Mixed Palletizing and Task Completion for Virtual Warehouses

Team Description

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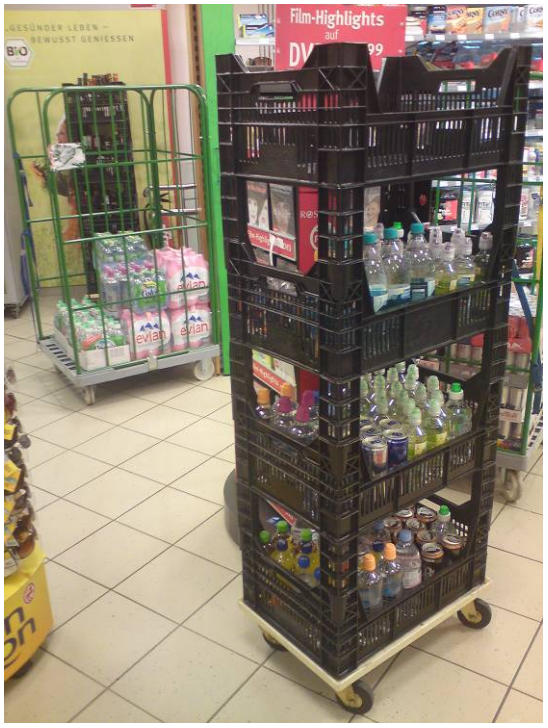
Motivation

- Palletizing is important to many applications



- The VMAC challenge combines nicely operations research, industrial and mobile robotics

Palletizing – General Idea

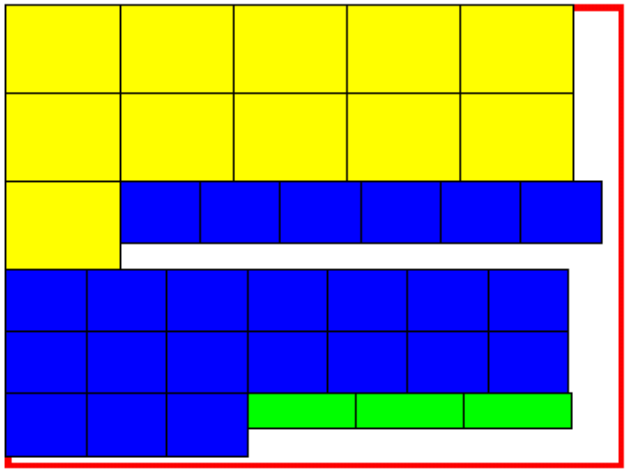
- Assumption: The order will contain many articles of equal height.
- Reduce the 3D knapsack problem to a 2D one
  - Arranging objects of same height in one layer will create a nearly seamless surface on the top. Hence another layer can be easily placed on it.
  - However, in most orders there will be a number of articles that are left over from being arranged into separate layers or are not enough to form their own layer to start with. Those articles will be put on top of the previously arranged layer stack.

Arranging Articles in Layers

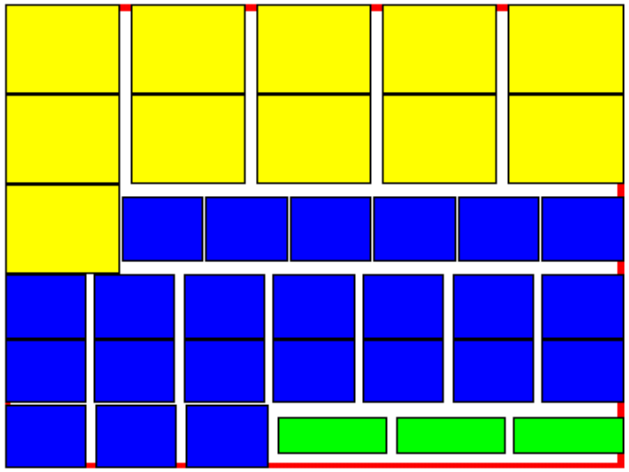
- All articles in one layer are of the same height
  - Sort all articles by height
- However, overall performance depends on the quality of this subtask (which is also NP-hard)
  - Sort rectangles by size
  - Put article into the upper left corner of the unused space
  - Partition the space into two subspaces with the leftovers
  - Use a tree-like structure for the remaining area
  - Traverse the tree for every input operation in BFS to find unused space
  - Finally, spread out the articles

Arranging Articles in Layers, cont.

- Example



(a) rectangles arranged on pallet area



(b) rectangles spread out over pallet area

- Increase flexibility by sort by base area, or weight or..
- Process articles rotated by 90°
- Rotate pallet by 90°, 180°, and 270°
- …

Further Optimizations

- run algorithm on half or quarters of a pallet and join the individual results afterward
- try 3D-CBL for the leftover articles or for whole orders
  - Three dimensional corner block list

    Yuchun Ma, Xianlong Hong, Sheqin Dong, and C.K. Cheng. 3D CBL: An efficient algorithm for general 3D packing problems. IEEE Transactions on Circuits and Systems, 2:1079–1082, 2005.
- Since it is hard to decide on a one-size-fits-all strategy without sacrificing performance in special cases, **all possible permutations of the options above are enumerated by the algorithm and compared against the evaluation software**. The configuration that produces the highest score will be the final output of the algorithm.

Palletizing Results

- Results using last years scoring file

	GT	Dexel	Jacobs	Jacobs2
D1R1	84.36	67.59	90.43	94.14
D1R2	28.96	32.94	81.96	84.13
D1R3	9.69	26.45	80.99	80.99
D1R4	40.63	44.46	87.81	88.04
D2R1	78.18	39.61	89.87	92.65
D2R2	21.56	-	80.27	80.64
D2R3	4.80	-	75.69	76.15
D2R4	37.88	-	81.61	83.63

Task Completion

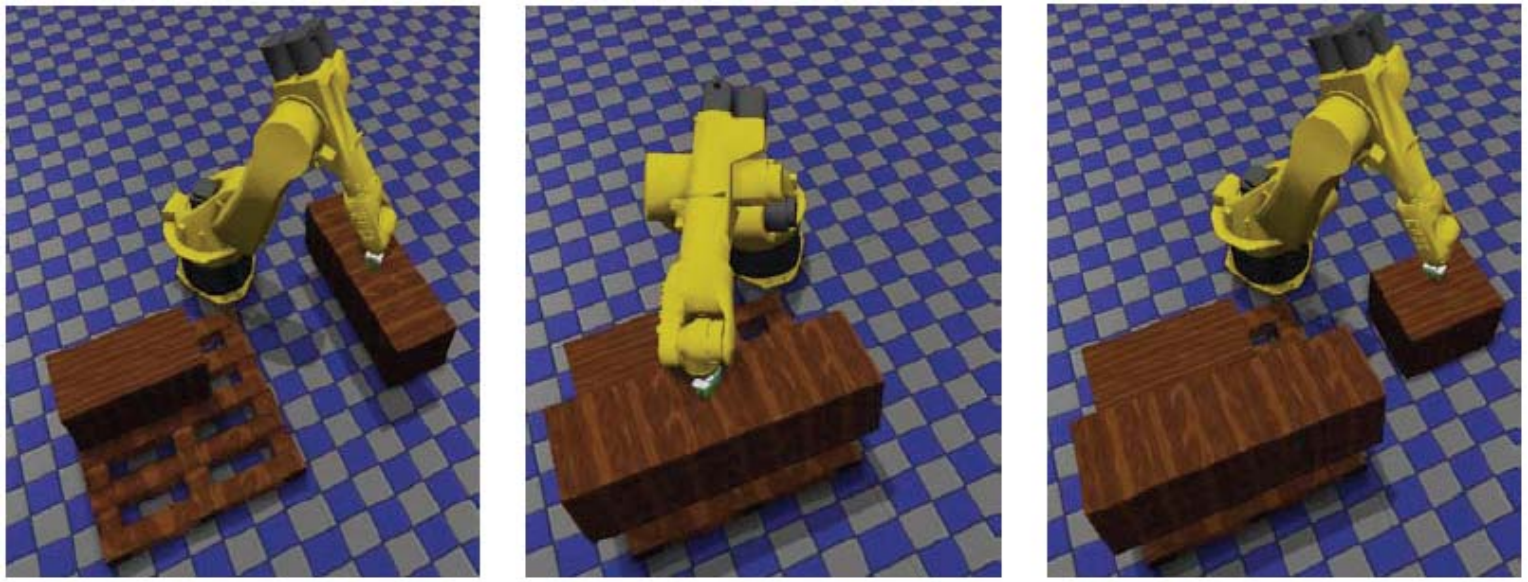
- We use KR60 in USARSim
- Two approaches to inverse kinematics (IK)
  - Geometrical IK like given in a textbook

    Wolfgang Weber. Industrieroboter – Methoden der Steuerung und Regelung. Fachbuchverlag Leipzig im Carl Hanser Verlag, 2nd edition, 2009.
  - Use ROS
    - Generate Unified Robot Description Format (URDF) for the robot
    - Use `tf` to do the forward kinematics
    - Compute Jacobian numerically and do the IK

Task Completion Results

- ROS nodes do not work properly
- Thus, we have only geometric IK
  - Accuracy limited

(video)



Future Work

- Try to learn from the order and scoring files the choice of the heuristic to use for creating good pallets
- Make the numerical IK working using ROS
- Main focus next year: Mobility challenge