OPTIMAL SORTING OF PRODUCT INTO FIXED WEIGHT PACKAGING

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Compac Sorting Equipment make very nifty machines for sorting fruit by weight, diameter, colour, density, blemish or even shape. Compac sought solutions to two closely related problems: the boxing problem and the bagging problem. The boxing problem requires graded fruit to be assigned to outlets where boxes are filled with a specified number of fruit to a minimum weight (and a specified tolerance for underweights). The aim is to maximise the number of boxes packed. The decision must be made after all information is known, but before the fruit passes the first outlet - a few seconds total. Further, information about fruit already packed in a given box is incomplete (we don't know exactly which fruit ended up in a box). The bagging problem requires bags to be filled to a minimum weight - no tolerance for underweights, and no constraints on the number of fruit per bag. In this case complete information is available on fruit already assigned to a bag. Again the aim is to maximise the number of bags packed. The MISG team were able to provide a 'close to optimal' solution to the boxing problem for the simplest information scenario where an irrevocable decision is made for each fruit in turn, and no memory of previous assignments is kept. This information scenario is the least demanding of real time measurement for Compac and is also the simplest to analyse and optimise. Basically, it is an attempt to improve on an old idea already implemented by Compac - static cut points. Cut points define the category (and hence the outlet) a fruit will be assigned to. Potentially, the value of the fruit may be different for different categories. The cut point optimisation problem was formulated with the objective of revenue maximisation. The determination of globally optimal solutions is non trivial but some approximations

*Note:Due to the competitive situation of the Industry concerned, it was agreed that the technical details developed during MISG be kept confidential. The description here is the same as the "Equation-Free Summaries" concluded earlier.

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and assumptions yielded a tractable solution method. We are confident that the solutions given by this approach won't be substantially worse than those from any other approach; hence we claim a 'close to optimal' result. Compac believe that there is value in adapting the choice of the cut points to the distribution of the incoming fruit. The solution method proposed does depend on this distribution and it can be re-run if the distribution changes significantly. We were able to provide software to solve the cutpoint optimisation and a simulation of the resulting decision system. The simulation results compared favourably with Compac's current approach. The team investigated a range of approaches to realise the potential benefits of richer information scenarios. Each method assumed some knowledge of previous assignments to an outlet. They also exploited the fact that the system has some time Page 15 of 15 between when all information about the fruit is known, and when it must commit to a decision. Some tens of fruit can therefore be considered together. These approaches use the fact that weight allowances of fruit categories overlap. An 18kg, 100-fruit box has an average weight of 180g per fruit. But if we aim for a target weight of 180g, the variance in individual weights means we will often get underweight boxes. The proposed methods choose target weights sufficiently above the minimum target (180g in this case) using the variance for weight of fruit already sent to the outlet so that it is unlikely a box will be underweight. The trick then is to minimise the variance. One of the algorithms looked for good combinations of pairs of fruit (even pairs of pears). It was not possible to fully quantify the improvements that use of this extra information would yield but a range of algorithms were developed and can be investigated further. We looked at the bagging problem in two ways. The first concentrated on the physical aspects of the problem. The physical constraints have a very large impact on the problem. For example, fruit from a near-side lane arrives faster than far-side lanes, so if we are just finishing off a bag, near-side fruit is much preferred. Restrictions in the number of fruit that can be allowed to cycle must also be observed. A Matlab model was created that simulates some of these physical restrictions, and has been made available to Compac. An algorithm for choosing the fruit based on "preference zones" was developed, where bags close to finishing were allowed to choose fruit from their "most-preferred" zone before other bags got to pick over the remaining fruit. Unfortunately, we didn't have enough time to run it through the simulation. A second approach concentrated on trying to find the best three or four fruit to finish off a bag. A method was presented that is feasible for real time implementation both in terms of the information (measurements) and computation required. Simulations suggested that this algorithm significantly out-performs the current, simplistic approach of first-in-first-out. It currently assumes pre-graded fruit but could be made more generic - allowing fruit that can be classed into more than one grade.