

Automatic determination of LAHSO surface paint pattern orientation in Airport Mapping Database (AMDB)

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Abstract - The goal of this research is to provide a generic method to derive correct Land And Holdshort Operation (LAHSO) orientation information from the GIS data of the aerodrome features based on geo-spatial layout, for usage in any 3D Airport Moving Map (AMM) display application. AMM helps orient the flight crew to the aircraft's positional information on the ground with respect to runways, taxiways, and airport structures, without paper chart reference. It is primarily intended to improve operator's safety and operational efficiency margins through improved positional awareness and reduced flight crew workload. AMM uses Airport Mapping Databases (AMDB) to create the airport layouts. AMDBs represent a collection of aerodrome information that is organized and arranged for ease of electronic storage and retrieval in systems that support aerodrome surface movements. These databases consist of vectors and attributes e.g. runway thresholds, hold lines, and aircraft stand locations etc. AMDBs also contain positional information describing the location of aerodrome information elements. The LAHSO lines, one of hold line types are part of AMDBs that indicate the locations of markings used for Land and Hold Short Operations. AMM uses LAHSO information from AMDB and displays the real world four lines (two solid and two broken) markings at the required location in the right orientation.

Index Terms – Airport Moving Map (AMM), Airport Mapping Database (AMDB), Hold Lines, Land and Hold Short Operation (LAHSO), Geographical Information System (GIS), DO-272, DO-291, Aeronautical Information Exchange Model (AIXM), ARINC 816.

I. INTRODUCTION

There are few markings on the ground in an aerodrome where an aircraft is supposed to stop for hold short operations. The operations include landing and holding short of a critical aerodrome area such as the runway/runway, runway/taxiway, and taxiway/taxiway intersections and ILS/MLS areas. These markings are captured as line geometries in the supplier's data for AMDB and called as Hold Position Lines.

AMDB contains the following Hold Position Lines:

- Land and Hold Short Operation (LAHSO) Line (markings on runways)
- Taxiway Hold Position Line (includes both Runway Hold Position Line and ILS Hold Position Lines)(markings on taxiways)
- Taxiway Intersection Marking (markings on taxiways)

The LAHSO lines indicate the locations of markings used for Land and Hold Short Operations. The operations include landing and holding short of an intersecting runway, an intersecting taxiway, or on some other designated point on a runway other than an intersecting runway or taxiway.

These LAHSO features contain data attributes to specify about the information/properties they represent. Two attribute fields viz. 'idp' and 'idthr' have been used in this paper which have been defined in DO-272B as below:

idp: Object identifier of runway or taxiway being protected.

idthr: Object identifier

The capture rule for LAHSO defined in DO272B is as follows: "The lines shall be captured along the outer edge (away from intersecting runway/taxiway) of the LAHSO line as painted on the runway or marked by other means (e.g. lighting)." This can be depicted as shown in Figure 1.

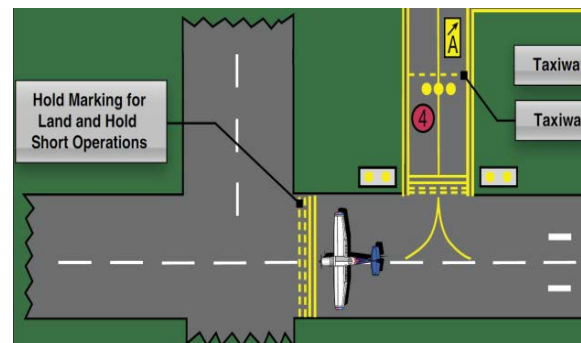


Fig.1 LAHSO on a graphical view

After capturing the LAHSO as a line segment, it's difficult to ascertain on which side of the line the intersection lies until visually looking at the layout of the airport. This loss of information in the AMDB data creates difficulty in representing the pattern of LAHSO in any flight display application.

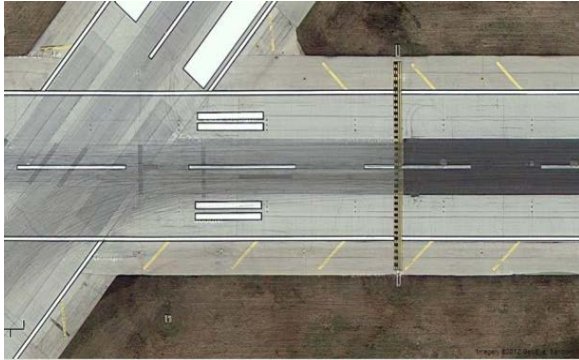


Fig.2 LAHSO in satellite image

As on date, the aircraft onboard 3D display application meant for displaying Airport Moving Map (AMM) is required to depict/represent the actual LAHSO paint on ground and conform to their actual position and depict the information on them. The LAHSO symbology used in the application assists the pilot in identifying the location of the runway used for LAHSO operation and the runway to protect. It consists of **2D marker**, **LAHSO pattern** and **hold short runway label**. Figure 3 depicts one LAHSO in 3D application.

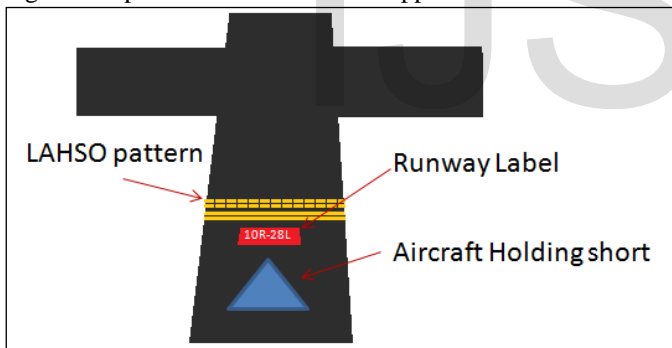


Fig.3 Depiction of LAHSO in 3D application

Figure 4 shows how the data is being captured and supplied by supplier.

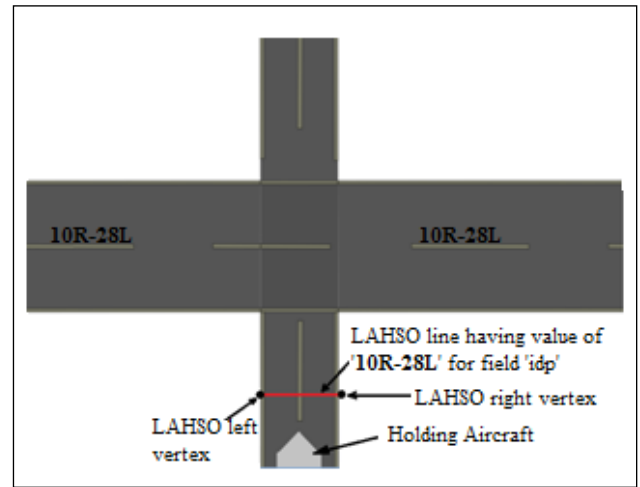


Fig.4 LAHSO data from supplier displayed on GIS tool

At present, only two data endpoints are available to delineate a hold short line. Consequently, the real world four line (two solid and two broken) markings cannot be reliably illustrated, because it is unknown on which side of the solid lines the broken lines should be drawn.

Therefore, it is required to capture the two end vertices correctly in order to enable the application to display the symbology in correct orientation for the pilot to use this feature in the onboard display system effectively.

LAHSO lines are being captured into AMDB by the end vertices of the front continuous line of LAHSO Lines. This is illustrated in Figure 5.

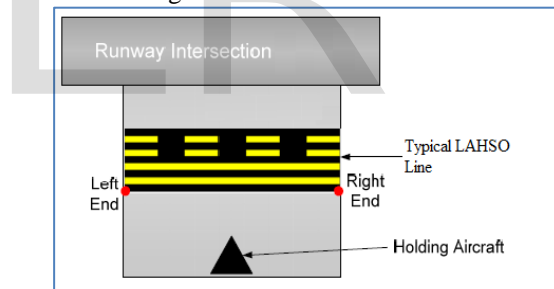


Fig.5 Capturing LAHSO lines

Table I shows some of the various aerodrome features that are being provided by suppliers to depict the physical environment to the pilot while on the aerodrome surface [1].

TABLE I AERODROME FEATURES

Runways	Taxiways	Aprons
Shoulders	Service Roads	Stands
Hold Lines	Paint Features	Jetways
Centerlines	De-icing Pads	Pavement Segments

In the current research, the following features have been used:

1. LAHSO(line geometry)
2. Painted Centre Line (line geometry)
3. Runway Threshold (point geometry)

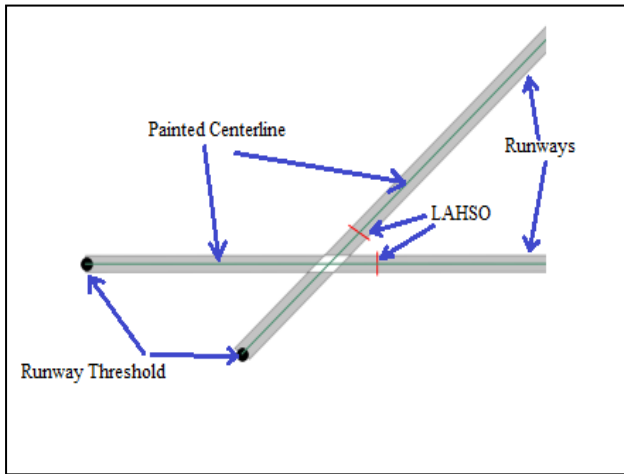


Fig.6 Layout of the above three aerodrome features

Figure 6 shows the layout of these features in an aerodrome.

Painted Centerline and Runway Threshold features have been described in DO-272B as below.

Painted Centerline: Continuous line captured along the painted line in the centre of a runway connecting the two thresholds [1].

Runway Threshold: The beginning of the portion of the runway that is available for landing [1].

In this research, a method has been developed that identifies the left/right vertices of the LAHSO with respect to the holding-short runway and arranges the runway numbers that indicates the direction to the corresponding runway threshold. The convention of right hand rule is used to define the positive direction of the third axis in the Cartesian coordinate system given the first two. If we define the surface with two vectors rather than two lines, we can use the right hand rule to define the positive direction of the normal.

The objective of this algorithm is to:

1. capture the end vertices(left & right) of LAHSO in the correct orientation
2. capture runway text orientation per cockpit i.e. left number indicates left end of the runway and right number indicates the right end of the runway when the aircraft is holding before the marking.

II. PROPOSED SOLUTION DESCRIPTION

At the outset, this paper exploits the concepts of right hand rule for cross product of two vectors. The right hand rule is a convention used to define the positive/negative direction of the third axis in the Cartesian co-ordinate system given the first two. If the surface can be defined with two vectors rather than two lines, the right hand rule can be used to define the positive/negative direction of the normal. The cross product of two vectors is a third vector of the magnitude of the area defined by the two vectors, and in a direction perpendicular to both in the direction defined by the right hand rule [2, 7]. Figure 6 depicts vector cross product of \vec{A} and \vec{B} .

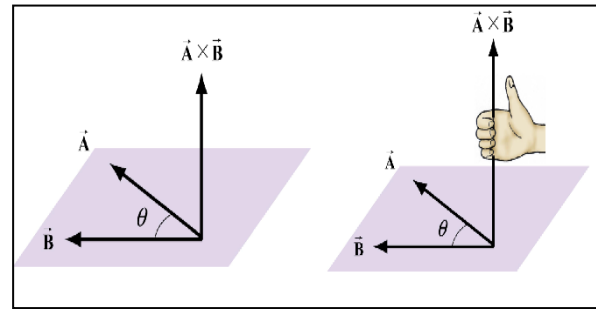


Fig.7 Diagrammatic representation of vector cross product

This right hand rule concept is used in the current research as explained in the following paragraphs, in order to get the LAHSO orientation correctly.

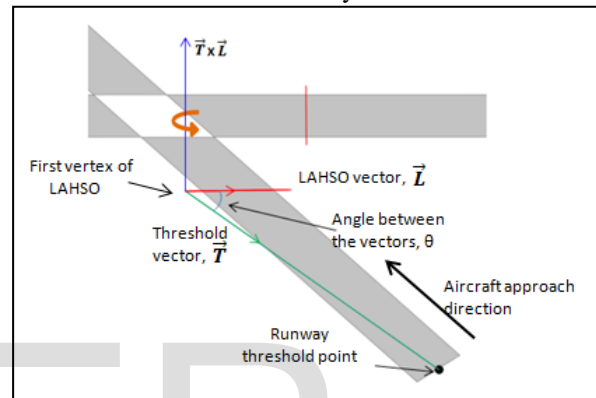


Fig.8 Correct line orientation for LAHSO

Figure 8 shows how the LAHSO should be oriented with respect to the intersection. The arrow indicates direction of the line from left vertex to right vertex with respect to the aircraft.

Two vectors can be formed originating from the first vertex of the LAHSO as shown in Figure 8. LAHSO vector \vec{L} is defined from first vertex to second vertex of the LAHSO line and Threshold vector, \vec{T} is defined from first vertex of the LAHSO line to the threshold point, the angle between them being θ .

The magnitude of the cross product of these two vectors can be computed as given in equation (1) [2, 7]:

$$\|\vec{T} \times \vec{L}\| = \|\vec{T}\| \|\vec{L}\| \sin \theta \quad (1)$$

where $\|\vec{T}\|$ and $\|\vec{L}\|$ denote the magnitudes of \vec{T} and \vec{L} , respectively. The angle between the vectors is limited to the values $0 \leq \theta \leq \pi$ insuring that $\sin(\theta) \geq 0$.

The direction of this cross product is defined using the convention which is commonly called as "right-hand rule" which is perpendicular to the plane of \vec{T} and \vec{L} . In this discussion, a rotation in counter-clockwise is taken as positive which indicates that the LAHSO line is oriented in the required orientation with respect to the hold short runway.

Therefore, for the scenario shown in Figure 8, it is not required to re-orient the LAHSO line since the resultant of the product is positive (counter-clockwise).

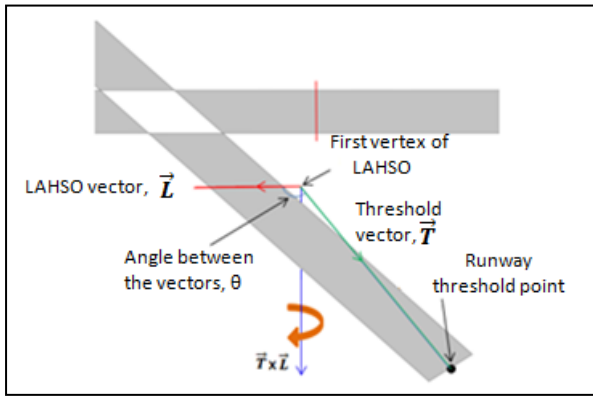


Fig.9 In-correct line orientation for LAHSO

Whereas for the scenario shown in Figure 9, $\vec{T} \times \vec{L}$ is close-wise and therefore it is required to reverse the line orientation. This shows an example of LAHSO that is oriented incorrectly with respect to aircraft approach direction. The arrow indicates direction of the line from first vertex to second vertex.

The algorithm to capture the LAHSO line correctly can be described as follows:

Step1: Identify the corresponding threshold point to each LAHSO. There is one corresponding runway threshold point for each LAHSO defined by 'idthr' attribute. Assume this point has coordinates as (t_x, t_y) .

Step2: Identify the two end points (first and second point) of the LAHSO line. Assume these points have coordinates as $(11_x, 11_y)$ and $(12_x, 12_y)$.

Step3: Construct the two vectors as defined in equation (2) and (3):

$$\vec{T} = (t_x - 11_x) \hat{i} + (t_y - 11_y) \hat{j} \quad (2)$$

$$\vec{L} = (12_x - 11_x) \hat{i} + (12_y - 11_y) \hat{j} \quad (3)$$

Figure 10 depicts the two vectors graphically.

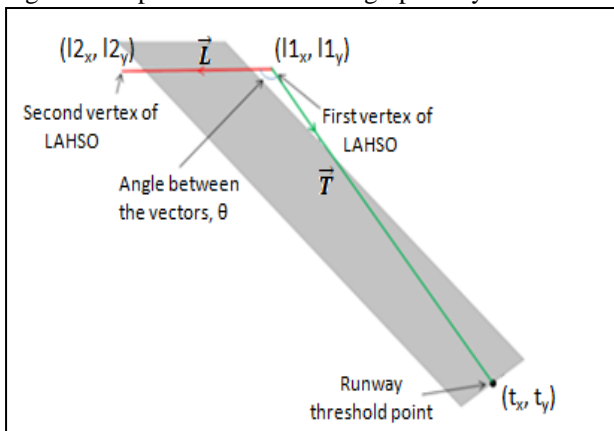


Fig.10 Threshold (\vec{T}) and LAHSO (\vec{L}) vector representation

Step4: Compute the magnitude of $\vec{T} \times \vec{L}$ as derived in equation (4):

$$\|\vec{T}\| \|\vec{L}\| \sin \theta \cong (t_x - 11_x) (12_y - 11_y) - (t_y - 11_y) (12_x - 11_x) \quad (4)$$

$\sin \theta$ could be neglected since it does not have any impact on the sign of the magnitude.

Step5: I) If computed magnitude in Step4 is +ve, the supplied orientation of the line is correct. Capture the line into AMDB as it is.

II) If computed magnitude in Step4 is -ve, the supplied orientation of the line is incorrect. Reverse the orientation and capture the line into AMDB.

The flow chart for rectifying line orientation is given in Figure 11.

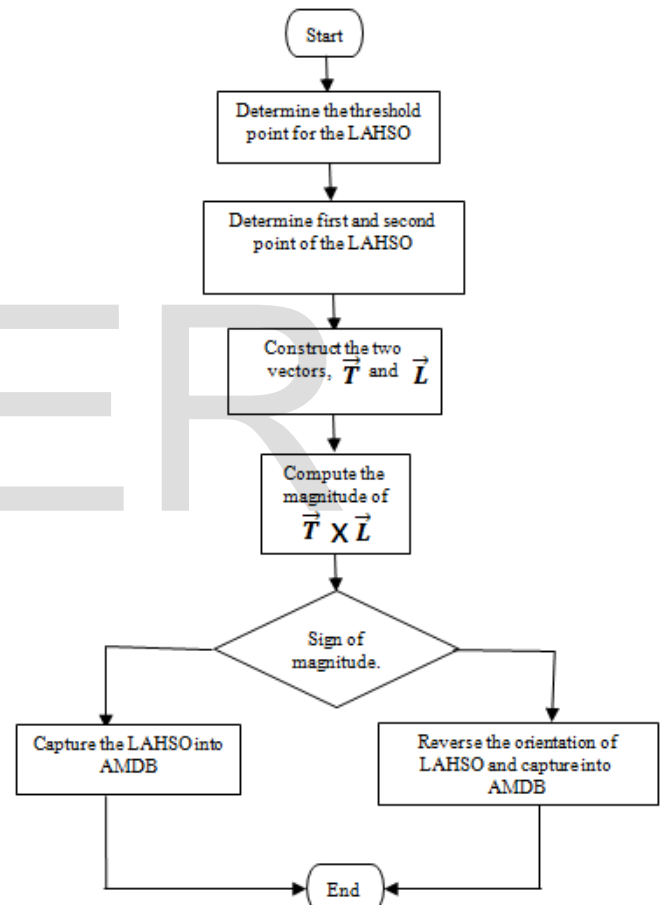


Fig.11 Flow Chart for rectifying line orientation

The line orientation is rectified now. The next task is to orient the text of the hold short runway label as per cockpit. The above algorithm could be used for the purpose. The two vectors are formed with another set of vertices as shown in Figure 12.

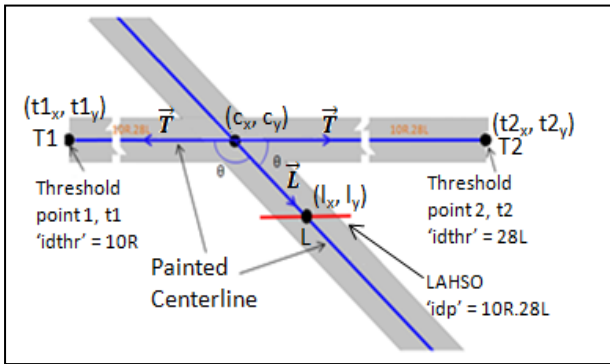


Fig.12 Threshold (\vec{T}) and LAHSO (\vec{L}) vector representation for runway label orientation

In Figure 12, C is the point of intersection of the two Runway Centre lines with (c_x, c_y) as coordinates. T1 and T2 are the threshold points of the hold-short runway with $(t1_x, t1_y)$ and $(t2_x, t2_y)$ as coordinates. L is the point of intersection of the runway centre line (on which the LAHSO is located) and the LAHSO with coordinate as (l_x, l_y) .

The algorithm to capture the runway label for LAHSO line correctly can be described as follows:

Step1: Identify the two relevant runway centre lines (runway on which LAHSO is located and the hold short runway) for each LAHSO. One painted centerline corresponds to the 'idp' value of LAHSO and the other one intersects spatially with LAHSO line.

Step2: Find the intersection point (c_x, c_y) of these two centre lines.

Step3: Find the intersection point (l_x, l_y) of the centre line and LAHSO line.

Step4: Identify the two threshold points of the hold-short runway. Assume the coordinates of them as $(t1_x, t1_y)$ and $(t2_x, t2_y)$ respectively.

Step5: Construct the two vectors as defined in equation (5)-(7):

$$\vec{L} = (l_x - c_x) \hat{i} + (l_y - c_y) \hat{j} \quad (5)$$

$$\vec{T} = (t1_x - c_x) \hat{i} + (t1_y - c_y) \hat{j} \text{ -- with T1} \quad (6)$$

$$\vec{T} = (t2_x - c_x) \hat{i} + (t2_y - c_y) \hat{j} \text{ -- with T2} \quad (7)$$

Step6: Compute the magnitude of $\vec{L} \times \vec{T}$ as derived in equation (8) and (9):

$$\|\vec{L}\|\|\vec{T}\| \sin \theta \cong (l_x - c_x) (t1_y - c_y) - (l_y - c_y) (t1_x - c_x) \quad (8)$$

$$\|\vec{L}\|\|\vec{T}\| \sin \theta \cong (l_x - c_x) (t2_y - c_y) - (l_y - c_y) (t2_x - c_x) \quad (9)$$

$\sin \theta$ could be neglected since it does not have any impact on the sign of the magnitude

Step7: I) If computed magnitude in Step6 is +ve, the supplied runway label orientation of the line is correct. Capture into AMDB as it is.

II) If computed magnitude in Step6 is -ve, the supplied runway label orientation of the line is incorrect. Reverse the orientation and capture into AMDB.

The flow chart for rectifying runway label orientation is given in Appendix A.

III. EXPERIMENT AND RESULTS

Figure 13 shows two scenarios, before applying the method where the line orientation (arrow direction shows from first vertex to second vertex) with respect to the runway intersection and the text (in idp) with respect to the two threshold points (for the protecting runway) are incorrect. After applying the current method both (the line orientation and the text) are corrected which is shown in Figure 14.

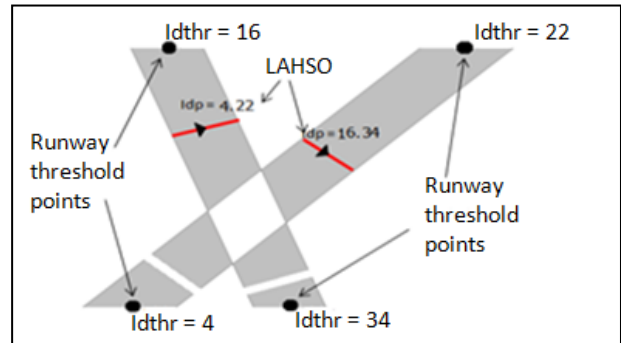


Fig.13 Sample LAHSO configuration before applying current method

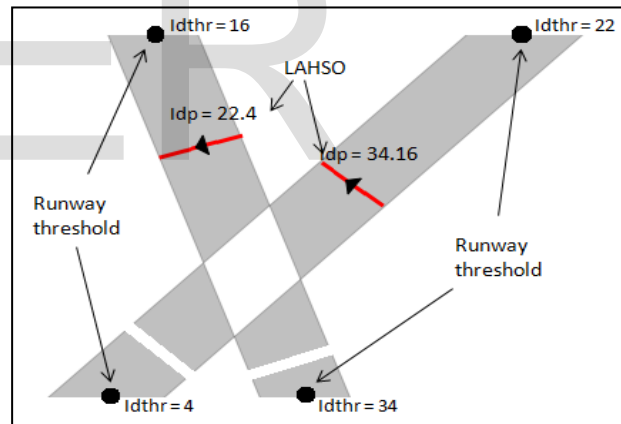


Fig.14 After applying current method

The result for this scenario is shown in Table II.

TABLE II RESULT OF THE SCENARIO

LAHSO	Line orientation (before)	Text (before)	Line orientation (after)	Text (after)
1	right to left	4.22	left to right	22.4
2	right to left	16.34	left to right	34.16

The current method has been applied to around 41 no. of LAHSOs and found working correctly. Table III shows the results of the method.

TABLE II RESULT OF THE METHOD

No. of LAHSO features	No. of LAHSO features with correct line orientation from supplier	No. of LAHSO features corrected for line orientation using the current method	No. of LAHSO features with correct text string from supplier	No. of LAHSO features corrected for text string using the current method
41	39	2	20	21

software only solution is unreliable to highlight taxiway from start to end seamlessly and correctly when pilot selects a Taxiway. This paper discusses an algorithm that enables us to achieve the twin objectives of highlighting the taxiway geometry correctly as well as making it visually pleasing.

IV. CONCLUSION

The objective of this research is to propose an automatic algorithm of rectifying the LAHSOs present in an airport. It constructs two vectors with key points from LAHSO, painted centerline, and runway threshold in order to apply the right hand thumb rule and to get the required result. Experimental results prove the algorithm is quite efficient and accurate.

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The goal of this paper is to provide a generic method to enable taxiway highlighting feature to appear correct and aesthetic at the same time in any Airport Moving Map (AMM) display application. Efforts like AMM are being made to increase aircraft flight crew situational awareness during ground operations. As part of this effort, a format for airport surface map databases has been developed that can be used to render airport surface maps on one or more flight deck displays. AMM helps orient the flight crew to the aircraft's positional information on the ground with respect to runways, taxiways, and airport structures, without paper chart reference. It is primarily intended to improve operator's safety and operational efficiency margins through improved positional awareness and reduced flight crew workload. AMM uses Airport Mapping Databases (AMDB) to create the airport layouts. AMDBs represent a collection of aerodrome information that is organized and arranged for ease of electronic storage and retrieval in systems that support aerodrome surface movements. Pilots are given provision to select and highlight features like Taxiways on an onboard display system. Since taxiways (and other features) are represented by arbitrary polygonal divisions in the AMDB,

Appendix B Flow chart for correcting the text string of LAHSO

