Bid Price Controls for Dynamic Pricing in the Airline Industry

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Maximising Revenue

• Products (seats and extras) are divided into fare classes.

• Those in fare class \( n \) generate greater revenue the smaller the value of \( n \).

• Have a fixed seat capacity.

• Strategically limit the number of low-revenue products sold, according to demand forecasts.
Bid Prices

One method of implementing limits.

Act as a threshold price.
Motivation

Bid prices are calculated based on remaining capacity, remaining time-to-flight, and demand forecasts.

How effective are bid prices when demand does not match the forecast?

Is it beneficial to update bid prices, according to observed demand?
Methods
Calculating Bid Prices

- Bid prices are the **difference** between the value of selling a seat now, versus in the future.

- This means they are calculated **recursively**.
Modelling Demand

Multinomial model assumed.

<table>
<thead>
<tr>
<th>Event Outcome (in one time period)</th>
<th>Class 1 Arrival</th>
<th>Class 2 Arrival</th>
<th>No Arrival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecasted Arrival Probability</td>
<td>0.05</td>
<td>0.1</td>
<td>0.85</td>
</tr>
<tr>
<td>Fare</td>
<td>120</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure: Single simulation of demand arrivals.

Figure: Single simulation of revenue, using bid prices based on forecast.
Deviation from Forecast
Deviation of Overall Demand

- Ratio of demand between classes the same.
- Demand probabilities homogeneous across booking horizon.
- Both probabilities increased/decreased from forecast by some factor.

**Figure:** The effect of the deviation of overall demand from forecast on average simulated revenue.

**Figure:** The effect of updating bid prices on average simulated revenue, for different deviations of overall demand.
Deviation of Demand Over Time

- Total expected demand matched forecast.
- Demand probability changes mid-way through booking horizon.

![Graph showing deviation of demand over time](image)
Deviation of Demand Over Time: General Findings

- Larger decreases in revenue the earlier low-value demand arrived, and the later high-value demand arrived.

- Some increases in revenue for later low-value demand arrival and earlier high-value demand arrival.
Deviation of Demand Over Time: Updating Bid Prices

Need to re-calculate bid prices every time probabilities change.

Figure: Demand for both classes decreases over time.

Figure: Demand for both classes increases over time.
Should We Always Update?
Updating doesn’t always **increase revenue**

In general: more revenue by **failing to update** when demand **increases** over booking horizon.
Updated bid prices $\neq$ change in booking controls

Updating can only affect revenue if it changes which fare classes are open.

Example - updated bid prices for 50% increase in overall demand.

![Figure](chart.png)

**Figure:** Each coordinate represents an updated bid price. Only those highlighted changed which fare classes were open.
Not all updated bid prices will be required

Figure: Number of times bid prices were utilised, when demand matched forecast.
Main Conclusions

1. Bid prices are not robust to substantial deviations from forecasted demand.

2. Updating bid prices can, in cases, increase revenue.

3. Frequently updating is impractical.

4. Updating is not beneficial in all cases.
Future Work

Explore possibilities to **selectively update**.

- Only when updating increases revenue.
- Only for bid prices likely to be used.


Dynamic Programming for Bid Prices

The difference in value function (optimal expected revenue) from sale of the next seat, evaluated at the previous time period. Where,

\[ v_t(x) = \sum_{j \in J(x)} p_{jt} \max\{r_j - \Delta_{tj}(x), 0\} + v_{t+1}(x). \]

- \( v_t(x) \) - value function, at time \( t \), for remaining capacity \( x \)
- \( J(x) \) - the set of fare classes
- \( p_{jt} \) - probability of class \( j \) demand during time period \( t \)
- \( r_j \) - revenue from class \( j \)
- \( \Delta_{tj}(x) = v_{t+1}(x) - v_{t+1}(x - 1). \)