IPAM-RIPS + HP = Procurement is Possible

The 2006 HP Labs / IPAM-RIPS project will focus on novel graph-based algorithms for extracting k-best solutions to auction winner determination problems, particularly for procurement auctions, and on decision-support techniques based on k-best solutions.

HP regularly conducts multi-million dollar procurement auctions for material inputs, e.g., power cords, cooling fans, motherboards, etc. Suppliers submit bids offering to sell HP some or all of the required quantities of each item. HP's procurement executives must select winning bids to satisfy HP's demands for the items subject to certain side constraints (e.g., on the number of suppliers chosen and the distribution of expenditure across suppliers). The standard approach to such an auction is to formulate the auction winner determination problem as a mixed integer program. The difficulty here is that while some constraints on a winning combination – such as a maximum proportion of each item to buy from a single seller – are easy to incorporate into such a program, others are difficult to articulate in advance. The procurement executive might "know a good solution when she sees one," but cannot state its properties up front.

To help executives in this context, we have adapted algorithms that generate k-shortest paths in a graph. We reformulate the auction winner determination problem as that of finding a path in a graph such that the cost of the auction solution is equal to the length of the path. This enables us to efficiently generate k-cheapest solutions to the auction winner determination problem, where k can range from the tens of thousands to the tens of millions. We can then filter the results to find solutions that a procurement executive might find acceptable and to shed light on the competitive landscape. Several challenges remain in the domain which we intend to explore this summer:

- **Incorporating hard constraints in the solution-generation process:** For those constraints that *can* be stated explicitly, we would like ways of changing the topology of the graph so that any path between start and end nodes automatically satisfies the constraint. We know how to do this for some constraints, but it is an open problem to characterize the kinds of constraints that map efficiently into graph topologies.
- **Dominance pruning:** We can generate an unwieldy list of k-cheapest solutions, which must be filtered or reduced for the decision-maker's benefit. If the decision maker has defined ordinal preferences over solution attributes, then dominance pruning to obtain a reduced Pareto frontier of solutions is an obvious approach. There are two open issues: one is the computational cost of dominance pruning if the number of original solutions and the number of criteria are large; another is the specific criteria that make the most sense in this domain.
- **Data mining & visualization:** The wealth of data contained in k-cheapest solutions should provide opportunities for understanding the competitive landscape (e.g., particular regularities in demand between different items, particularly scarce availability for some items, etc.) both quantitatively via

data mining and statistical methods, but also qualitatively via visualization techniques.

- **Algorithmic improvements & implementation:** Some of the algorithms involved have not been implemented, or have sub-optimal implementations. A body of work will focus on algorithmic efficiency improvements and implementation.

We anticipate that side-effects of the project will include:

- Usable code
- Efficient algorithms
- Insightful post-processing and visualization techniques
- Solid theoretical contributions
- Academic papers, e.g., at the level of the ACM E-Commerce Conference (EC)

A description of our preliminary work is in publication; a technical report is also available at http://www.hpl.hp.com/techreports/2006/HPL-2006-40.html