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Determination of the Optimal Path in Taxiways at Airports via the Probability Method

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ABSTRACT

The problem of flights delay has been addressed in this article. A new program to help the air controller has been implemented. The main objective is to improve the airport performance ability to receive more aircrafts during the rush hours by accelerating the taxiway and landing operations through two strategies. First, determine the optimal path in the taxiway network for arrival and departure flights. A modeling of the Taxiway network has been programmed by C Language. The probability theory of Dijkstra has been applied to determine the optimal path ensuring minimum taxi time in the taxiway network. A new function of speed change has been introduced, which guarantees the comfort of the passengers while the airplane is moving on the taxiway. The fuel consumption is also estimated as the aircraft passes through the taxiway network paths. Second, the program predicts the time of landing and approaching according to aircraft type using the aircraft performance analysis equations. This increases the efficiency of choosing the optimal way and decreases the flights delay for landing since it deals with the situation according to the aircraft type, size and speed. The program arranges automatically the arrivals flights expected to arrive to the airport at the same time according to the predicted landing and approaching time of the aircraft. This program helps to decrease the time delay and the fuel consumption. The paper presents an example of six arrival flights with different aircraft types. This example shows that using the proposed program decreases the flight delay for about 17 minutes which is really an important time.

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1. INTRODUCTION

The problem of flight delays can be addressed through two methods, the flight program management and the control of airport performance. Michael B. and Guglielmo L. [1] proposed an optimization of the Ground Delay Program (GDP), an air traffic flow management mechanism is used to decrease the rate of in-coming flights into an airport when the arrival demand exceeds airport capacity. In this program, a set of flights destined for a single airport is assigned ground delays. A “distance-based” GDP is defined as a parameter that only applies to flights whose origin airports located on less than a prescribed distance from the destination airport. It is shown that this measure provides an improvement over unrecoverable delay. The cost of flight delay or cancellation is purely economic way without addressing the type of aircraft or the reasons for delay in the airport ground and taxiways. Furthermore, the application of this program is linked to agreements for the airport with airlines companies so that it can cancel or postpone flights, therefore many airports cannot use it. Statistical models of airport delay and single flight arrival delay were developed by Yuqiong B. in [2]. The models use the Airline On-Time performance data from the Federal Aviation Administration (FAA) and the surface airways weather data from the National Climatic Data Center (NCDC). Multivariate regression, ANOVA, neural networks, and logistic regression were used to detect the pattern of airport delay, aircraft arrival delay and schedule performance. The results of the research show that the daily average arrival delay at Orlando International Airport (MCO) is highly related to the departure delay at other airports. The daily average arrival delay can also be used to evaluate the delay performance at MCO. The daily average arrival delay at MCO is found to show seasonal and weekly patterns which is related to the schedule performance. The precipitation and wind speed are also found contributors to the arrival delay. The capacity of the airport is not found to be significant. This may indicate that the capacity constraint is not an important problem at MCO. There is another area of research which focused on management of aircraft movements at the airport. Our research is related to this methodology. The most important program was produced by NASA called the advanced Surface Movement Guidance and Control System program, SMGCS. SMGCS depends on direct air traffic control by satellites, but it does not apply any arbitrary modern theory in the process of taking the control decision. The reader is referred to [3] for the details about it. Quantitative models and techniques for computing pushback forecasts are developed by Francis R. [4]. These are tested against a dataset of 17,344 real-world airline ground operations covering 3 months of Lufthansa flights transiting Frankfurt International Airport. The Lufthansa dataset includes detailed timing information on all of the turn processes, including deboarding, catering, cleaning, fueling and boarding. The dataset is carefully filtered to obtain a sample of 3820 minimum uncertainty ground events. The forecast models and techniques are tested against this sample, and it is observed that current pushback forecast errors (on the order of 15 min) cannot be reduced by a factor of more than 2 or 3. A ceno-scale model instance is created for Newark International Airport where the parameter sensitivity and model fidelity are tested against a detailed real-world dataset based on the validated model framework. Several robust dual control strategies are proposed for airport surface traffic. Wolfgang S et al. [5] proposed navigation algorithms for carrier phase ambiguity integrity monitoring to support aircraft surface movement. The enhanced integrity monitoring algorithm addresses the very stringent integrity requirements for surface movement by the use of multiple test statistics and a group separation concept for single and multiple failure detection and exclusion. The algorithms are subject to a detailed performance characterization for precision approaches and airport surface movement, using simulations as well as static and dynamic field trials, taking into account operational specificities, such as multipath and potential decorrelations between the reference station and aircraft due to ionospheric anomalies. Results show that the proposed algorithms have the potential to satisfy airport surface movement requirements if the ionospheric anomalies are monitored using a special ground-based network. A number of computational methods, in the literature, have been applied to solve the problem of routing on ground among them:

The Genetic Algorithm [6]: This model imitates the natural process of selection and reproduction of the fittest individuals in every generation. The success of this method depends on how well a potential solution of the specific problem can be encoded in a data structure such that the operations of crossover and mutation can be performed with meaningful results. A balance between exploitation of the best solutions and exploration of the search area is also a key factor, as in most heuristics.

Ant Colony System [7, 8]: It imitates the way ants tend to follow the shortest paths on their movements among their colonies and how these paths tend to stabilize towards optimality even after changes in the search area. Some very interesting applications which show the efficiency and robustness of the Ant Colony Systems as optimization algorithms can be found in the refereed references [7, 8]. Logarithmic model of Dijkstra [9] is found as the best model to solve the problem of the shortest path. An efficient heuristic which assumes the existence of a distance table between the destination and each intermediate vertex of the network graph in order to be applied [9, 10]. When a sufficient short path does not exist, it becomes important to find alternative solutions like the models K-shortest [11]. It is possible to organize the routing on ground networks so that it consists of a number of primary and secondary networks. The goal of this method that form the hierarchy network is to distinguish the minimal cost of the level of the network respectively. This must include a primary route from the beginning of an estimated node to the end of another estimated node. Any node does not belong to the primary path must connect to another node on this path via the secondary path [12]. The success of the genetic method extends to an encryption of the solutions that can collect the different parts of the paths network in a general solution for paths. Therefore, it is possible to be an effective way to treat this problem. Ant colony system seems to be promising more according to its flexibility and its ability to stabilization where it is possible to be implemented dynamically while the aircraft passes within the path by sending factors (ants) on a regular basis about the destination to find the shortest path at that point of time and the adoption of the airplane paths accordingly. Our research will depend on the management of aircrafts movements to benefit from the previous literature researches. However, it will not take the section of airport building or the push-back, but it will depend on improving the performance of the passages movement by finding the shortest time for the passage of the aircraft in the paths network of any airport in the world, after the transformation of this network to scheme of vertices and edges and applying Dijextra theory to find the shortest path. We will also use the aircraft performance analysis according to its type and infer the time required for landing and take-off in order to anticipate a better time, especially when approaching the layers of the ionosphere. As we enter convoys theory in the selection of the airplane when overcrowding in the paths nodes or the Ramps. This research adds the performance as well of all types of aircraft analyze and calculate the landing and taking off time and passing in the network paths in addition to avoid change speed and thus ensure passengers comfort. The expected fuel consumption for the engines of the airplane is also estimated as the aircraft passes through the network paths, so we can compute all the costs corresponding to each path in the network before choosing it.

1. MATHEMATICAL MODEL

1.1 Structure and Entities definitions

An airport usually has a network of taxiways, resembling a city road network in the sense that there might be intersections, 90 degrees turns, speed limits and defined directions that an aircraft must follow when moving on the taxiway. So, the taxiways are where the surface movement mentioned in the previous paragraph takes place. On arrivals, this movement starts from the runway where the aircraft lands and ends at a specific parking position on the apron. On departures it is the other way around. Therefore, a taxiway usually provides a link between the runway and the apron. The first main entity that composes the problem of 4D Taxi Routing on Ground is the Taxiway Network. The taxiway structure of an airport is more or less static; it does not change frequently. The generation of a path connecting a runway exit and a parking stand on the apron would be a trivial task on an empty taxiway. What provides the dynamic aspect to the whole procedure is the concurrent movement of other aircraft on the taxiway network, making the availability of certain paths a function of time. The second main entity of the problem is thus the Aircraft. The interaction of the taxiway network system with its surroundings is the information of the source destination pair and the time that an aircraft appears at the source, as an input, and the time that the aircraft reaches its destination (and possibly other metrics), as an output. This information depends on several different factors, which can be grouped together under the term Airport Operations. This is the third entity of the problem. The airport operations include:
The daily / weekly / seasonal flight schedule that provides the expected times of arrivals and departures.
The runway usage pattern, especially in airports with more than one runway. The usage of the runway(s) and the direction of arrivals and departures on them affect the choice of the runway exits as starting or ending points of the taxiway routing. The airlines operating on the given airport and the corresponding airports of the flights departing from or arriving at the given airport. The combination airline - source airport defines the terminal of the given airport where the aircraft will be parked, so it affects the choice of the parking stands. As a conclusion, one can say that for the problem of the 4D Taxi Routing on Ground, the taxiway network provides the structure or topology (the spatial dimensions), the movement of aircraft adds the 4th dimension (time) to the system and the airport operations stand for the environment, connecting the system to the real world by providing data and operational constraints. After the definition of the main components that share in addressing the problem, it must now modeling the problem in order to develop mathematical algorithms and through the establishment of the scheme, which represents a network of taxiways and gives its characteristics and factors aiming to acquire a network of paths. As a work environment, we only need a map of specific airport with databases containing numerical representations of the dimensions of the airport (paths) and limitations of its structure (maximum wing extension and weight). So as a case study in this research, Stockholm-Arlanda airport, Sweden, has been chosen because we have information databases for this airport and for its special features.

2. CASE STUDY, STOCKHOLM-ARLANDA AIRPORT

It is the largest airport in Sweden, the third largest airport in the Nordic countries, and the second busiest in terms of international passengers [14]. The choice was mainly based on the size of the airport and the complexity of its taxiway network. As of October 2011, Stockholm-Arlanda has 3 runways and 4 terminals and its traffic density can be categorized as follows:
According to [13], "aerodrome traffic density is medium where the number of movements in the mean busy hour is of the order of 16 to 25 per runway or typically between 20 to 35 total aerodrome movements." Also, the number of movements in the mean busy hour is the arithmetic mean over the year of the number of movements in the daily busiest hour. Either a take-off or a landing constitutes a movement. The published statistics for Stockholm-Arlanda airport [15] show that for the year 2010, the daily busiest hour was from 17:00 to 17:59 with an average of 39 movements (20 take-offs and 19 landings).
According to these facts, Stockholm-Arlanda can be considered as a medium to heavy traffic density airport. For the purposes of the present work, the airport that would serve as a case study should be fairly large and complex, in order to help exploring the problem dimensions. The maps of Stockholm-Arlanda airport are displayed in Fig. 1.
The runways included in Fig. 1 are drawn as long rectangles and the runway exits/ entrances are the rectangular green vertices. The triangular red vertices

(P. . .) are the exits / entrances of the taxiway leading to and from parking areas on the apron.

The specific gates that can be reached from a given taxiway exit are also shown on the legend of the graph. It should be noted here that the parking areas / gates are located on the apron, so they are not a part of the taxiway structure. The rectangular green (X..., Y...) and triangular red vertices are the terminal points of the graph. The circular yellow ones stand for the taxiway intersections; note the existence of crossings, merges, splits and combinations of them. A detailed comparison of the figures 3 and 4 with the respective maps can lead to the conclusion that some parts of the apron are excluded from the graph, i.e. there are no taxiway exits leading to and from them. The reason for the exclusion is that these locations are used for other purposes. They can be maintenance hangars or serve cargo aircraft, however, they are not used for commercial flights. Detailed information about the local regulations at aircraft parking stands can be found at [16] and [17]. Edges with arrows on both ends represent taxiways that can be traversed both ways. In this case, one direction is for arrivals and the other is for departures. A comparison between the maps that display the same part of the airport but in different modes (northern part: map A for arrivals and C for departures / southern part: map B for arrivals and D for departures) leads to the conclusion that there are significant differences. There are edges used only for arrivals, edges used only for departures, edges used for both modes in the same direction and finally edges used for both modes in opposite directions. The last of these four "edge types" can be distinguished on the figures 3 and 4 by the existence of arrows on both ends, as mentioned before.

The example figures 2, 3 and 4 can be used for distinguishing the four edge types. The edges starting from runway exits Y6 and Y7 are used only for arrivals. The edges starting from parking area exits P5 and P8 are used only for departures. Runway exits Y8, Y9 and Y10, as well as parking area exits P6 and P7 are used for both modes (bimodal) in opposite directions. Finally, the two vertical axes – named Y and Z on the maps – are used for both modes but in one direction. The next section summarizes the necessary steps for the transition from an airport map to a graph that captures all the essence of taxiway routing and serves as a basis for the mathematical model. Before proceeding to that, a last remark that can be derived from the figures above is that when an aircraft reaches a vertex on the graph, the possible next movements are not determined only by the graph itself, but also by some transition table. For example, on figure 3, an aircraft reaching vertex ZL can be directed towards the parking area of P6 or can turn to V1. From V1 the only choice is to continue to V2, which corresponds to a crossroad, so in this case the aircraft must continue to V3. In order to reach the parking area of P7, an aircraft must be coming from ZK.

3. SUMMING-UP: FROM AN AIRPORT MAP TO THE TAXIWAY NETWORK GRAPH

Stockholm-Arlanda airport was used as a case study or the present work in order to get some insight into the processes regarding taxiway routing. However, the conclusions must be independent of a specific airport. The model must be generic enough and applicable to all types of airports with the minimum of adjustments. The purpose of this section is to define the steps for formulating a graph, including any accompanying information, for the entity of the Taxiway Network, using a mapping database of a given airport. After the previous discussion and the identification of the problem, the map-to-graph procedure can be summarized in steps as follows:

- Obtain and study the maps showing the taxiway network structure. Using airport regulation information, limit the taxiway network to the set of taxiways used for arrivals and departures.
- Identify the runway exits and the exits to parking stand areas and define the modes on which they are operated. These shall be the terminal vertices of the graph.
- Identify all the taxiway intersections in the area of interest. These shall be the inner vertices of the graph.
- Connect the vertices with edges according to the taxiways on the maps. For each edge record the crucial information: its type (one of the four types defined in the discussion above), its length (in meters or some other base unit) and any existing constraints, like maximum speed wingspan and weight. The maximum speed is usually not stated explicitly, but there are some empirical limits depending on the form of the taxiway.
- For each edge and allowed direction record the possible next edges, thus creating a list of allowed transitions.

An example of tables with all the necessary data for a taxiway network graph is displayed below. Table 1 shows some edges with the data of step 4. For example, the edge (27, 28) has a length of 59 meters, the maximum speed is a fraction 0.6 of the global maximum for the specific airport (because this edge corresponds to a turn on the taxiway, so the speed limit must be lower), the maximum wingspan is 65 meters and the edge are used only for departures. The edge (29,30), on the other hand, is used on both modes in opposite directions, i.e. from vertex 29 to 30 on arrivals and from vertex 30 to 29 on departures, and has a length of 100 meters etc. Also, the edge (31, 33) is used on both modes but in the same direction and has no wingspan limit.

V From	V To	Length	Speed	wingspan	Arrival	Departure
27	28	59	0.6	65	0	1
27	31	34	1	0	1	1
29	30	100	0.8	65	1	-1
31	33	89	1	0	1	1
32	120	48	1	65	1	0

Table 1: Information about edges for taxiway network diagram

3.1 The Aircraft

The second entity is the Aircraft. The dimensional features of an aircraft that concern the taxiway routing process are its length, wingspan and weight. The length of an aircraft in combination with its current position determines its distance from other aircraft routing on the taxiway, which is obviously important for the avoidance of conflicts. Furthermore, instead of following a very detailed approach of using the length of each aircraft, the alternative approach is considering each aircraft as a moving point, thus just record its position at each time. Being the dynamic entity of the taxiway, an aircraft has also some features that change with time. One of them is the position on the taxiway. This position could be recorded using the coordinates of an aircraft at each time unit, but since the taxiway network is modeled as a graph, the position of the aircraft on the graph is denoted by a triple figure [from-vertex, to-vertex, distance]. For example, if the current position of an aircraft is (29, 30, 45), the aircraft is currently situated on edge (29, 30) – with direction from vertex 29 to vertex 30 and its frontal part is located 45 meters from the beginning of the edge (from vertex 29). Obviously, the distance variable of the position triple must be less than or equal to the length of the current edge. Another feature that changes with time is the speed of the aircraft. The speed is usually in the range from 0 (when the aircraft is on hold) to a maximum allowed speed for the specific taxiway, where the aircraft is currently situated. For example, using the data from Fig. 3 and assuming that the usual maximum taxiway speed for an airport is 25 knots [18], an aircraft currently situated on edge (29, 30), where the speed is set to the 0.8 of the overall maximum - should taxi with a speed of no more than (0.8*25=20 Knots). The aircraft speed is especially important for the taxi routing process, because it has the key-role of binding the model together.
The speed determines the distance covered at each time unit, so it determines the position of the aircraft too. The speed together with the length of the route that an aircraft will follow determines the total taxi time, which is the central metric of the problem of 4D Taxi Routing on Ground. Finally, the changes of speed are themselves recorded and used as another metric of the quality of an assigned route. As already stated and described, the aircraft is the entity that enhances the taxiway model with the dimension of time, because of its movement that by definition makes its important features 28 (position, speed) functions of time. The aircraft is the entity that also keeps the metrics of the problem objectives: taxi time, hold time and speed changes. There are some typical limits on the taxiway routing speed, dictated by safety rules. A typical taxi speed is 15 to 20 knots on a straight taxiway and 7 to 12 knots on 90 degrees turns, while the usual maximum speed is 25 knots and is reached in cases when an aircraft is delayed reaching the parking position [8]. The structural characteristics and restrictions of an airport's taxiway, as well as the speed limits, where applicable, do not depend on the aircraft routing on the taxiway; they are uniform. However, there are other restrictions that affect only certain types of aircraft. One of them is the maximum wingspan allowed on certain (narrower) taxiways. Another is the maximum weight, which can be met as a restriction on airports that include bridges in their taxiway structure.

4. ANALYSIS OF THE PROCESS

4.1 The airport scheme

The performed program opens a window allowing the introduction of the vertices positions at the airport directly or they can be added in the window of SQL databases through a table as in Table 2.

idNode	X	Y	EndRunway	StartRunway	Name
19	2	2	False	True	S1
20	6	2	False	False	X1
21	6	8	False	False	X2
22	10	10	False	False	X3
27	10	15	False	False	X4
28	15	15	False	False	X5
29	20	15	False	False	X6
30	20	20	False	False	X7
31	25	20	False	False	X8
32	25	25	False	False	X9
33	30	25	True	False	E1
1031	30	30	False	False	X10
1032	35	40	False	False	X11
1033	50	40	False	False	X12
NULL	NULL	NULL	NULL	NULL	NULL

Table 2: The introduction of peaks points (vertices) in SQL databases

Then we enter the edges characteristics as in Table 3

idLinker	Node1	Node2	Distance	Speed	IsBusy
6	19	20	3	0.6	False
7	20	21	5	0.4	False
8	20	22	10	1	False
9	21	20	6	0.6	False
10	21	22	6	1	False
11	22	27	7	0.4	False
12	22	28	10	0.7	False
13	28	29	5	1	False
14	27	28	6	0.8	False
15	27	29	15	0.4	False
16	28	29	10	0.8	False
18	30	29	4	0.4	False
19	30	31	10	0.6	False
21	32	33	26	0.2	False
22	31	32	10	1	False
23	29	30	12	0.6	False

Table 3: The introduction of the edges characteristics in SQL databases

Table 3 shows the characteristics of edges that link the vertices to form a complete outline of the airport. The allowed aircraft speed on each edge is entered in addition to the length and width of each edge. After finishing the entry process, the program opens an own interface showing the taxiway network at the considered airport. It is as the form shown in Fig. 5.

4.2 Determination of the starting and ending points of the path

First, the considered flight is called as the following: Flight pattern is A or D. In the case of A, the flight is arriving, thus the starting point of the runway will be sequentially from the farthest point to the nearest point. This is linked to the direction of the coming flight or according to the wind direction and in contrast, the end point is at the airport terminal. The end point is inferred after the intersection of the flight information as a kind of airline flight and destination airport, from which it is coming in this case. Each airline and airport have a specific gate at any airport in the world as mentioned previously. In the case of D, the flight is leaving, the starting point is inferred from the intersection of the flight information. The end point will be the beginning or end of the runway, according to the wind direction, in our research, we studied both cases, after determining the starting and ending points of the path in order to choose the optimal taxiway, presented in the next section.

4.3 Choosing the optimal way

The main screen shows a table of airport flights on the right arranged according to their time zone with a rating according to the type of the Aircraft Code, its Airline Code and the destination airport (IATA Code). On the left, the airport map is shown at the main runway.

The theory of Dijkstra algorithm has been programmed so that the scheme, which has already been drawn, is defined. The program measures the shortest passage time of all the available ways, and then order them according to the preference. The program studies the distances of each way, and since the specific speed to each way has been already defined, this enables the program of the direct calculation of each way time. Plus, it calculates the number of times that the speed has changed, and thus the function of speed change, which is directly related to the comfort of the passengers. The program also calculates the fuel consumption for each aircraft type depending on its engine model and number of engines so that the software will extract the fuel consumption values (kgm /s)/kgf is linked to the time of aircraft movement and the engine thrust force. The fuel consumption is shown in kgm after the multiplication by time-course and the engine thrust force. Afterwards, the program determines the optimal way. This way guarantees a shortest passage time, a least fuel consumption and a least speed change which is directly related to the comfort of the passengers. The proposed way is shown in Fig. 7 for an aircraft which enters the taxiway network from Y3. On the screen, we can see that the required time for this way is 01:16.6 s, the fuel consumption (kg)=6.242 and the airplane changes its speed 4 times on this way. In case that the first probable optimal way is busy, the program chooses automatically the second probable optimal way.

When the aircraft arrives to its final location at the end of the way, the program gives a message showing the real taxiway time for the airplane with fuel consumption details and speed change as well as the time required for landing and takeoff as shown in Fig. 8. It is important to mention that the program uses the theory of queuing in the congested areas at the vertices. The need to choose one of the aircrafts before the other is performed through two consecutive phases: the first phase is to give priority to the company which has a contract with the airport in the case of a private contract between the airport and a number of companies. The second phase, the program calculates the expected remaining time for each aircraft and to choose the aircraft that require greater time (a greater delay) in order to give it priority and ensure a reduction in the delay time.

4.4 Predicting of landing and approaching time at the height of 1000 m:

Performance analysis equations are used to calculate landing and approaching time at the height of 1000 m which allows the controller to take the appropriate decision for the landing or rotating around the airport. The advantage of the proposed program, reflected in time gain, will be demonstrated through the following example. Let us take a group of six aircraft of different types among them one Boeing 747-400 and assume that the aircraft will arrive to the airport all at the same time. The program calculates the time required for each aircraft to land from a height of 1000 m and also calculates the time delay caused by the arrival of the aircraft together if we did not use the aircraft type feature, random landing, as in the table 4. whereas if we use the aircraft type while giving the landing order at a height of 1000 m, the time delay will be as in the Table 5 and figure 9. We can see that the program offers a time gain of 25:22-13:47= 11.35 min.

Aircraft Type	Landing time/min	Delay time
Airbus A321	02:22.7	00:00.0
Airbus A330-300	02:38.9	02:22.7
Boeing 717	02:14.4	05:01.6
Boeing 747-400	14:24.1	07:16.0
Boeing 767-300	03:41.9	21:40.1
Boeing 777-200	02:49.5	25:22.0

Table 4: Delay time in case a random landing

Aircraft Type	Landing time/min	Delay time
Boeing 717	02:14.4	00:00.0
Airbus A321	02:22.7	02:14.4
Airbus A330-300	02:38.9	04:37.1
Boeing 777-200	02:49.5	07:16.0
Boeing 737-300	03:41.9	10:05.5
Boeing 747-400	14:24.1	13:47.4

Table 5: Time gain from the use of aircraft type feature while giving the landing order at a height of 1000 m

Now we will estimate the time gain of using Dijextra theory to determine the optimal way for the same example. This is shown in Table 6.

It can be seen from this table that the use of Dijextra theory offers a time gain of 5.13 min for the studied example. Therefore, the total time gain obtained by using the proposed program with the two proposed strategies is 5.13+11.35 = 16:47 min for six aircraft. This time is really an important time gain.

Figure 9 shows that the program has automatically arranged the flights according to the landing time of each aircraft using performance equations.

Aircraft Type	Taxi Time without Dijextra/min	Taxi Time with Dijextra/min	Time gain/min
Boeing 717	00:57.4	00:53.5	00:03.9
Airbus A321	02:04.8	00:42.1	01:22.7
Airbus A330-300	01:49.8	00:34.3	01:15.5
Boeing 777-200	02:01.9	00:38.8	01:23.1
Boeing 737-300	01:11.1	01:10.7	00:00.4
Boeing 747-400	02:02.8	00:55.0	01:07.8
Total taxi time	10:07.8	04:54.4	05:13.4

Table 6: Time gain from the use of the Dijextra theory for the six-aircraft example

5. CONCLUSIONS

In this article, a new program to help the air controller has been implemented. The main objective is to improve the airport performance ability to receive more aircrafts by accelerating the taxiway and landing operations through two strategies. First, determine the optimal path in the taxiway network for arrival and departure flights. A modeling of the Taxiway network has been programmed by C Language. The probability theory of Dijkstra has been applied to determine the optimal path ensuring minimum taxi time in the taxiway networks. A new function of speed change has been introduced, which guarantees the comfort of the passengers while the airplane is moving on the taxiway. The fuel consumption is also estimated as the aircraft passes through the taxiway network paths. Second, the program predicts the time of landing and approaching according to aircraft type using the aircraft performance analysis equations. This increases the efficiency of choosing the optimal way and decreases the flights delay for landing since it deals with the situation according to the aircraft type, size and speed. The program arranges automatically the arrivals flights expected to arrive to the airport at the same time according to the predicted landing and approaching time of the aircraft. This program helps to decrease the time delay and the fuel consumption. The paper presents an example of six arrival flights with different aircraft types. This example shows that using the proposed program decreases the flight delay for about 17 minutes which is really an important time.

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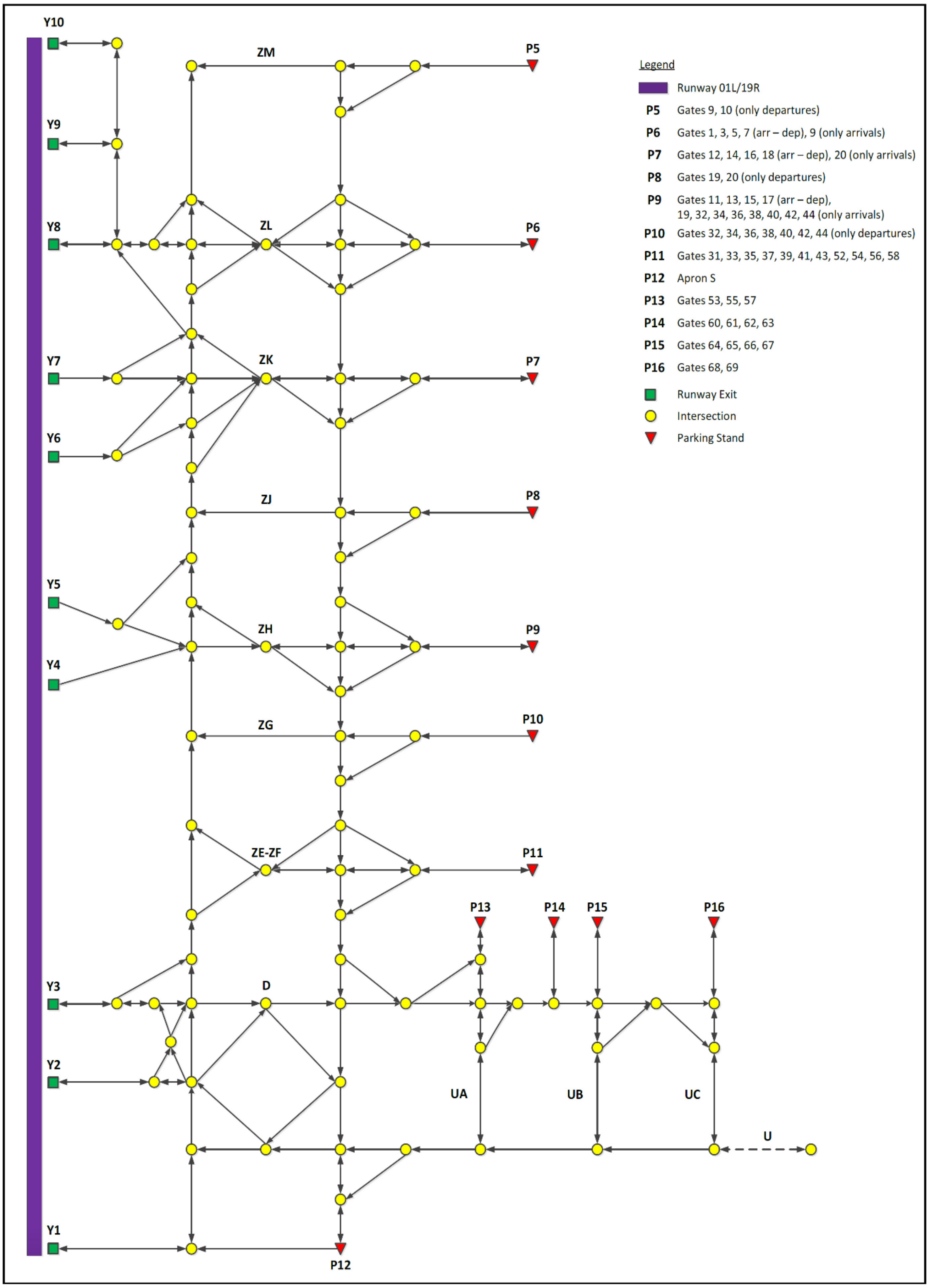

Figure 1: The southern part of Stockholm-Arlanda airport taxiway network

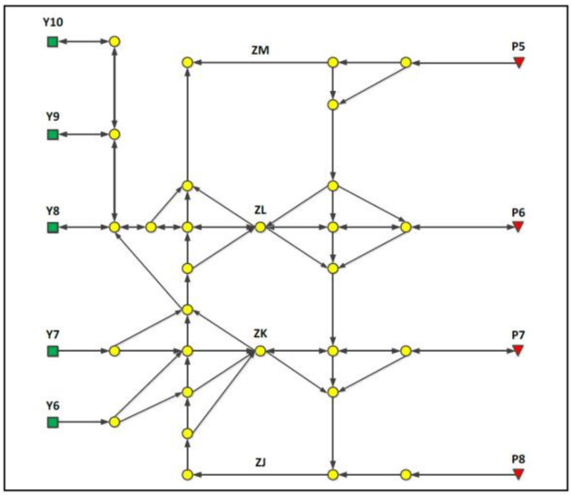

Figure 2: Part of the graph of Fig. 1

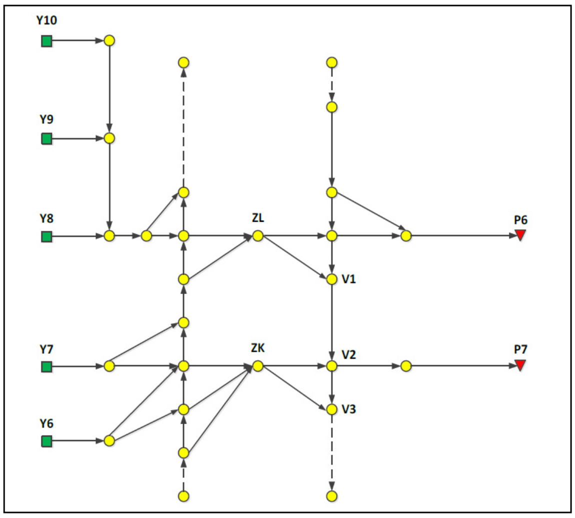

Figure 3: The arrival component of the graph of Fig. 1

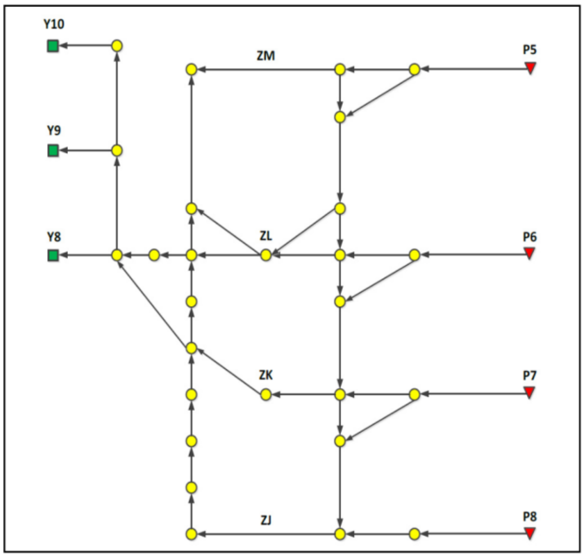

Figure 4: The departure component of the graph of Fig. 2

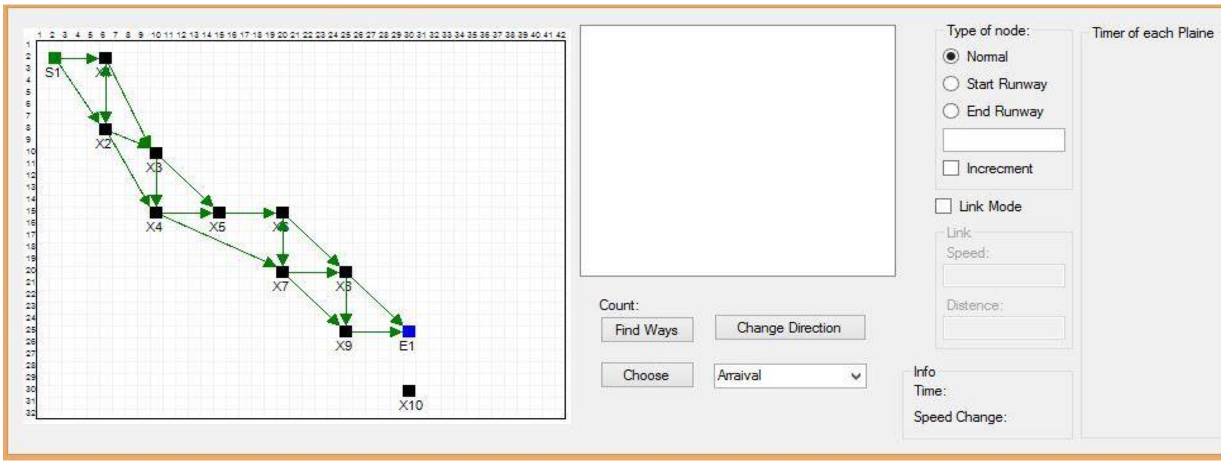

Figure 5: The interface taxiway network at the considered airport

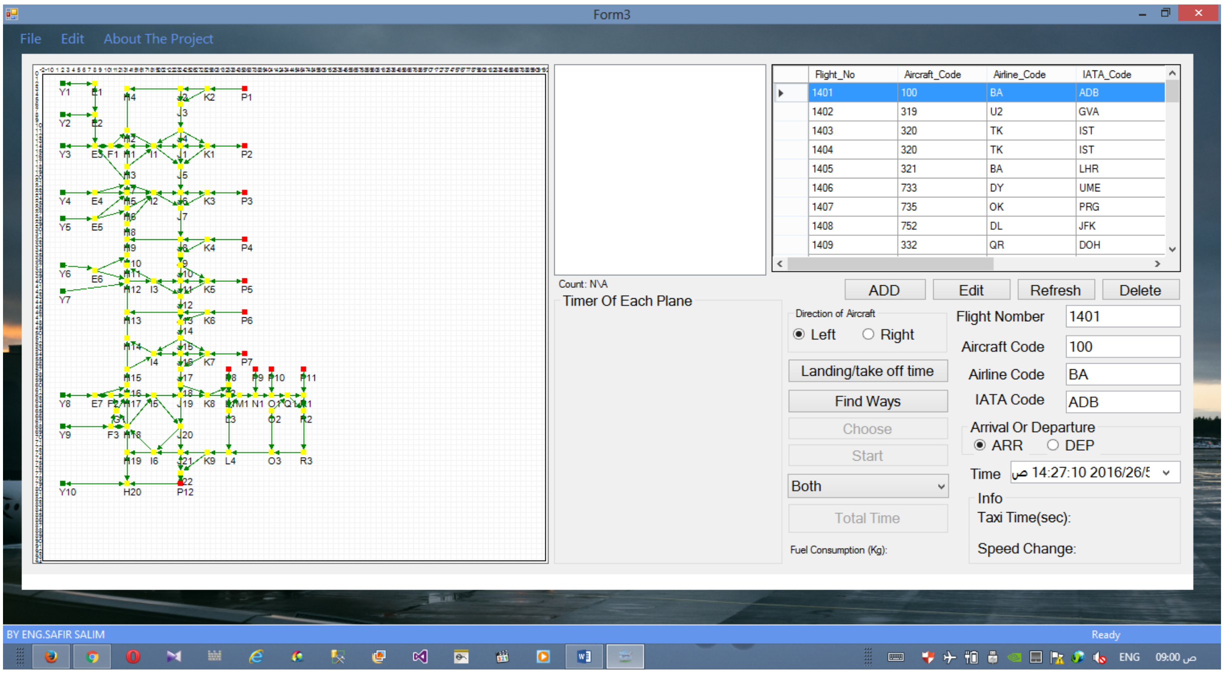

Figure 6: Program main window

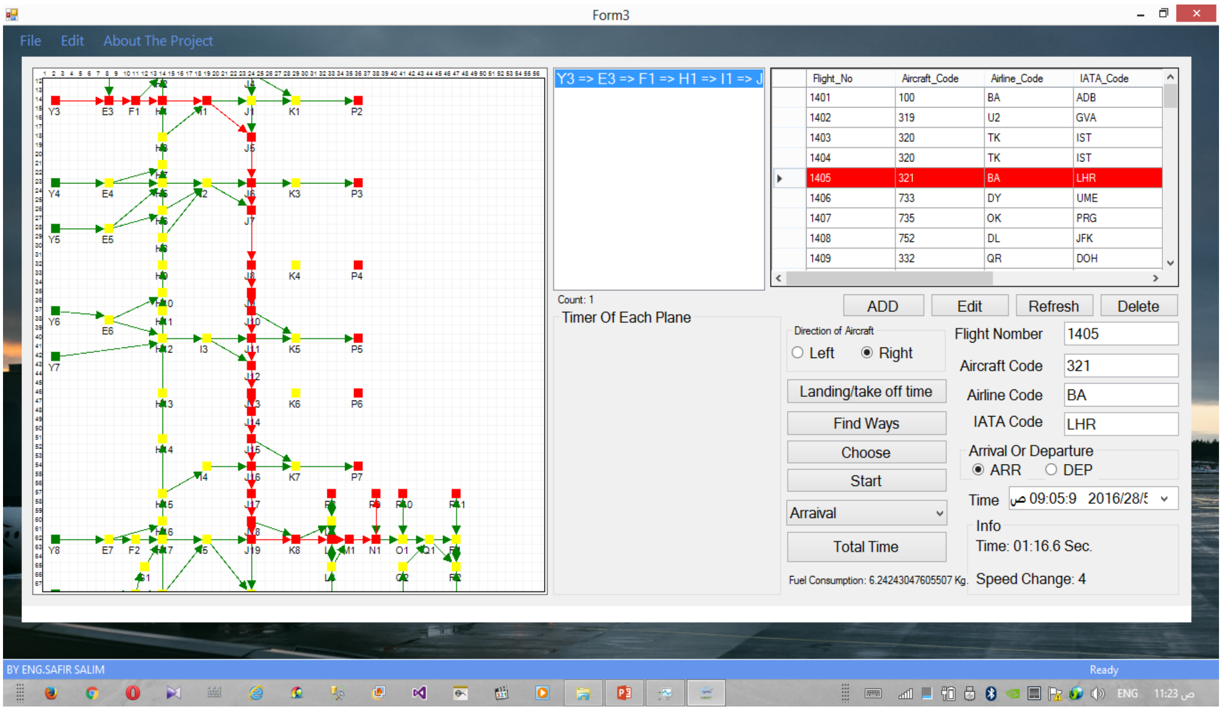

Figure 7: The optimal way obtained according to Dijkstra theory

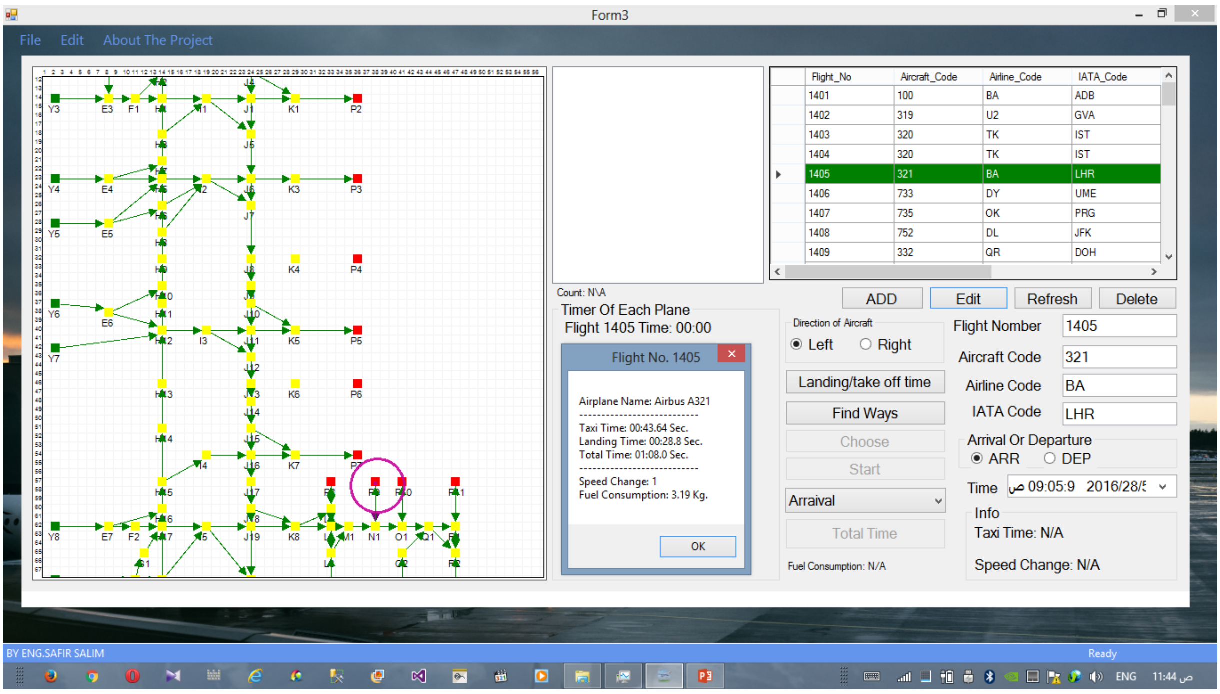

Figure 8: Real taxiway time for the airplane with fuel consumption details and speed change

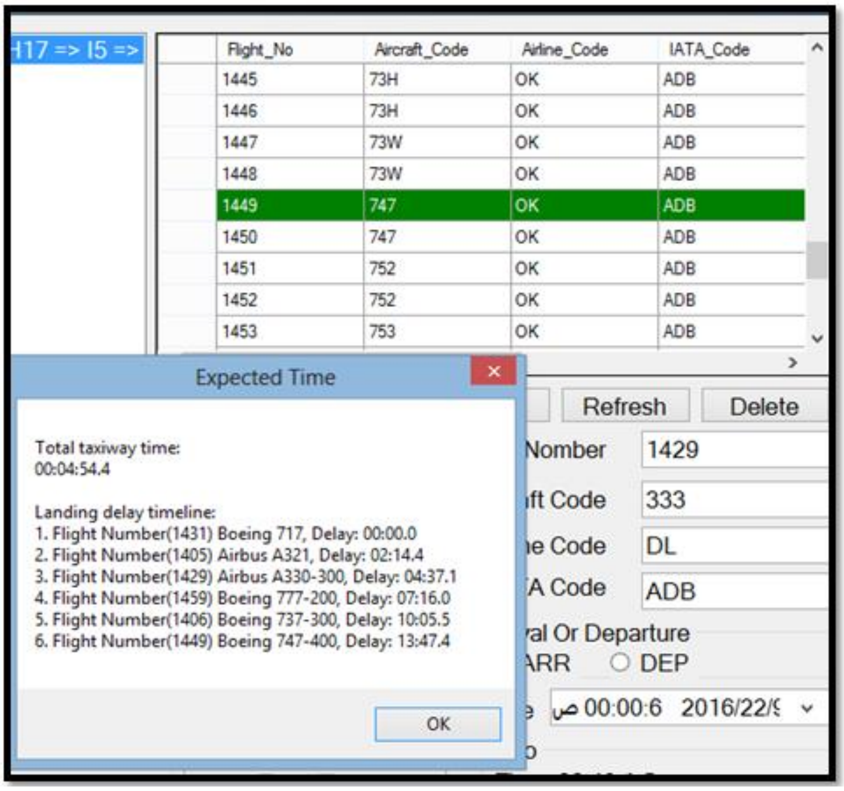

Figure 9: Sequence of the six flights by aircraft type with total time calculation of the taxiway

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