Efficiency Improvement of Inertial Navigation System (INS) Based on Artificial Neural Network (ANN)

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Abstract

This research presents a new technique to increase the efficiency of inertial navigation system (INS) by using artificial neural networks (ANN) and reverse propagation algorithm to train the network, As known the inertial navigation system (INS) Shows the actual path of the plane and matches this path with the assigned flight route of the plane, which is set by the competent engineer pre-flight and saved in the aircraft memory of the inertial navigation system (INS). The actual path of the plane in the air it's not straight but zigzag because of the difference in (temperature, density and pressure) for the layers of the atmosphere. The main work of the inertial navigation system is to match the actual path of the plane with the real path and to find a new path closer to the assigned flight route. The idea and purpose of this research are to increase the efficiency of the inertial navigational system, by using artificial neural networks. The method to accomplish this, is to represent of the (INS) work on the plane by using program (GIS) a geographic information system which is a powerful tool used for computerized mapping and spatial analysis and (Matlab, Simulink Release program). The results achieved of the modeling process, by taking three cases of assumed aviation cases for different time periods. Through reading correction ratios from the modeling process show that the ANN have the ability of showing high matching accuracy in the system behavior.

Keywords: (Navigation systems, Artificial neural net work (ANS), Inertial navigation systems (INS), Simulation, Global Positioning System (GPS) •

الخلاصة

فى هذا البحث قدمت طريقه جديده لزياده كفاءه منظومه الملاحه بالقصور الذاتى (INS) . باستخدام الشبكات العصبيه الاصطناعيه (ANN) وخوارزميه الانتشار العكسى لتدريب الشبكه . كما هو معروف نظام الملاحه بالقصور الذاتى يبين المسار الفعلى للطائره اثناء الطيران ويطابق (يصحح) هذا المسار مع المسار الحقيقى للطائره الذى يحدد من قبل المهندس المختص قبل الطيران استنادا على احداثيات مسار الرحله الجويه ويتم خزنه فى ذاكره نظام الملاحه بالقصور الذاتى (INS). المسار الفعلى للطائره اثناء الطيران ليس مستقيما ولكن متعرج بسبب الاختلاف فى (درجه الحراره، الكثافه، الضغط) لطبقات الجو. العمل الرئيسى لنظام الملاحه بالقصورالذاتى هو لتطابق المسار الفعلى للطائره مع المسار الحقيقى وايجاد مسار جديد اقرب الى مسار الرحله الحقيقى. الفكره والغرض من هذا البحث هو زياده كفاءه منظومه القصور الذاتى (INS) باستخدام الشبكات العصبيه الاصطناعيه .طريقه انجاز البحث تمت بتمثيل نظام الملاحه بالقصور الذاتى للطائره ببرنامج (GIS) ونمذجه العمليه باستخدام برنامج (Matlab, Simulink program). النتائج التى تحققت من عمليه النمذجه بعد اخذ أربع حالات طيران مفترضه على اساس المسار الاصلى بفترات زمنيه مختلفه بينت ان الشبكات العصبيه قادره على اظهار نتائج عاليه الدقه فى اسلوب النظام .

كلمات المفتاحية :انظمه الملاحة ، الشبكات العصبية الاصطناعية ،انظمه الملاحه بالقصور الذاتى ، المحاكاه ،نظام تحديد المواقع العالمى.

1. Introduction

The inertial navigation system (INS) is a system that measures the Direction of the Aircrafts and which extracts information about the speed and location using successive integrations. All (INS) devices follow the same method; this system is unique because of its many benefits and advantages. This system is crucial for aircraft, especially when operating these Aircrafts in bad conditions far from the surface of the earth and where the signals are subject to interference. The main measure in this system is the accelerometer, which has the ability to detect the direction of Aircrafts at all condition. Today the pilot depends on electronic systems for more accurate navigation .By the use of the inertial instruments (gyros, accelerometers) and a high speed computer. The pilot can find his position quickly and easily with much more accuracy than if had to perform all the calculations himself. Inertial Navigation Systems (INS) has been developed for a wide range of planes. (Sukkarieh, 2000) developed a (GPS/INS) system for straddle carriers that load and unload cargo ships in harbors. When the carriers would move from ship to ship, they would periodically pass under obstructions that would obscure the GPS signal. Also, as the carriers get closer to the quay cranes, it became more difficult to get accurate positions due to the GPS signal being reflected about the cranes metal structure. This increases the time of light of the GPS signal and results in jumps in the position. During these times the INS would then take overhand guide the slow moving carrier until a reliable GPS signal could be acquired.(Bennamoun ,M.,boashash, B.,Faruqi,F and Dunbar, M., 1999) developed a (GPS/INS/SONAR) system for an autonomous submarine. The (SONAR) added another measurement to help with accuracy, and provided appositional reference when the GPS antenna go submerged and could not receive a signal. Integration of (GPS/INS) is a growing trend for military munitions (i.e. bombs, missiles, artillery shells, remotely operated vehicles). (Ohlmeyer , E, Pepitone, T and Miller, B 2000) developed a (GPS/ INS) system for new smart munitions, the EX-171. Due to the high speed of the missile, update rates of 1 second from a GPS only solution were too slow, and could not provide the accuracy needed and thus needed to include the INS. (Kariya, S. and Kaufman, P 2002) has developed a (GPS/INS) kit that converts old gravity bombs into precision-guided smart bombs. A control unit is attached to the end of the warhead which contains the (GPS/INS) system and battery powered motors to control the flight of the bomb. Actual use by American aircraft in Afghanistan during the 2002 War on terrorism proved these bombs can strike within 13 meters of their intended target.

2. Inertial Navigation System (INS) Principles.

In inertial navigation systems, the aircraft position and/or velocity are not measured directly, but rather are arrived at by sensing aircraft accelerations and performing calculations to obtain the aircraft velocity and present position. As shown in Fig.1. (Eric Foxlin.2005). (Daniel Roetenberg.2006).

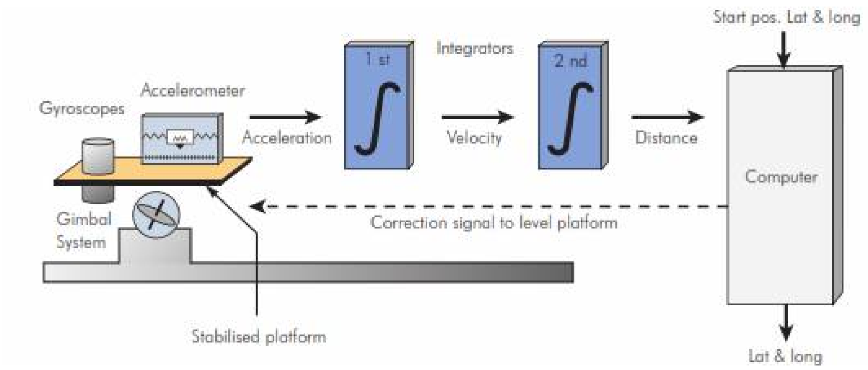

Fig.1. Inertial navigation system principles.

This technique may be thought of as a specialized form of dead reckoning in which aircraft movements are continually sensed by inertial referenced sensors and used to automatically calculate the information. Just as in any dead reckoning approach, knowledge of the starting point or position is necessary in order to keep track of present position. The inertial navigation system (INS) is a dynamic dead reckoning device which is composed of the following components as shown in Fig.2. (Walchko, K.andMason, P., 2002)

- Inertial measurement unit (IMU), which contains the inertial sensors that detect aircraft accelerations and rotational movements and provides the computer with changes in velocity, acceleration and attitude.
- Computer unit (CU) which computes aircraft velocity, distance traveled percent position and attitude based on time and data supplied by the (IMU).

Control and display unit (CDU), which displays to the pilot the computed information and allows manual insertion of data into the computer unit.

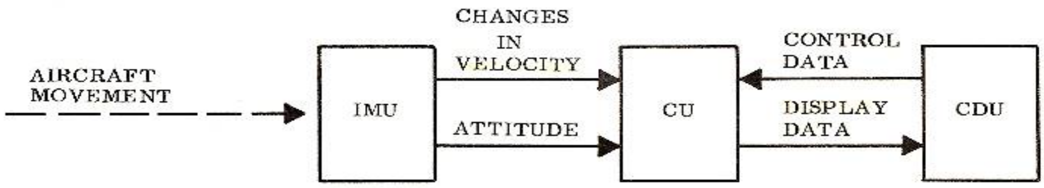

Fig. 2. Inertial navigation system component

Fig.3. illustrates the data flow within an (INS). The inertial measurement unit (IMU) senses aircraft acceleration and attitude changes and provides this information to the computer unit (CU). The computer unit (CU), having previously obtained present position and total velocity, calculates the changes in velocity and position resulting from the sensed acceleration and adds them to their previous values to obtain current values. The computer unit (CU) then performs other calculations necessary to display the required information to the pilot and transfers it to the control and display unit (CDU). The control and display unit (CDU) acts as the interface between the pilot and navigation system. It provides the capability of reading out the required information in a form which is directly usable to him. In addition, the (CDU) serves as the device through which the pilot can insert necessary data such as departure latitude and longitude prior to flight. (Chatfied, A, 1997).

3.

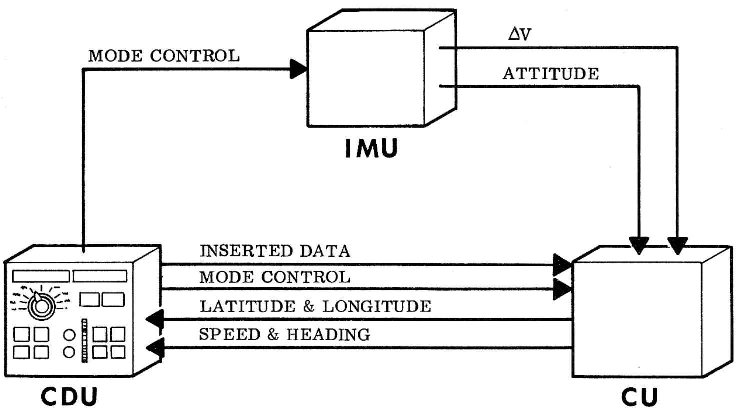

Fig. 3. Data Flow within an INS

3. The mechanization of (INS).

Now consider the functions of an inertial navigation system (INS) without regard to its individual components. These functions are:

- Platform stabilization.
- Attitude measurement.
- Acceleration measurement.
- Velocity and position measurement.
- Control and display.

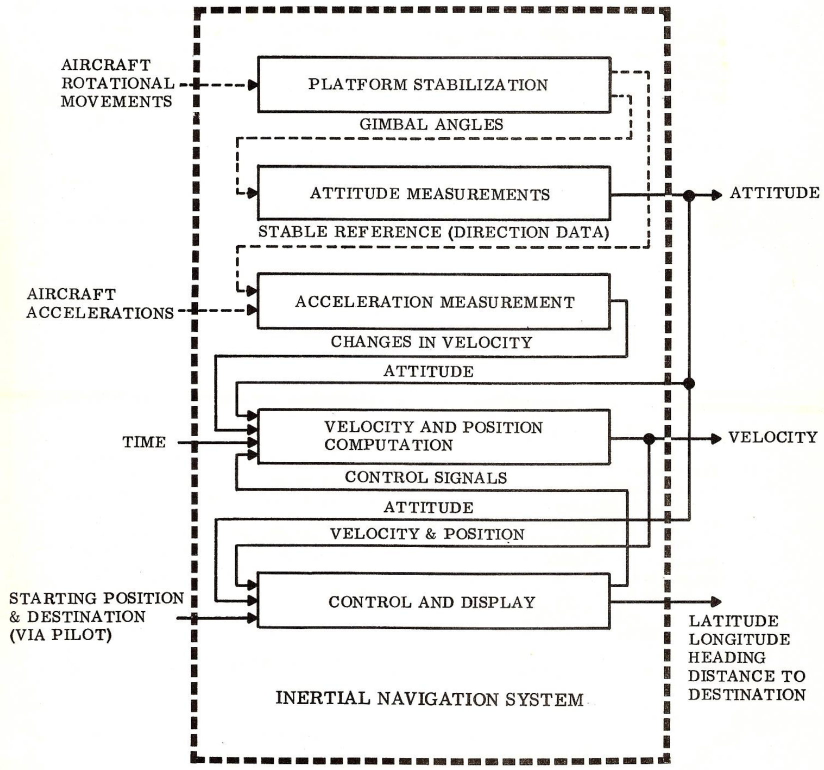

Fig.4. Inertial Navigation System Function

These functions are interconnected as shown in fig.4. Notice that the platform stabilization function senses rotational movements and provides gimbals angles and stable reference. The attitude measurement function converts the gimbals angle into a usable form identified as attitude. The acceleration measurement function uses aircraft accelerations and the stable reference to provide the change in velocity.(Soltz,J Arnold, Donna, James I.,Greenspan, Richard I.,1989).(Shin, Eun-Hwan.2001).

- **Acceleration Measurement**

The inertial technique of sensing aircraft acceleration is a mechanization of Newton's second law which states that an unbalanced force (F) which acts on a body will result in an acceleration (a) of that body in the direction of the force and of a magnitude which is inversely proportional to the mass (m) of the body or

$$F = ma \qquad (1)$$

A small proof mass (m) is located within the IMU which experiences the same acceleration as the airplane. (W.Bolton, 1999) Thus, if the force (F) required accelerate the proof mass (m) can be measured, the acceleration (a) of the aircraft can be determined. The sensing device which mechanizes Newton's second law is the accelerometer. An accelerometer is sensitive along only one axis called an input axis (IA). As the aircraft accelerates in the direction of the input axis (IA) of the accelerometer, the proof mass (m) will experience a force (F) which produces a torque about the accelerometer output axis (OA). Since this torque is proportional to the force caused by the accelerated mass (m), a force sensor is attached to accelerometer OA. The output signals f this force sensor is then an indication of the aircraft's acceleration. (W.bo l ton1999) Since accelerometers are sensitive along only one axis, the input axis (IA), a minimum of two such accelerometers positioned with their IA's at right angles to each other are required to successfully measure accelerations of the aircraft over the surface of the earth. The orientation of these accelerometers is shown in fig.5. Accelerometer)A) will sense acceleration of the airplane to the East and West, while accelerometer (B) will sense aircraft acceleration in the North and South directions.

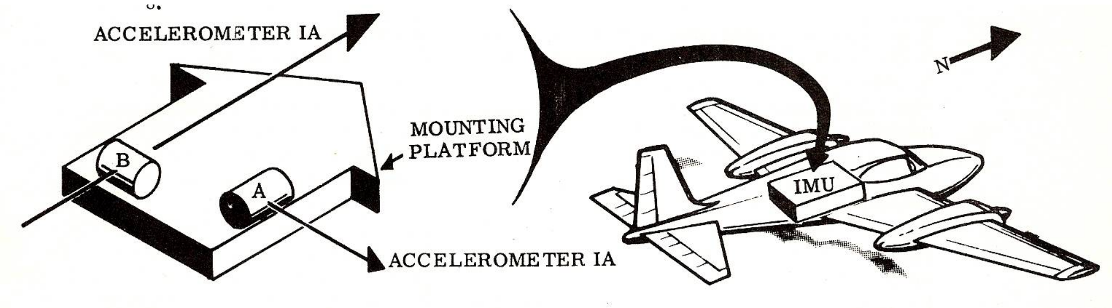

Fig.5. Orientation of accelerometers (A&B).

The pendulum is the sensing device within the accelerometer. It senses force which is proportional to acceleration. From basic physics, acceleration times an incremental time period equals an incremental change in velocity (a $\Delta t = \Delta v$) as shown in Fig.6.The pendulum, when offset from a null position by a force for an incremental period of time, produces a pulsed output. Each of the output pulses are proportional to the incremental time period and therefore are equal to a change in velocity (Δv). (Seng, K.Y., Lam, P.M. Lee, V.S.2003).

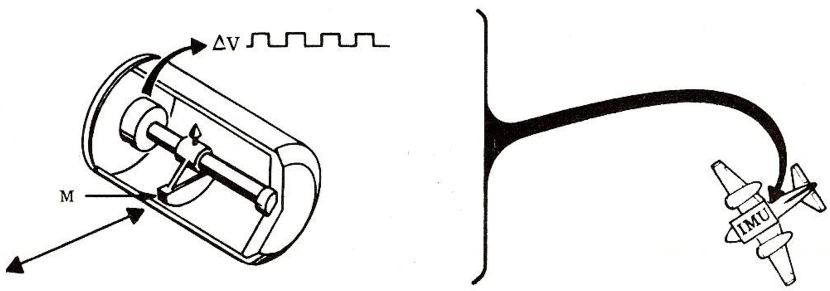

Fig.6. Change in velocity (Δv)

Let's stop here and consider the term velocity. Velocity is a vector, which means that it has a magnitude and a direction. The term speed is comparable to the magnitude portion of velocity. The accelerometer unit itself is a translation sensing device and its output is only the magnitude portion of velocity. The direction portion of the accelerometer output is due to the fact that the accelerometer is mounted on a gyro stabilized platform. Therefore, the gyros (rotation sensors) provide the direction component to the velocity vectors.

- **Platform Stabilization**

It is of prime importance that the position of the accelerometers with respect to the earth be known by the computer at all times so that the computer is able to determine the vector direction of acceleration experienced and thus determine resulting changes in velocity and position. This results in a requirement to initially align the platform to some known orientation with respect to the earth, such as B accelerometer heading north, whenever the system is energized. Consequently, the physical structure of the IMU must be such that the accelerometers can be maintained in a known position with respect to the earth regardless of any changes of aircraft attitude. This is normally done by a series of gimbals which support a common mounting platform for the accelerometers as shown. If the gimbals structure as shown in fig.7.is perfectly balanced and no friction exists in the pivots, the accelerometer orientation will be unaffected by airplane attitude changes. Unfortunately, since friction exists at all pivots, there is always a platform disturbance when the aircraft changes attitude, resulting in the tendency of the platform to move. To compensate, gyroscopes are mounted on the platform to sense its disturbances and develop error signals which are used in conjunction with servo loops, including torque motors on the gimbals, to keep the platform in its desired position regardless of aircraft attitude changes. (K.R.Britting, 1971), (Grunell, 2005).

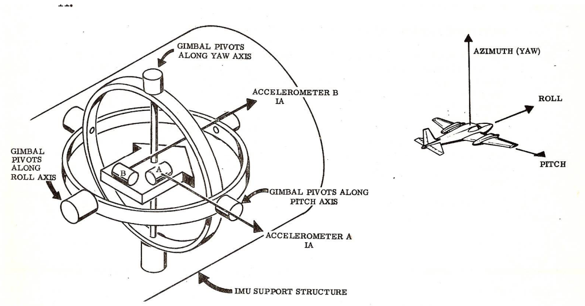

Fig. 7. Series of gimbals

- **Attitude Change Measurement and Computation.**

The IMU platform is maintained earth referenced and is isolated from aircraft attitude through a stabilization subsystem composed of the gyros, gimbals and gimbals torque motors. Consequently, this same platform can be used as a reference from which aircraft attitude changes can be determined .(Jung,D.and Tsiotras,P.,2007) All that is required to obtain this change in attitude information is to monitor the change of the gimbals positions from their initial orientation when the platform and accelerometers were initially aligned to an earth reference. From this point on (initial earth referenced alignment), all attitude changes occur about the platform and are reflected in gimbals position changes. (Taylor, B., Bil, C., 2008) Therefore, sensors can be placed on the gimbals and used to provide aircraft attitude change information to the computer unit. The gimbals position sensors develop an output proportional to any change of the gimbals position and supply this output to the computer unit (CU). The CU adds these changes in position to the initial gimbals position data at "take-off and the result is the aircraft's present roll and pitch attitude and azimuth heading. These present attitude signals would normally be supplied to cockpit indicators and other systems requiring freedom from the aircraft attitude, such as the Doppler radar antenna as shown in fig.8. (Hine, B., and Zornetzer, S.2003).

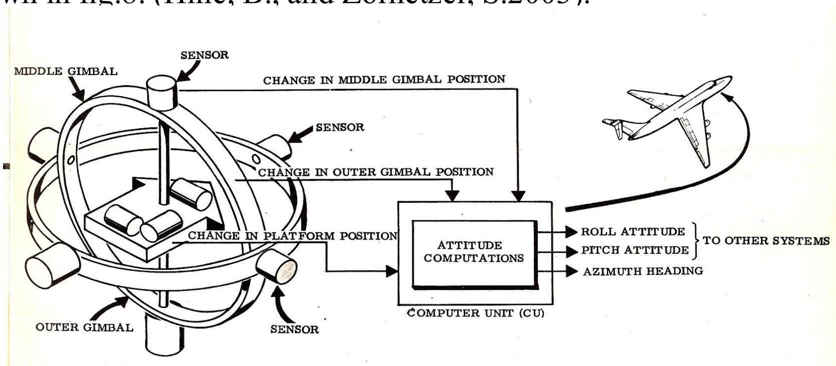

Fig.8. Attitude computation

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- **Velocity and Position Computation**

The ΔV output from the accelerometers is summed in the CU's velocity summation block. The vector sum of these two yields the ground track speed of the aircraft while the integrals of the velocities with respect to time

$$\int_0^t v_n \quad dt \quad and \int_0^t v_e \quad dt \qquad (2)$$

Directions respectively. By adding these distances traveled to the initial latitude and longitude of the aircraft at take-off, the present position is determined and available for display. (P.G.Savage, 1998), (Ojeda, L.,Borenstein,J, 2007).

- **Control and Display**

The control and display unit (CDU) provides for control of the INS and display of navigation data such as longitude, latitude, speed, and heading. The control aspects include the application of INS power, initiation of computer controlled platform alignment, initiation of various computer navigation computations, and selection of various information for display. As shown in fig.9. (Rogers, M.2007).

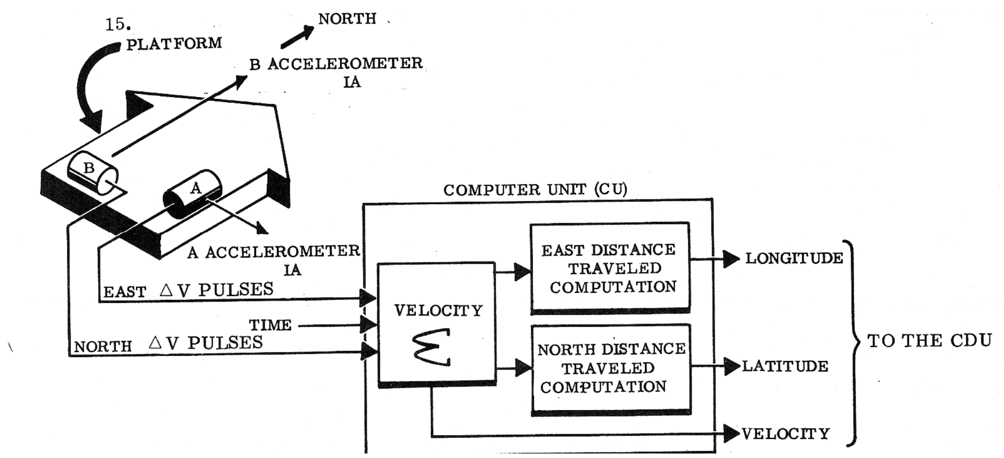

Fig.9. Velocity and Position Computation

4. The relationship between the inertial navigation systems (INS) and global positioning system (GPS).

As is well known that finding a global positioning system (GPS) with high specifications but the work is controlled by the state manufactured for this reason, the use of (GPS) in terms of security is incomplete. The piece is preferable to use (INS) with the (GPS) for a better flight.

Table shows 4.1. A comparison between the (INS) and the GPS). (Reddy, M. Mun, J. Burke, D. Estrin, M. Hansen, and. M ivastava, 2010)

INS **Inertial Navigation System**	GPS **Global Position System**
1. Do not rely on ground stations. Depends on the movement plane self depending this means working independently without foreign interference or influence 2. Cannot be jamming and interference with her because the principle of work depends on the driven plane	1. Dependent on ground stations. This means that the country is completely factory controls in the system and is able to prevent the beneficiary of finding the coordinates of the site. Country factory is not given the original code, but the commercial code. 2. Can be jamming and interference with

3. Can be easily repaired and maintained because they need to expertise in this area 4. The system works in all climate conditions and different times of the year and all the high. 5. Indefinite system the age of and depends on the use of the correct technical. 6. Given the amount of deviation in degrees system which facilitates the process on the pilot.	her because the principle of work depends on the frequency 3. Cannot be easily repaired and maintained for being modern technology and some of its parts requires sent to manufacturers 4. Employment Status depends on the receipt of information from satellite 5. The age of specific system because it depends on the age of satellites and this specific age 7.5 years. 6. Given the amount of deviation in the direction in meters, which requires time to turn them into degree.

5. Simulation work

Simulation work includes four stages, Assigned flight route, Actual flight route(1), Actual flight route (2) and Actual flight route (3).

5.1 Represent the work of the (INS).

The representation the work of (INS) by geographic information system (GIS) which is a powerful tool used for computerized mapping and (Matlab, Simulink program). By these two programs, we can get.

- The assigned flight route that we have chosen within the map of Iraq. As shown in fig.10. (Ismeel,S.A2003)
- Four hypothetical paths Based on the assigned flight route in different time periods as shown in below fig. (10, 11, 12, 13).

5.1.1 Assigned flight route

Fig.10. and table

5.2. Represent the assigned flight route estimate by geographical information system (GIS).

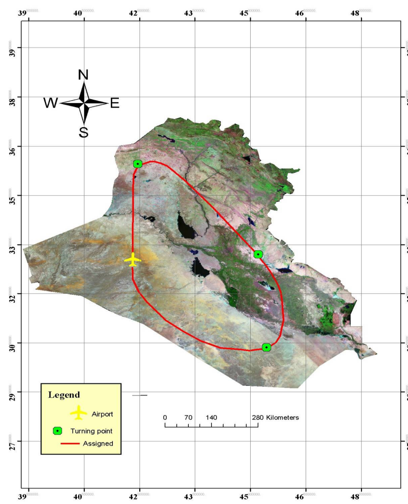

Fig.10. Assigned flight route estimate (GIS)

Table 5.2. Latitudes and longitudes coordinates assigned flight route estimates (GIS).

NO.	East (X)			North (Y)			NO.	East (X)			North (Y)		
	Long. D(X_1)	Long. M(X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)		Long. D(X_1)	Long. M (X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)
1.	41	49	5.22	33	08	38.8	14.	45	07	23.6	32	16	44.4
2.	41	49	30.8	33	24	50.6	15.	45	29	8.5	32	46	22.6
3.	41	49	30.8	33	32	56.8	16.	45	49	3.5	31	02	42
4.	41	49	30.8	34	02	22.3	17.	45	52	28.2	30	20	29.2
5.	41	49	30.8	34	30	5.6	18.	45	47	46.7	30	17	22.1
6.	41	49	56.3	34	59	5.5	19.	45	09	49.4	30	23	20.4
7.	41	50	21.9	35	37	54	20.	45	06	16.8	30	35	16.8
8.	42	30	52.8	36	00	30.2	21.	43	36	51.2	30	46	47.7
9.	43	05	51	35	34	29.3	22.	43	18	31	31	59	9.8
10.	43	39	6.9	35	00	47.9	23.	43	00	10.7	32	46	30
11.	44	11	57	34	23	16.1	24.	42	10	42.5	32	27	0.9
12.	44	24	19.2	33	08	20.6	25.	41	48	57.5	33	46	8.2
13.	44	42	39.5	33	47	1.2	26.	41	47	14.7	32	08	38.3

5.1.2 Actual flight route (1).

Fig.11.and table 5.3. Represents the actual flight route (1) estimate by geographical information system (GIS).

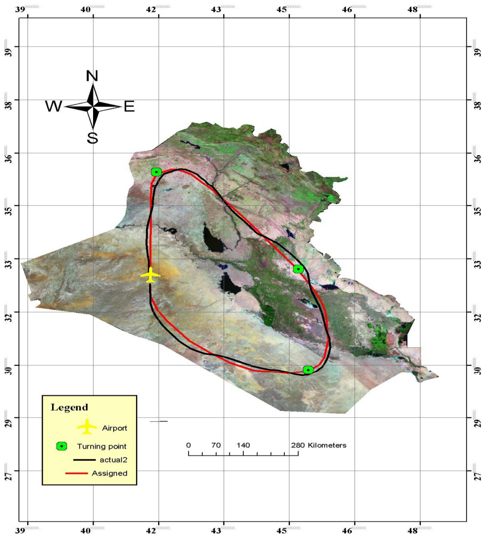

Fig.11. Actual flight route (1) estimate (GIS).

Table 5.3. Latitudes and longitudes coordinate actual flight route (1) estimate (GIS).

NO.	East (X)			North (Y)			NO.	East (X)			North (Y)		
	Long. D(X_1)	Long. M(X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)		Long. D(X_1)	Long. M (X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)
1.	41	49	5.22	33	08	38.3	14.	45	11	39.4	33	20	9.1
2.	41	49	30.8	33	24	50.6	15.	45	2637	35	31	44	40.2
3.	41	46	57.2	33	32	31.2	16.	45	54	32.6	31	58	52.1
4.	41	45	14.9	34	01	31.2	17.	45	49	10.5	31	20	3.6
5.	41	48	14	34	30	31.1	18.	45	10	54.7	31	42	6.2
6.	41	50	21.9	34	58	39.9	19.	45	10	15	30	16	5.4
7.	41	54	12.2	35	38	19.8	20.	44	10	32.7	30	34	51.2
8.	42	31	4.4	36	04	46	21.	43	42	23.9	30	43	23
9.	34	33	06	35	46	02	22.	43	20	38.9	30	43	55.7
10.	34	34	25.4	34	55	40.8	23..	42	54	38	30	56	10.6
11.	44	07	41.2	34	19	25.8	24.	42	06	52.2	31	44	27.1
12.	44	07	41.2	34	19	25.8	25.	41	48	57.5	32	27	0.9
13.	44	46	29.7	33	49	34.7	26.	41	49	57.5	33	08	38.3

5.1.3Actual flight route (2).

Fig.12 and table 5.4. Represents the actual flight route (2) estimates by geographical information system (GIS).

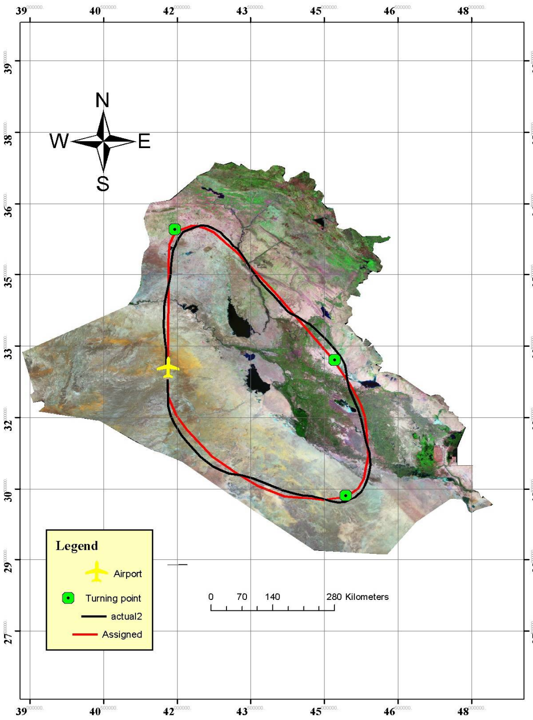

Fig.12. Actual flight route (2) estimates (GIS).

Table 5.4. Latitudes and longitudes coordinate actual flight route 2 estimates (GIS).

NO.	East (X)			North (Y)			NO.	East (X)			North (Y)		
	Long. D(X_1)	Long. M(X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)		Long. D(X_1)	Long. M (X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)
1.	41	49	5.22	33	08	38.3	14.	45	16	20.9	33	20	9.1
2.	41	49	30.8	33	24	50.6	15.	45	27	51.8	32	44	40.2
3.	41	4435	14.9	33	32	31.2	16.	45	45	13.2	31	58	52.1
4.	41	44	32.5	34	01	31.2	17.	45	53	19.9	31	20	3.6
5.	41	51	49.3	34	30	31.2	18.	45	51	37	31	42	6.2
6.	41	58	13.1	34	58	39.9	19.	45	09	49.4	30	16	5.4
7.	41	32	2.5	35	38	19.8	20.	44	05	25.6	30	34	51.2
8.	42	10	35	36	04	46	21.	43	41	7.1	30	43	23
9.	43	36	6.9	35	40	02	22.	43	19	22.1	30	48	55.7
10.	43	36	58.9	34	55	40.8	23.	42	52	4.5	30	56	10.7
11.	44	08	58	34	19	25.8	24.	42	02	36.3	31	44	22.1
12.	44	08	58	34	19	25.8	25.	41	48	57.5	32	27	0.9
13.	44	49	54.4	33	49	34.7	26.	41	49	5.22	33	08	38.3

5.1.4 Actual flight route (3).

Fig.13 and table 5.5. Represents the actual flight route (3) estimate by geographical information system (GIS).

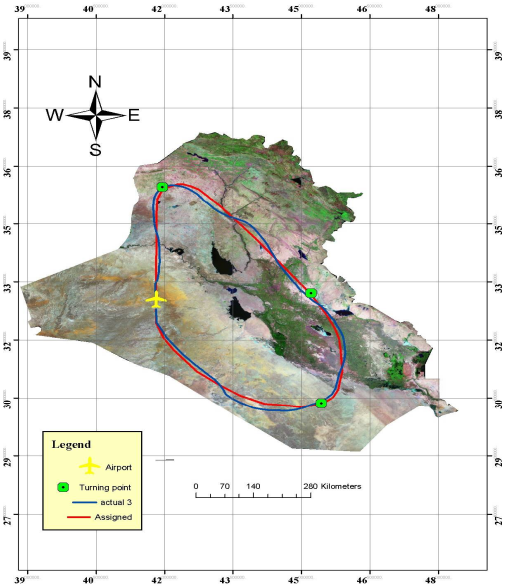

Fig.13. Actual flight route (3) estimates (GIS).

Table 5.5. Latitudes and longitudes coordinates' actual flight route (3) estimates (GIS).

NO.	East (X)			North (Y)			NO.	East (X)			North (Y)		
	Long. D(X_1)	Long. M(X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)		Long. D(X_1)	Long. M (X_2)	Long. S(X_3)	Lat. D (Y_1)	Lat. M(Y_2)	Lat. S(Y_3)
1.	41	49	5.22	33	08	38.3	14.	45	02	16.5	33	14	10.9
2.	41	49	30.8	33	24	50.6	15.	45	30	25.3	32	47	39.3
3.	41	50	47.5	33	34	13.3	16.	45	56	18.5	31	56	13.6
4.	41	53	21.1	34	00	14.4	17.	45	54	10.6	31	23	2.7
5.	41	52	29.9	34	30	5.6	18.	45	34	30.8	30	42	57.4
6.	41	46	57.2	34	56	57.6	19.	45	08	32.7	30	18	13.3
7.	41	45	40.5	35	37	28.4	20.	43	57	19.5	30	14	2.3
8.	42	32	35	35	54	57.5	21.	43	34	17.7	30	25	53.9
9.	43	02	51.9	35	27	14.3	22.	43	16	48.9	30	44	39.8
10.	43	45	5.1	35	03	47	23.	42	59	19.5	31	04	16.8
11.	44	15	21.8	34	27	32	24.	42	12	50.4	31	52	37.1
12.	44	15	21.8	34	27	32	25.	41	48	57.5	32	27	0.9
13.	44	39	40.3	33	44	02	26.	41	49	5.22	33	08	38.3

5.1.5 Training and design of artificial neural networks.

The Design artificial neural network is according to the information we have obtained from (GIS) described in the table 5.6. (Chiu, C.C, 2005).

Table5.6. Neural network specifications.

No.	Item	Value
1	No. of pattern	6
2	Layer No.	3
3	No. of Neuron in i/p layer	6
4	No. of Neuron in hidden layer	13
5	No. of Neuron in o/p layer	6
6	Momentum	0.99
7	Learning Rate	0.9

After the design phase of artificial neural network. Training phase begins on the assigned flight route of the plane and the results are saved for to the next stage as shown in fig.14.

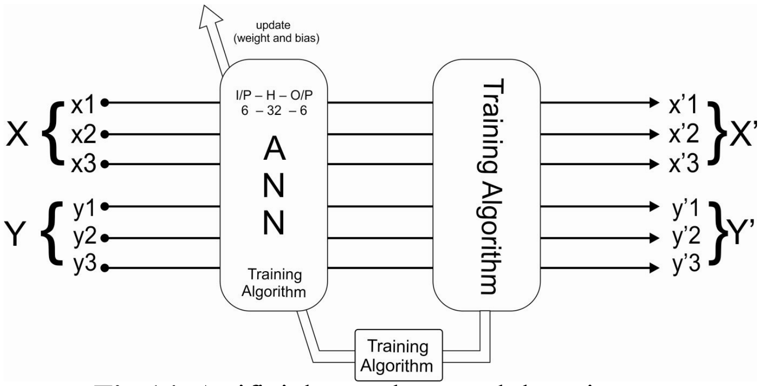

Fig.14. Artificial neural network learning

5.1.6 Testing Process

After the training process and saving of the results, the neural network will be ready for the debugging process based on the information stored on the original route. Debugging process begins to match the actual path of the plane with the assigned flight route and collect a new path which will be closer to the assigned flight route fig.15.(Yeo,M.S, Kim,K.W.2003).

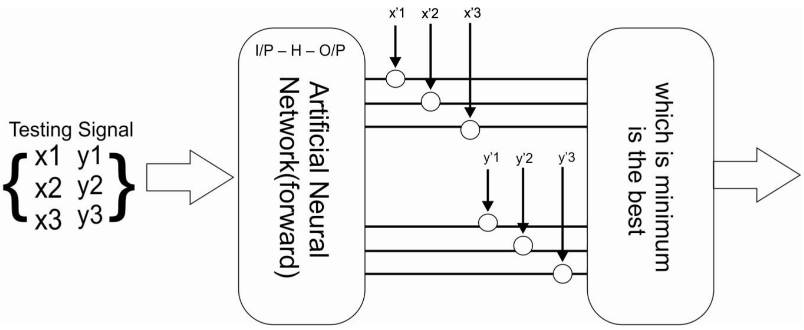

Fig.15. Testing Process

6. Result and discussion

The assigned flight route of the plane is in the form of straight lines depending on the navigational points of the international shipping routes. The actual Air plane path is with right and left deviations from the assigned flight route. Correction process in this research is to bring and match the actual track with the assigned flight route. Correction process leads to reduce flight time and that means economy in the amount of fuel for the plane. And at the same time ensure aviation security.Fig.16.Shows the assigned flight route as saved in the (INS) memory. These routes are normally saved pre-flight. The airplane actual routes are corrected according to it.

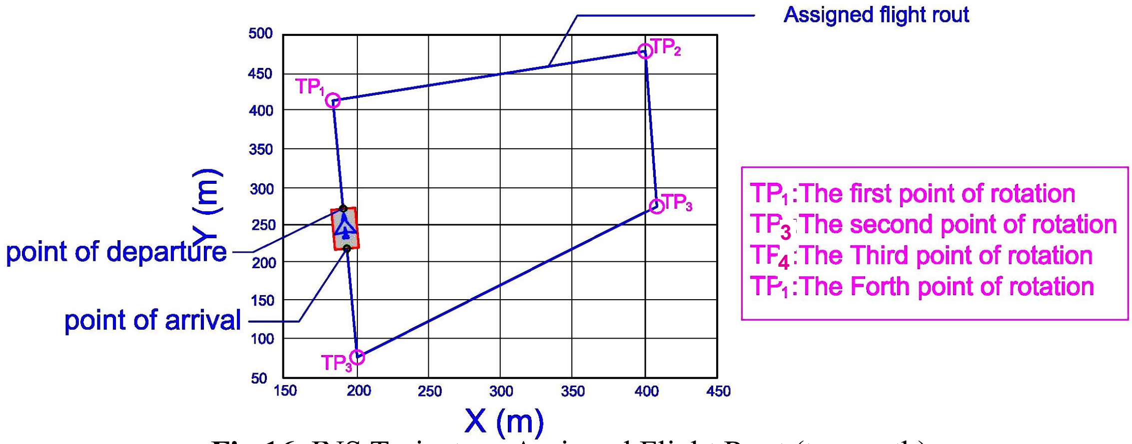

Fig.16. INS Trajectory Assigned Flight Rout (true path)

Fig.17. shows the assigned flight route (input route given pre-flight) and saved in the aircraft memory of (INS).It also shows the corrected route estimate by (INS) and by the proposed (ANN). It shows that the proposed (ANN) increase the efficiency of the correction made by the aircraft (INS). Table 6.7 shows the numerical correction. It shows that the (INS) 81% close to the input route (assigned flight route) while the proposed (ANN) is 84%.

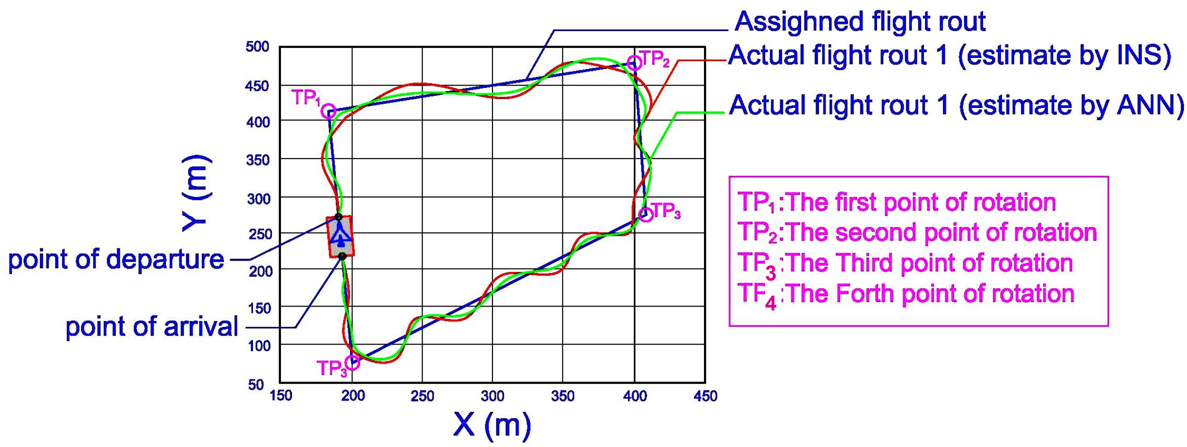

Fig.17. trajectory assigned flight rout with actual flight rout (1) estimate (INS) and flight route estimate ANN)

Table6.7. Rate correction actual flight rout (1) estimate by (INS &ANN)

Rate correction estimate by INS	Rate correction estimate by ANN
81 %	84 %

Fig.18. shows the assigned flight route (input route given pre-flight) and save in the aircraft memory of (INS). it also shows the corrected route estimate by (INS) and by the proposed.(ANN). It shows that the proposed ANN increase the efficiency of the correction made by the aircraft INS. Table 6.8 shows the numerical correction. It shows that the INS 85% close to the input route (assigned flight route) while the proposed ANN is 89%.

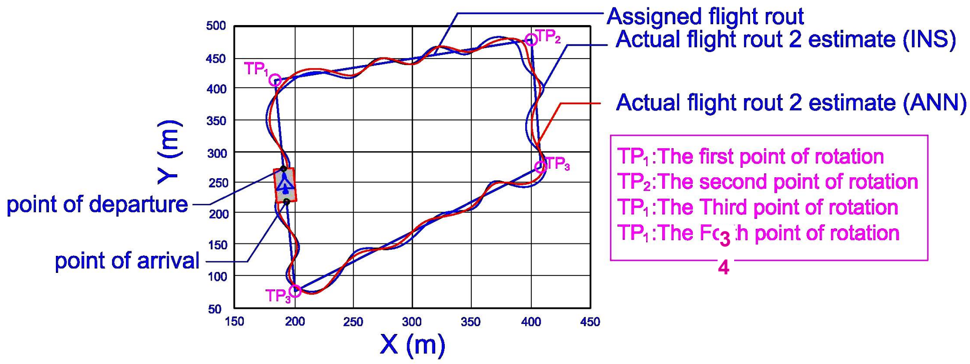

Fig.18. Trajectory assigned flight rout with actual flight rout (2) estimate (INS) and flight route estimate ANN)

Table 6.8. Rate correction actual flight rout (2) estimate by (INS &ANN)

Rate correction estimate by INS	Rate correction estimate by ANN
85 %	89 %

Fig.19. Shows the assigned flight route (input route given pre-flight) and saved in the aircraft memory of INS. it also shows the corrected route estimated by INS and by the proposed ANN. It shows that the proposed ANN increases the efficiency of the correction made by the aircraft INS. Table 6.9. Shows the numerical correction. It shows that the INS is 89% close to the input route (assigned flight route) while the proposed ANN is 95%.

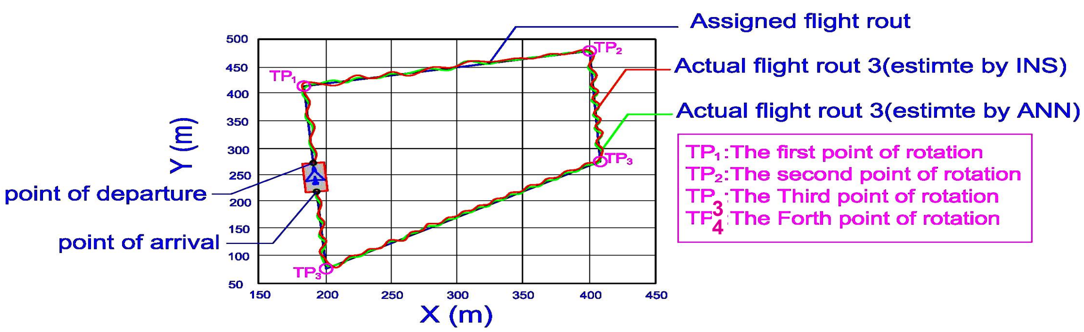

Table 6.9. Rate correction actual flight rout (3) estimate by (INS &ANN)

Rate correction estimate by INS	Rate correction estimate by ANN
89 %	95 %

7. Conclusion.

In this research the path of the plane has been modeled using artificial neural network (ANN) and (Matlab, Simulink program). four flight cases were studied to implement the proposed technique. The results showed that the artificial neural network is able to show high-definition resolution in the behavior of the system. Correction of the actual path of the aircraft on the basis of the assigned flight route of the plane is very important to the airlines, and to Military aircraft. This is because the correction of actual path means that the aircraft track is free of distractions as much as possible and this helps to reduce the time and reduce fuel consumption. This is a good economic situation. And aircraft, whether civilian or military is first to reach the target in time. Secondly is the fuel economy. For these reasons perfect aviation navigation systems should provide high precision and without mistakes and without deviation from the original flight line as prescribed by the airport authority.

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