Bid Price Controls for Dynamic Pricing in the Airline Industry

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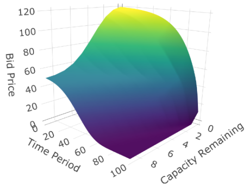
Maximising Revenue

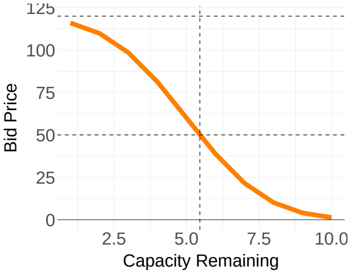
- Products (seats and extras) are divided into fare classes.
- Those in fare class n generate greater revenue the smaller the value of n.
- Have a fixed seat capacity.
- Strategically **limit** the number of low-revenue products sold, according to demand forecasts.

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.

Event Outcome (in one time period)	Class 1 Arrival	Class 2 Arrival	No Arrival
Forecasted Arrival Probability	0.05	0.1	0.85
Fare	120	50	0

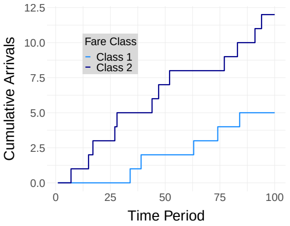


Figure: Single simulation of demand arrivals.

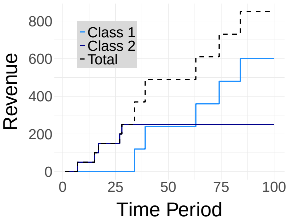


Figure: Single simulation of revenue, using bid prices based on forecast.

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.

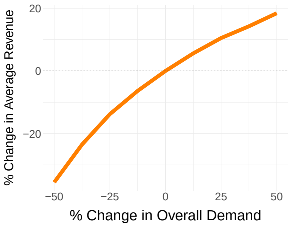


Figure: The effect of the deviation of overall demand from forecast on average simulated revenue.

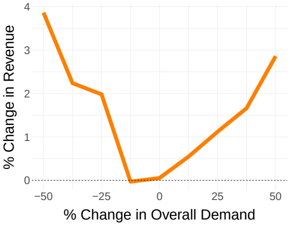
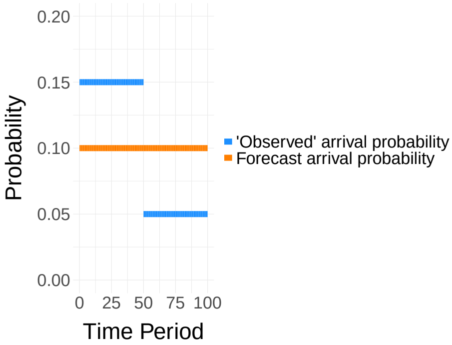


Figure: The effect of **updating** bid prices on average simulated revenue, for different deviations of overall demand.

Deviation of Demand Over Time

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



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.

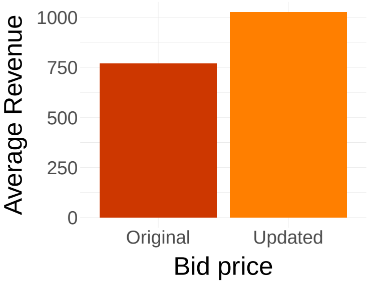


Figure: Demand for both classes decreases over time.

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.

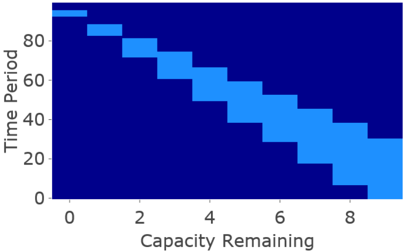


Figure: Each coordinate represents an updated bid price. Only those highlighted changed which fare classes were open.

Not all updated bid prices will be **required**

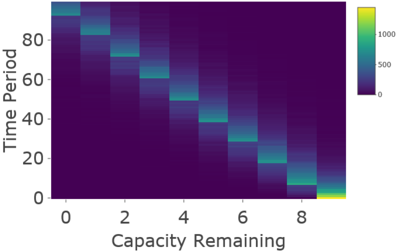


Figure: Number of times bid prices were utilised, when demand matched forecast.

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.

References

- van Ryzin, G. J., & Talluri, K. T. (1998). An analysis of bid-price controls for network revenue management. *Management Science, 44*(11), 1577-1593. `https://doi/abs/10.1287/mnsc.44.11.1577`
- van Ryzin, G. J., & Talluri, K. T. (2005). An introduction to revenue management. *INFORMS TutORials in Operations Research*, pp. 142-194. `https://doi.org/10.1287/educ.1053.0019`
- Williamson, E. L. (1992). *Airline network seat inventory control: Methodologies and revenue impacts* (Doctoral dissertation). `https://dspace.mit.edu/handle/1721.1/68123`

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
- $\Delta_{tj}(x) = v_{t+1}(x) - v_{t+1}(x-1)$.