

Airborne delay prediction for optimal air traffic management

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Context
Objective

Introduction

- Consequences of air traffic uncertainty : work disruption - non optimal use of available resources - economic cost.
- Consequences of air traffic sustained growth : lack of capacity in air traffic management - increasing uncertainty in predicting the air traffic - delays at each flight phase.
 - Urge for new tools to an optimal planning and control of traffic flows.

Considering an aircraft located at a given point on its trajectory after taking-off phase :

- Propose a statistical and stochastic model in order to predict accurately airborne delays.
- Model requirements :
 - run dynamically in real time.
 - be able to predict the crossing time of an aircraft at future point on its planned trajectory based on explanatory variables.
- Model engine : CART (Classification And Regression Trees) method.

Methodology

Given an aircraft i

$$t_i^P = t_i^{P/n} + f(\mathbf{X})_i + \epsilon_i. \quad (1)$$

where :

- t_i^P : the crossing time of i at M_i^P .
- $t_i^{P/n}$ forecasted based on BADA performance model.
 - This simulation begins at $M^o(t_o)$ and provides the new trajectory updated between points $M^o(t_o)$ and $M^P(t^P)$.

Given an aircraft i

$$t_i^p = t_i^{pln} + f(\mathbf{X})_i + \epsilon_i.$$

where :

- f is a determinist function of \mathbf{X} .

$$\mathbf{X} = (\text{Pln, Weather, Complexity, Par_current})_i,$$

- ϵ_i are the residuals.
- The forcasted crossing time achieved from (1) is :

$$\widehat{t}_i^p = t_i^{pln} + f(\mathbf{X})_i,$$

- The delay is :

$$\Delta\tau_i = t_i^p - \widehat{t}_i^p.$$

We assume that an aircraft i crosses a sector s on its trajectory. For a given couple (i, s) :

- the $t_{i,s}^P$ modeling is formulated as follows :

$$t_{i,s}^P = t_{i,s}^{pln} + f(\mathbf{X})_{i,s} + \epsilon_{i,s},$$

and

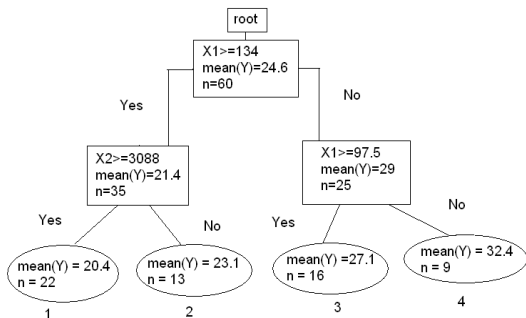
- the delay prediction at the sector entry can be induced accordingly :

$$\widehat{\Delta T}_{i,s} = f(\mathbf{X})_{i,s}.$$

CART algorithm

CART algorithm is based on two steps :

- To split recursively sample based on independent variables $X=(X_1, X_2)$, into the most homogeneous subsets which do not overlap.
- To predict for each subset, the value of dependent variable Y .
 - This prediction is the mean value of the dependent variable Y estimated within the node.



Data

Our sample covers 23 days 4th – 23th september 2007 :

- sample size : 8137 points for 2412 aircrafts,
- data related to the aircraft flights are from EUROCONTROL (Flight plan, CPR),
- data related to the weather are from Meteo-France on the same period,
- $t_o \in \{8 : 00, 11 : 00, 14 : 00, 17 : 00\}$ is the day period which aircraft is observed on its current trajectory,
- to include a flight in the studied sample, its actual trajectory must be very close to its planned trajectory. An illustration is as follows :

Flight no 738421 04/09/2007:to=8h

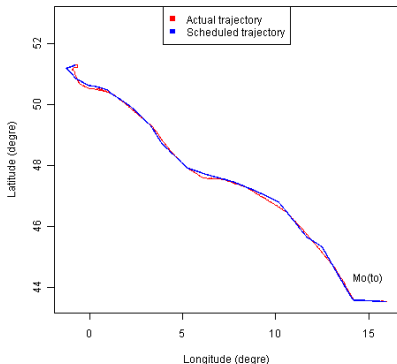


FIG.: Horizontal trajectories

Flight no 738421 04/09/2007:to=8h

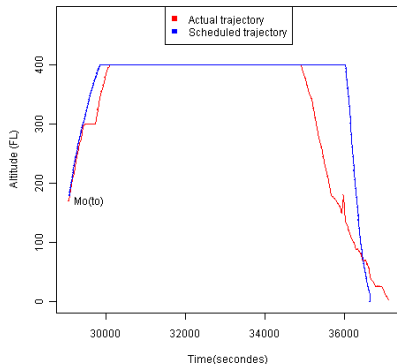
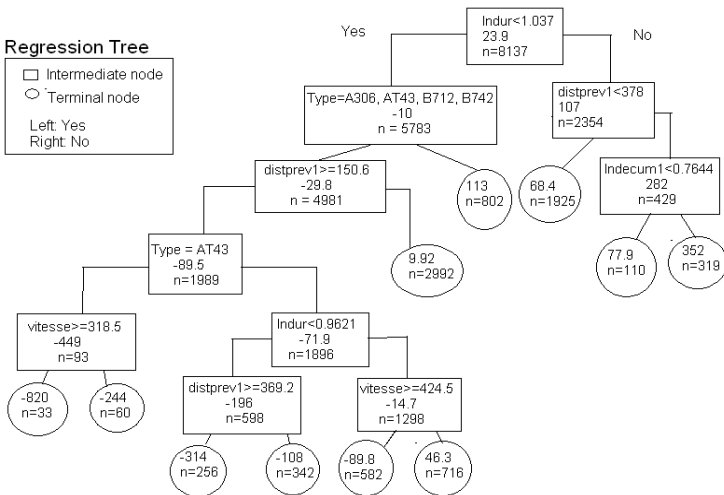
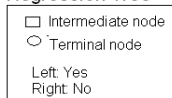


FIG.: Vertical trajectories

Airborne delay modeling based CART algorithm

Regression Tree



Improved CART model

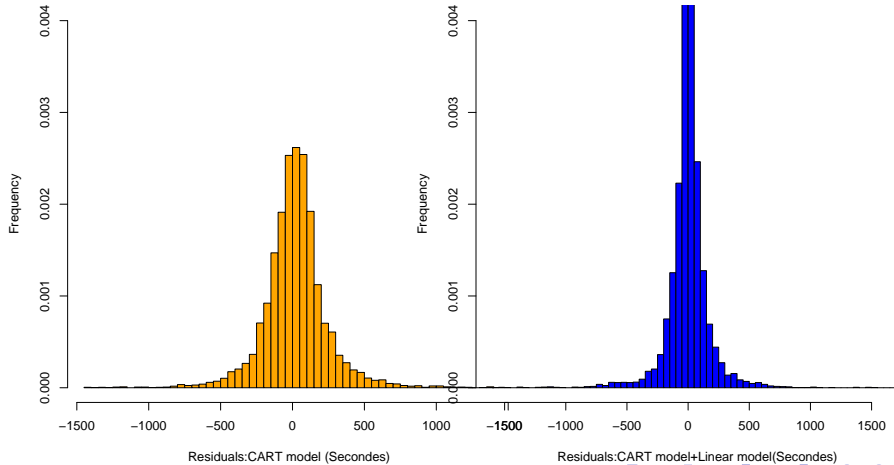
Improved CART model is based on two steps :

- Step 1 : CART algorithm produces the *terminal nodes*.
- Step 2 : In each terminal node, airborne delay is predicted using *Stepwise*.
- In other words, linear model :
 - Prediction based on the node instead of mean value.

Indicators per node are : Adjusted R-squared and F-statistic

Nodes	1	2	3	4	5	6
Adjusted R-squared	0.95	0.51	0.71	0.37	0.31	0.17
F-statistic	73.73	10.71	56.8	23.25	36.89	21.48
Mean delay	-820	-244	-314	-108	-89.8	46.3
Nodes	7	8	9	10	11	
Adjusted R-squared	0.08	0.27	0.21	0.42	0.70	
F-statistic	28.64	33.48	52.29	7.87	74.01	
Mean delay	9.92	113	68.4	77.9	352	

TABLE.: Indicators of Improved CART model within nodes



	CART model	Improved CART model
Residuals	Percentage (%)	Percentage (%)
$] \infty, -500[$	1.68	1.62
$[-500, -300[$	3.74	1.95
$[-300, -100[$	17.30	12.84
$[-100, 100]$	48.02	66.77
$]100, 300]$	21.77	13.42
$]300, 500]$	4.94	2.24
$]500, \infty[$	2.54	1.16
Total	100	100

TAB.: Model errors : CART model vs Improved CART model

Conclusion and the future works

Conclusion

- CART model provides the classification of aircraft trajectory points.
- CART model falls in predicting the great absolute value of the airborne delays.
- Improved CART model exhibit better prediction capability than the previous model.

Future works

- The linear model step will be replaced in the improved CART model by the PLS (Partial Least Square) model,
- The model will be integrated in a more general model for computing the quantity of conflicts and predicting workload in the airspace area.