Rule Based Aircraft Performance System

Metin Zontul

Abstract— For aircrafts, there are many rules for takeoff and landing performance calculations. These rules are defined according to aircraft configuration, MEL/CDL items, Turn Procedures, Airport and Obstacle Database and Weather Conditions. In this study, a general database is created to include all kinds of aircraft, airport information and rules effecting aircraft performance. The rules include aircraft configuration, MEL/CDL items and external conditions. Rules can be simple or complex in such a way that composite conditions can be used all together and simple rules can be combined in a complex rule. This study is different from other studies in that all aircraft types can be combined in a single server based database systems and rule checking process is very dynamic and flexible. This server database can be extended to create national or international aircraft and airport information system in the future. Besides the advantages of operational safety resulting from making point calculation instead of conventional calculations, with the implementation of this system fuel conservation, emissions of CO2 decrement, aircraft engine health management are achieved.

Index Terms— Aircraft Performance, EFB Database, Performance Rule, Rule Based System.

I. INTRODUCTION

The economic situation of recent years forces to operate at highest payloads possible and therefore maximum allowable take-off masses of an aircraft. An optimization of performance calculations plays then important role much more than ever before.

Most airlines use programs supplied by the airplane manufacturers for each airplane type, and interface these programs with their own computer operating environment, airfield database, and data output format requirements. These programs are generally included in a special device called as Electronic flight bag (EFB) which is an electronic information management device that helps flight crews perform flight management tasks more easily and efficiently with less paper. There is IATA Standard Computerized Airplane Performance (SCAP) Interface Specification in order to reduce the development effort for the airlines and manufacturers [1] [4]. The airline industry depends on accurate and timely takeoff and landing performance data to provide flight crews and dispatchers with accurate airport descriptions. This data is maintained by suppliers, operators, and government organizations and exchanged between all users in a variety of media.

The transmission of this data between suppliers and operators can be facilitated by the use of a common data interchange format (SCAP) [15]. The use of a single format will allow the suppliers to supply a single, consistent formatted to operators and other users which, in turn, can use the data in a consistent manner independent of who supplied the data to them.

Manuscript received September, 2013.

Metin Zontul, Department of Software Engineering, Istanbul Aydin University, and Istanbul, Turkey.

For aircrafts such as BOEING and AIRBUS, there are many rules for takeoff and landing performance calculations. These rules are defined according to aircraft configuration, MEL (Minimum Equipment List) / CDL (Configuration Deviation List) items, Turn Procedures (if available), Airport and Obstacle Database (AODB) and Weather Conditions [2] [14]. In this study, a general database is created to include all kinds of aircraft, airport information and rules effecting aircraft performance. This database system is server based and can be accessed from everywhere. The rules include aircraft configuration such as airframe/engine combination, flap setting, airconditioning, anti-ice, thrust rating, aircraft CG position, climb method etc. , MEL/CDL items and external conditions such as AODB and weather conditions such as runway condition, wind direction, wind speed, outside air temperature, QNH and NOTAMs (if available). Rules can be simple or complex in such a way that composite conditions can be used all together and simple rules can be combined in a complex rule.

There is no any published study related to rule based systems on aircraft performance system. Therefore, this study will help many researchers that want to apply rule based systems on aircraft performance systems.

In second part, a literature survey is given to show where rule based systems are used in flight operations. In third part, our rule based performance system is explained and it is shown how to prepare rules. Fourt part is conclusion part to discuss what is the benefit of our system and what can be done in future.

II. LITERATURE SURVEY

There are many studies related to rule based flight systems which are generally called as flight expert sytems. The objectives of these studies can be classified in terms of aircraft performance, flight safety, optimal fuel consumption, aircraft optimal loading.

In one of these studies, the design and implementation of a prototype rule-based front end expert system for integrity enforcement for the Naval Aircraft Flight Record relational data base is discussed including a set of rules that define the update operation that triggers the testing of an integrity rule, a specification of the condition to be tested, and the action to be taken in case of attempted violation. These rules are stored in a knowledge base, which the inference engine of the expert system uses to enforce data base integrity [8].

A study proposed a rule-based reactive model for the simulation of aircraft on airport gates to bring together object-oriented simulations and knowledge-based systems to produce a new kind of model in which knowledge-based technologies can be more deeply structured within a simulator and the simulation can be entirely embedded in a knowledge-based system [9].

Wu and et. all. Designed an intelligent and autonomous flight control system for an

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

atmospheric re-entry vehicle based on fuzzy logic control and aerodynamic inversion computation. A linear transformation to the controller inputs is applied to tune the controller performance for different flight regions while using the same fuzzy rule base and inference engine [10].

Alam and et.all. proposed an ensemble approach for conflict detection (CD) in Free Flight. This approach consisted of several CD algorithms, a rule set for each algorithm describing its learned behavior from its past performance and a switch mechanism to choose an appropriate CD algorithm given probe characteristics [11].

A rule based optimization approach for airline load planning system was proposed to improve the operational efficiency while satisfying the constraints of weight and balance, aircraft structure limitation and flight safety. Based on such approach, a system with a visual rule editor, a business object modeler and a rule engine was developed and implemented in a North American airline [12].

A paper used the Dominance-based Rough Set Approach (DRSA) to formulate airline service strategies by generating decision rules that model passenger preference for airline service quality. According to this study, DRSA could help airlines eliminate some services associated with dispensable attributes without affecting passenger perception of service quality,and it could also help airlines achieve mass customization of airline services and generate additional revenues by active or passive targeting of quality services to passengers [13].

In this study, the objective is to combine rule based systems with EFB systems. There are some researches associated with EFB systems but they mentioned about only EFB standards and assesment criterias, and they did not go further in detail in terms of EFB internal structures [3] [5] [6] [7].

III. RULE BASED AIRCRAFT PERFORMANCE SYSTEM

This study has been developed as a EFB project for a private airline company in Turkey. There were different types of aircrafts of BOEING and AIRBUS such as BOEING 737-400, BOEING 737-800, BOEING 737-900 ER, AIRBUS 320 and AIRBUS 321. Normally, BOEING and AIRBUS have their EFB solutions in terms of Class1, Class 2 and Class 3 but these solutions are very expensive and they have limited flexibility. Because of these reasons, we decided to develope our EFB solution as Class 1 (stand-alone special laptop installed EFB software).

First of all, we examined all BOEING and AIRBUS aircrafts documents to determine basic requirements of EFB database [15]-[24]. We considered database systems for both server and client sides. Our intention was to enter all data related to EFB systems in a database server and then to distribute this data to all EFB client machines. We used MS SQL Server 2008 R2 database system for this project. Then, we created EFB database and its 55 tables associated with aircraft, airport, takeoff, landing, weight-and-balance and documentation so that we could combine all aircraft types data and airport data in a single database and we could share this information with any EFB client.

Our EFB database also contains rules including aircraft configuration such as airframe/engine combination, flap setting, airconditioning, anti-ice, thrust rating, aircraft CG position, climb method etc., MEL/CDL items and external conditions such as AODB and weather conditions such as runway condition, wind direction, wind speed, outside air temperature, QNH and NOTAMs (if available). Rules can be simple or complex in such a way that composite conditions can be used all together and simple rules can be combined in a complex rule.

Both manufacturer BOEING and AIRBUS give us some engine modules and their interfaces for takeoff and landing calculations so that we can develope our EFB software. As shown in Fig.1, EFB software must cominicate with manufacturer module (MM) over a predefined interface. We could not get all takeoff and landing calculations from this interface so we wrote our codes for speacial calculations. Generally, there is a executable file or DLL as manufacturer module that uses input and output text files. Before calling MM, input text file should be prepared in a given format according to inputs taken from EFB software interface so that MM can get inputs associated with aircraft, airport, wheather conditions etc. Then, MM generates output text files including some takeoff and landing calculations. There are many titles and their values for calculations. Some calculations can be shown directly on screen but some of them should be filtered by rule base system as shown Fig.2. As some rules include the impossibility of calculations in a special conditions, other rules includes positive and negative value affects for these calculations. EFB Software Interface for both input and output can be seen in Fig.3 as a takeoff module.

Input parameters are standardized by IATA to allow EFB developers to develope their software easily by communicating with MM. Input pameters are categorized as arrays so that we can assign input values to related array elements such as POPT(1), CONF(1) etc. Table 1 shows input arrays and Table 2 gives some input arrays possible values.

There are some restrictions related to these input array values. These restrictions are defined as rules in our EFB database. In order to define the rules, we determined a rule format as given in Table 3.

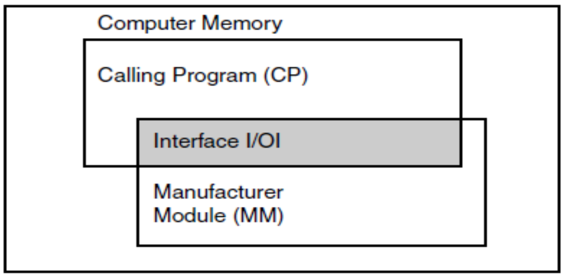
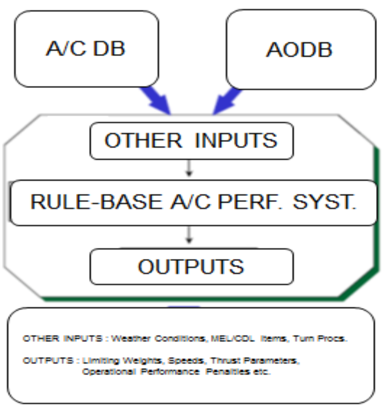


Figure 1. EFB Interface Diagram.



Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Figure 2. Rule Based A/C Performance System.

In Fig.4., two rules are given for aircraft TC-SKB. There are two types of operand in a rule:Target and Effecting Operand. Rule 1 and Rule 2 correspond to the following conditions respectively:

if POPT(5)=1 then POPT(14) cannot be 2,3 or 11.
if POPT(5)=4 then POPT(14) cannot be 2, 3 or 11.

The rules are written in a way that if an array element value is (is not) something then the other array element value should be (not be) something. “< >” operator is used as “different”. Also, “N/A” is used as “Not Applicable” when an operand or an operator is not necessary. Before inputs are sent to MM, input array values are checked to detect whether there is any conflict among input array values by using the rule based system. If there is no conflict, input array values are sent to MM and output values are calculated by MM.

Figure 3. EFB Software Interface for both inputs and outputs.

Table 1. Calculation Input Parameters pre-defined by IATA for the aircraft manufacturers to establish their values for the related aircraft.

Input Parameters	Description
POPT	Program Options Array
CONF	Aircraft Configuration Array
XMET	Meteorological Conditions Array
RWYD	Runway Array
OBSD	Obstacle Array
FPTD	Flight Path Turn Data array
UNIT	Units Array
SPIA	Supplemental Performance Interface Array

There are also MEL (Minimum Equipment List) and CDL (Configuration Deviation List) rules. MEL is a categorized list of systems, instruments and equipment on an aircraft that may be inoperative for flight. CDL is a listing of approved non-structural external parts that may be missing but the airplane remains airworthy. For both takeoff and landing, we defined MEL/CDL rules in our EFB database. Depending on these rules, it is possible to decide whether airplane is airworthy, and to adjust some input parameters such as array values and some variable values before calculation. MEL rule structure can be seen in Table 4 below. MEL can be divided into chapters that contain items. For each MEL item, it is possible to write one or more rules that are sometimes simple or complex. In table 4, the first sample is a simple rule that contains only one input array element as target operand. The second rule is a complex rule that contains more than one target operand. In this rule, “FL;OBS;CL;BE;TS” means there are 5 target operands which of each is a special variable for takeoff operation. These variables are takeoff weight variables separated by “;”. In this way, we can add more than one target operand in our rule. Target operator “-=” means that if XMET(01)>10 then FL, OBS, CL, BE, TS variables will be reduced by 2110 automatically during takeoff calculation for aircraft TC-SKB. Target operator “+=” can be used for incrementation in the same way. Target operands can be input array elements or special variables. The similar rules can be written for MEL landing or CDL takeoff and landing operations. This rule mechanism is very flexible.

Table 2. Some Input Array Values.

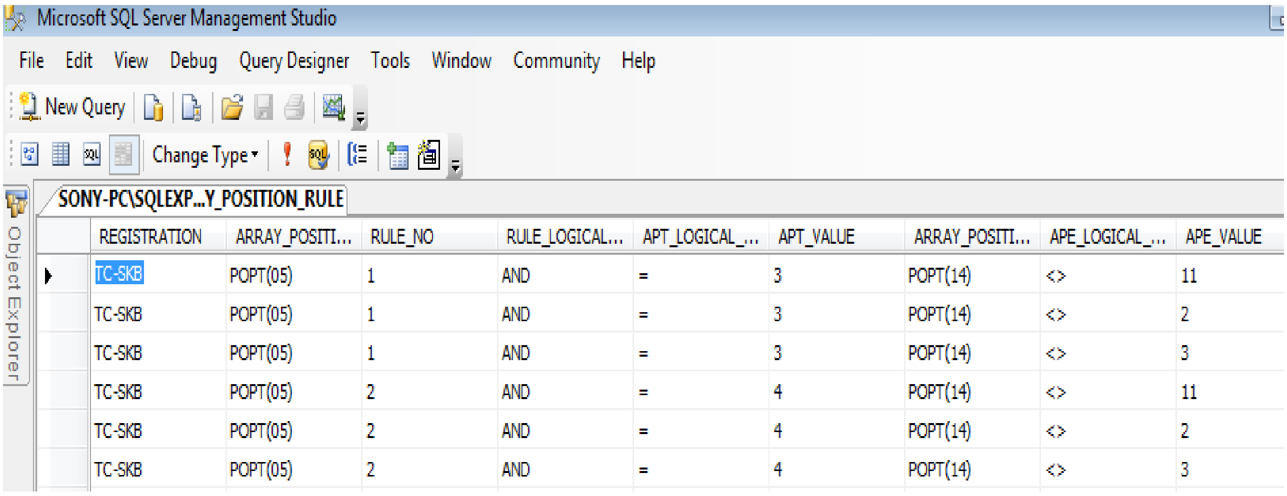
ARRAY POSITION	PARAMETER	VALID VALUES	COMMENT
POPT (14)	SURFACE CONDITION / TYPE OF CONTAMINATION	0 – DRY 1 – WET* 2 – STANDING WATER* 3 – SLUSH* 4 – COMPACTED SNOW * 5 – DRY SNOW* 8 – WET ICE* 11 – ADVISOTY WET	POPT (14) = 2,3,4,5 OR 8 NOT ALLOWED WITH POPT (1) = 4 * WITH DRY CHECK

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

XMET (6)	ACTUAL OUTSIDE AIR TEMPERATURE (USED FOR MINIMUM CONTROL SPEED AND POWER SETTING CALCULATIIONS)	VALUE OR 9.E20	INPUT IS OPTIONAL FOR POPT (1) SETTINGS OF 0., 1.,OR 2. INPUT IS OPTIONAL FOR POPT (1) SETTINGS OF 4.OR 9.

Table 3. EFB Rule Format.

Rule Fields	Description
REGISTRATION	Aircraft registration code
ARRAY_POSITION_TARGET	Target Array Position
RULE_NO	Rule No.
RULE_LOGICAL_OPERATOR	Logical operator between two rule parts
APT_LOGICAL_OPERATOR	Target Array Position logical operator
APT_VALUE	Target Array Position Value
ARRAY_POSITION_EFFECTING	Array Position effecting Target Array Position
APE_LOGICAL_OPERATOR	effecting Array Position Logical Operator
APE_VALUE	effecting Array Position Value



REGISTRATION	ARRAY_POSITI...	RULE_NO	RULE_LOGICAL...	APT_LOGICAL_...	APT_VALUE	ARRAY_POSITI...	APE_LOGICAL_...	APE_VALUE
TC-SKB	POPT(05)	1	AND	=	3	POPT(14)	<>	11
TC-SKB	POPT(05)	1	AND	=	3	POPT(14)	<>	2
TC-SKB	POPT(05)	1	AND	=	3	POPT(14)	<>	3
TC-SKB	POPT(05)	2	AND	=	4	POPT(14)	<>	11
TC-SKB	POPT(05)	2	AND	=	4	POPT(14)	<>	2
TC-SKB	POPT(05)	2	AND	=	4	POPT(14)	<>	3

Figure 4. EFB Array Rule Table.

Table 4. MEL Rule Structure.

MEL Rule Fields	Sample 1	Sample 2
REGISTRATION	TC-SKB	TC-SKB
AIRCRAFT_TYPE	B737-400	B737-400
CHAPTER_NUMBER	21	30
ITEM_NUMBER	21-01-01-05	30-03-02B
ITEM_DESCRIPTION	Air Conditioning Packs - Both Pack Inoperative	Engine and Nose Cowl Anti-Ice Valves - One Valve Inoperative Open
MANUAL_NAME	BOEING DDG	BOEING DDG
ITEM_PAGE_NUMBER	60	694
RULE_ID	1	3

RULE_TYPE	0	1
TARGET_OPERAND	CONF(04)	FL;OBS;CL;BE;TS
TARGET_OPERATOR	<>	-=
TARGET_VALUE	0.00000	2110.00000
EFFECTING_OPERAND	NULL	XMET(01)
EFFECTING_OPERATOR	NULL	>
EFFECTING_VALUE	NULL	10.00000

IV. CONCLUSION

This study is different from other studies in that all aircraft types can be combined in a single server based database systems and rule checking process is very dynamic and flexible. These rules can be managed easily on server. This server database can be extented to create national or international aircraft and airport information system in the future.

We have concluded that by making a point calculation and taking all of the parameters into account the accuracy of the results have been increased, operational safety is escalated and a user friendly user interface is prepared to decrease both pilot workload in the daily operations and engineering studies workload.

With the server database a national and international aircraft and airport database can be created in the future. Besides, with the implementation of this system fuel conservation, emissions of CO2 decrement, aircraft engine health management are achieved.

REFERENCES

[1] P. Skaves, “Electronic flight bag (EFB) policy and guidance”, Digital Avionics Systems Conference (DASC), 2011, IEEE/AIAA 30th (pp. 8D1-1).

[2] F. D. Florio, An Introduction to Aircraft Certification, 2011, Pages 97-136, ISBN: 978-0-08-096802-5, Elsevier Inc. http://dx.doi.org/10.1016/B978-0-08-096802-5.10005-4.

[3] R. A. Lusardi, S. M. Crockard, European Patent No. EP 1610094. Munich, Germany: European Patent Office, 2005.

[4] E. Theunissen, G. J. M. Koeners, F. D. Roefs, P. Ahl, , & O. F. Bleeker, Evaluation of an electronic flight bag with integrated routing and runway incursion detection functions. In Digital Avionics Systems Conference, 2005. DASC 2005. The 24th (Vol. 1, pp. 4-E). IEEE.

[5] D. C. Chandra, M. Yeh, V. Riley, & , S. J. Mangold , Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags (EFBs): Version 2 (No. DOT-NTSC-FAA-03-07,). Office of Aviation Research.

[6] D. C. Chandra, & M.Yeh, Evaluating Electronic Flight Bags in the Real World. Volpe National Transportation Systems Center,2006.

[7] D. C. Chandra, M.Yeh, & V. Riley, Designing and testing a tool for evaluating electronic flight bags. In Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (HCI–Aero) ,2004, Vol. 29.

[8] M.N. Kamel,”A prototype rule-based front end expert system for integrity enforcement in relational data bases: An application to the naval aircraft flight records data base”, Expert Systems with Applications, 1995, Volume 8, Issue 1, Pages 47-58.

[9] Y. Cheng, ”A rule-based reactive model for the simulation of aircraft on airport gates”, Knowledge-Based Systems, 1998,Volume 10, Issue 4, Pages 225-236.

[10] S.-F. Wu, C.J.H. Engelen, R. Babuška, Q.-P. Chu, J.A. Mulder, “Fuzzy logic based full-envelope autonomous flight control for an atmospheric re-entry spacecraft”, Control Engineering Practice, Volume 11, Issue 1, January 2003, Pages 11-25.

[11] S. Alam, K. Shafi, H. A. Abbass, M. Barlow,”An ensemble approach for conflict detection in Free Flight by data mining”, Transportation Research Part C: Emerging Technologies, Volume 17, Issue 3, June 2009, Pages 298-317.

[12] F. Li, C. Tian, H. Zhang, W. Kelley, “Rule-based optimization approach for airline load planning system”, Procedia Computer Science, Volume 1, Issue 1, May 2010, Pages 1455-1463.

[13] J. J. H . Liou, L.Yen, G.-H. Tzeng,, “Using decision rules to achieve mass customization of airline services”, European Journal of Operational Research, 2010, Volume 205, Issue 3, Pages 680-686.

[14] Airport & Obtacle Database, http://www.aodb.iata.org/index.htm

[15] Standardised Computerised Aircraft Performance (SCAP) Task Force, IATA,

[16] Boeing 737-800 Airplane Flight Manual, 2010,

[17] J.-M. Roy, Weather Technology in the Cockpit, Airbus Document.

[18] Boeing 737-600/700/800/900/900 ER Flight Crew Training Manual, 2008, http://www.flightdeck737.be/wp-content/uploads/2010/03/B738W-FCTM.pdf

[19] Boeing 737-900ER with Winglets SCAP (BTM/BLM) Database Release Notes, October 2, 2007.

[20] Boeing Land User Manual, October 23, 2009, A guide to LAND Version 1.4

[21] Boeing Standard Takeoff Analysis Software (STAS) USER MANUAL, October 27, 2009.

[22] AirBus OCTOPUS:SCAP DLL Manual

[23] Airbus, Flight Operations Briefing Notes, Airbus, 2004.

[24] Airbus, Performance Programs Manual, Airbus, 2000.