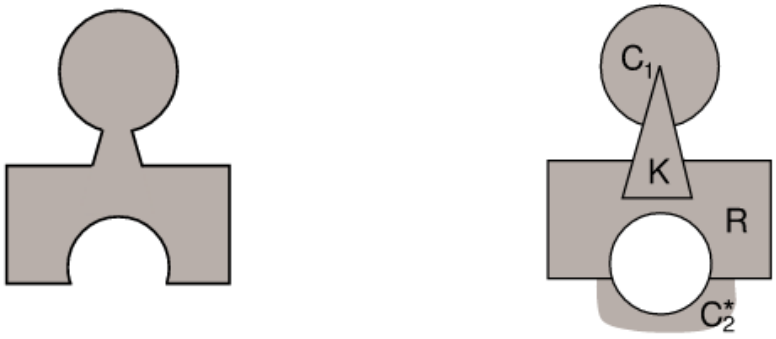

Fig. 4. An example of a composed phi-object, $C_1 \cup K \cup (R \cap C_2^*)$.

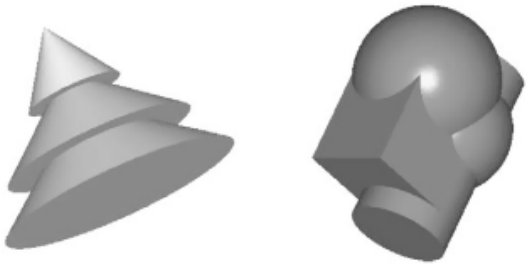

Fig. 5. Examples of composed phi-objects in 3D.

Figure 2: 2D/3D composite phi functions

4.2 Package design

[2]

When designing a package box, there are two major design decisions to consider:

- The net of the volumetric shape
- The stability of the volumetric shape

The net is the unfolded 2D space the volumetric shape occupies. In order to be able to mass produce the boxes, the shape has to be as compact and space efficient as possible. To do so, the author came up with 11 steps to efficiently create the net of most full body shapes. Figure 3 shows the outcome of following the following steps:

Step 1 Create 3D form

Step 2 Identify 2D faces

Step 3 Label edges on the faces

Step 4 Cut out lib/top of box

Step 5 Cut out shortest edges

Step 6 Unfold remainder of the box in ascending order of edge length

Step 7 Label lid/top outermost edge with T

Step 8 Label alternating outermost with T and X

Step 9 Ensure all T labelled edges can hold a Tab

Step 10 Determine the shape of each Tab by the shape of the corresponding X-labelled face

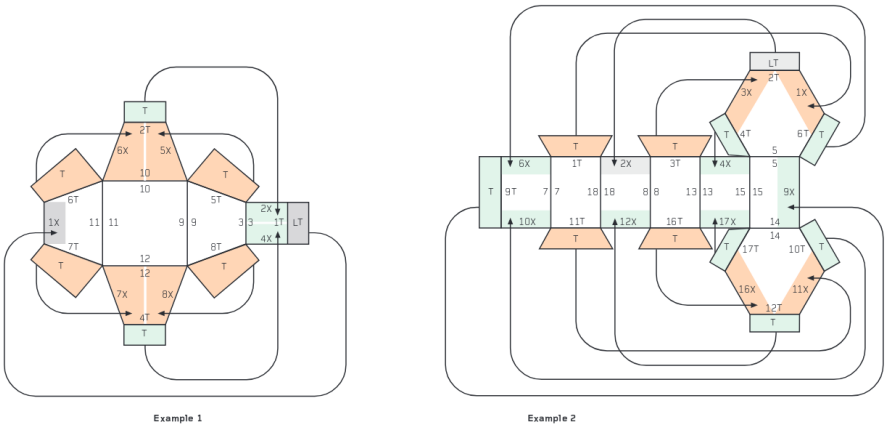

Figure 3: Procedurally generated nets

5 Timeline

The my personal timeline for next three weeks are as follows:

- **Week 10:**
    1. Re-negotiate data and problem scope for logistics management problem
    2. Re-scope ESD component (if applicable)
    3. Compile ideas from independent ideation for package design
- **Week 11:**
    1. Feasibility analysis of ideas
    2. ESD component (to be confirmed)
- **Week 9:**
    1. In-depth research on short-listed ideas
    2. ESD component (to be confirmed)

References

[1] N Chernov, Y Stoyan, T Romanova *Mathematical model and efficient algorithms for object packing problem* Computational Geometry, 2010

[2] P Jackson *Structural Packaging* Laurence King Publishing, 2014