AIRSIDE CONSTRUCTION EQUIPMENT SCHEDULING METHOD BASED ON HIGH-RESOLUTION REMOTE SENSING, BEIDOU AND ELECTRONIC FENCE

[0001] This patent application claims the benefit and priority of Chinese Patent Application No. 202310364392.9 filed with the China National Intellectual Property Administration on April 7, 2023, entitled "Method for scheduling airside construction equipment based on high-resolution remote sensing, BeiDou and electronic fence", the disclosure of which is incorporated by reference herein in its entirety as part of the present application.

TECHNICAL FIELD

[0002] The present disclosure belongs to the field of airside construction data identification technology, and particularly relates to a method for scheduling airside construction equipment based on high-resolution remote sensing, BeiDou and electronic fence.

BACKGROUND

[0003] In the airside construction area during airport expansion, there are not only strict restrictions on the activity area of airside construction equipment, but also strict requirements on the construction height. The airside construction area will change accordingly during the suspension air and non-suspension phases; and the construction height will change accordingly at different locations within the airside construction area. For busy airports, the time window changes quickly, and coordination of manpower and resources from multiple parties are required to ensure the normal construction of the airside construction area, which may lead to delays and missed time windows.

[0004] With above analysis, the existing technology has following problems and defects:

[0005] (1) The existing technology does not utilize the Beidou positioning and electronic fence technology based on the high-resolution remote sensing base map to provide a basis for the safe operation of the airside construction equipment in the space of the airside limited area and height, which results in a low safety efficiency. At the same time, there is no timely alarm for informing the operator to adjust the position of the airside construction equipment and construction height in a timely manner when the construct equipment fails to meet requirements of operation space.

[0006] (2) The existing technology does not utilize the electronic fence area superimposed on the high-resolution remote sensing image for real-time visual display and warning of the working range in the actual scenario.

SUMMARY

[0007] In order to overcome the problems in the related technology, embodiments of the present disclosure provide a method for scheduling airside construction equipment based on high-resolution remote sensing, Beidou and electronic fence, which includes:

[0008] according to received airspace information for a normal situation and airspace information for an emergency situation, delimitating, by a system background, an electronic fence area in an airside construction area;

[0009] according to the electronic fence area, marking, by the system background, points in near runway centerline and far runway centerline;

[0010] calculating a normal construction height of airside construction equipment, where under the normal situation, a height limit area is an inward horizontal transition surface and an inward transition surface;

[0011] calculating an emergency construction height of the airside construction equipment, where, under the emergency situation, the height limit area is a general transition surface;

[0012] Superimposing the electronic fence area on a high-resolution image base map of an entire airport to determine whether the airside construction equipment is working in a safe activity area and within a safe height.

[0013] In one embodiment, the delimitating, by a system background, an electronic fence area in an airside construction area, including:

[0014] (I) in airport airside area, based on the normal situation and the emergency situation both, determining movable areas, including electronic fence area S1, electronic fence area S2 and electronic fence area S3, of the airside construction equipment;

[0015] (II) using a survey instrument to collect location information of boundary points of the movable area of the airside construction equipment, including point A in a far runway line, point B in the far runway line, point C in a turning point line between an inward horizontal transition surface and an inward transition surface, point D in the turning point line between the inward horizontal transition surface and the inward transition surface, point E in near runway line for emergency situation, point F in the near runway line for the emergency situation, point G in a near runway line for normal situation, and point H in the near runway line for the normal situation;

[0016] (III) the electronic fence area S1 including an area surrounded by the point A in the far runway line, the point B in the far runway line, the point C in the turning point line between the inward horizontal transition surface and the inward transition surface, and the point D in the turning point line between the inward horizontal transition surface and the inward transition surface; and the electronic fence area S2 including an area surrounded by the point C in the turning

point line between the inward horizontal transition surface and the inward transition surface, and the point D in the turning point line between the inward horizontal transition surface and the inward transition surface, the point E in the near runway line for the emergency situation, and the point F in the near runway line for the emergency situation; and the electronic fence area S3 including an area surrounded by the point E in the near runway line for the emergency situation, the point F in the near runway line for the emergency situation, the point G in the near runway line for the normal situation and the point H in the near runway line for the normal situation;

[0017] (IV) according to mapping information, generating the electronic fence area in the system background, where S123=S1+S2+S3 is the electronic fence area under the normal situation and S12=S1+S2 is the electronic fence area under the emergency situation;

[0018] (V) Switching among the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3 according to the normal situation and the emergency situation.

[0019] In one embodiment, the marking, by the system background, points in near runway centerline and far runway centerline, includes：

[0020] generating an electronic fence boundary line based on collected information of boundary points of an activity area of the airside construction equipment.

[0021] In one embodiment, generating the electronic fence boundary line includes: collecting, by the system background, latitudes and longitudes of four points of each of the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3, and then performing calculation on longitude and latitude of the airside construction equipment acquired in real time and reported longitudes and latitudes of the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3, and determining whether point O for the airside construction equipment is in the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3 or not.

[0022] In one embodiment, calculating the longitude and the latitude of the airside construction equipment acquired in real time and the reported longitudes and latitudes of the electronic fence area S1 and determine whether the point O for the airside construction equipment is in the electronic fence area S1 or not, includes: determining whether the point O for the airside construction equipment is in the electronic fence area S1 through the point B in the far runway line and the point C in the turning point line between the inward horizontal transition surface and the inward transition surface. In a case of a longitude and a latitude of the point B in the far runway line being (lon2, lat2), a longitude and a latitude of the point C in the turning point line between the inward horizontal transition surface and the inward transition surface being (lon3, lat3), and the latitude and longitude of the point O of the airside construction equipment being (lon0, lat0),

the determining whether the point O of the airside construction equipment is in the electronic fence area S1 by the point B in the far runway line and the point C in the turning point line between the inward horizontal transition surface and the inward transition surface includes:

[0023] the longitude of the point C in the turning point line between the inward horizontal transition surface and the inward transition surface lon3 - the longitude of the point O for the airside construction equipment lon0 > 0, and the latitude of the point C in turning point line between the inward horizontal transition surface and the inward transition surface lat3 - the latitude of the point O of the airside construction equipment lat0 > 0;

[0024] the longitude of the point O of the airside construction equipment lon0 - the longitude of the point B in the far runway line lon2 > 0, and the latitude of the point O for the airside construction equipment lat0 - the latitude of the point B in the far runway line lat2 > 0;

[0025] determining that the point O for the airside construction equipment is within the electronic fence area S1when four inequalities hold simultaneously.

[0026] In one embodiment, under the normal situation, calculating the normal construction height of the airside construction equipment includes:

[0027] step (1) obtaining S123=S1+S2+S3, which is the electronic fence area under the normal situation;

[0028] step (2) having the near runway line for the normal situation, the near runway line for the emergency situation, the turning point line, and the far runway line be all parallel to a runway centerline; and the near runway line for the normal situation being distanced at a known distance D3, from the near runway line for the emergency situation, and the near runway line for the emergency situation being distanced at a known distance D2, from the turning point line, and the turning point line being distanced at a known distance D1, from the far runway line;

[0029] step (3) calculating distance d3 from the point O for the airside construction equipment to the near runway line for the normal situation, and determining an area where the airside construction equipment is located; if the airside construction equipment is in the electronic fence area S1, then construction height being below H0; if the airside construction equipment is in the electronic fence area S2 and the electronic fence area S3, then construction height H1 being calculated according to principle of similar triangles;

[0030] obtaining lengths of OG, OH, and HG with the latitude and longitude (lon0, lat0) of the point O for the airside construction equipment and the latitude and longitude (lon7, lat7) of the point G in the near runway line for the normal situation, and the latitude and longitude (lon8, lat8) of the point H in the near runway line for the normal situation being known, and calculating d3 according to Helen's formula, which is expressed as follow:

[0031] $p = \frac{OG+OH+HG}{2}$

[0032] $d3 = \frac{2\sqrt{p(p-OG)(p-OH)(p-HG)}}{HG}$

[0033] where OG denotes a distance from the point O for the airside construction equipment to measurement point G; OH denotes a distance from the point O for the airside construction equipment to measurement point H; HG denotes a distance from the measurement point H to the measurement point G; p denotes a half of circumference of △OHG; d3 denotes a height on a side HG of the △OHG; and the △OHG is a triangle formed by the point O for the airside construction equipment, the measurement point G, and the measurement point H;

[0034] step (4) deducing an allowable construction height limit of the airside construction equipment in airside electronic fence area according to different locations;

[0035] step (5) determining whether the airside construction equipment meets operational requirements based on a height sensor mounted on a top of the airside construction equipment, and the allowable construction height limit deduced in step (4).

[0036] In step (4), under the normal situation, constructable airspace is an area below the inward horizontal transition surface and the inward transition surface; in response to a determination that the point O for the airside construction equipment is in the electronic fence area S1, a maximum construction height is H_{max}; and then whether the point O for the airside construction equipment is in an area S2 + S3 is determined; according to a principle of similar triangular computation, a height of the electronic fence area S2 and the electronic fence area S3 under the normal situation is calculated as follow:

[0037] $h1 = \frac{H \cdot d3}{D2+D3}$

[0038] where D3 denotes a distance from the near runway line for the normal situation to the near runway line for the emergency situation, which is a known distance; D2 denotes a distance from the near runway line for the emergency situation to the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; H denotes a height of the inward horizontal transition surface under the normal situation, which is a known height; d3 denotes a perpendicular distance from the point O for the airside construction equipment to the near runway line for the normal situation; and h1 denotes a maximum construction height of the airside construction equipment in the area S2+S3 at a distance of d3.

[0039] In one embodiment, under the emergency situation, calculating the emergency construction height of the airside construction equipment includes:

[0040] (i) obtaining S12=S1+S2, which is the electronic fence area in the emergency situation;

[0041] (ii) calculating a distance d2 from latitude and longitude (lon0, lat0) of the point O for the

airside construction equipment to the near runway line for the emergency situation, and calculating a construction height h2 based on principle of similar triangles; where an area below the general transition surface is constructable area under the emergency situation;

[0042] $p = \frac{OE+OF+EF}{2}$

[0043] $d2 = \frac{2\sqrt{p(p-OE)(p-OF)(p-EF)}}{EF}$

[0044] Where OE denotes a distance from the point O for the airside construction equipment to a measurement point E; OF denotes a distance from the point O for the airside construction equipment to a measurement point F; EF denotes a distance from the measurement point E to the measurement point F; p denotes a half of circumference of △OEF; d2 denotes a height on a side EF of △OEF; and the △OEF is a triangle formed by the point O for the airside construction equipment, the measurement point E, and the measurement point F;

[0045] (iii) deducing an allowable construction height limit of the airside construction equipment in the airside electronic fence area according to different locations;

[0046] (iv) determining whether the airside construction equipment meets the operational requirements based on a height sensor mounted on a top of the airside construction equipment and the allowable construction height limit deduced in step (iii).

[0047] In step (iii), a height of the area S1and S2 under the emergency situation is calculated as follow:

[0048] $h2 = \frac{H \cdot d2}{D1+D2}$;

[0049] where D1 indicates a distance from the far runway line to a turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; D2 indicates the distance between the near runway line for the emergency situation and the turning point line of the inward horizontal transition surface and the inward transition surface, which is a known distance; H indicates the height of the inward horizontal transition surface under the normal situation, which is a known height; and h2 indicates the maximum construction height of the airside construction equipment in the electronic fence area S1+S2 at a distance of d2.

[0050] Another object of the present disclosure is to provide an airside construction equipment control system based on BeiDou positioning and electronic fencing, which is used to implement the method for scheduling the airside construction equipment based on high-resolution remote sensing, BeiDou and electronic fence, the system comprises:

[0051] an electronic fence area delimitation module, configured to delimit, by a system background, an electronic fence area in an airside construction area according to received airspace information for a normal situation and airspace information for emergency situation;

[0052] a centerline point marking module, configured to mark, by the system background, points in near runway centerline and far runway centerline according to the electronic fence area;

[0053] a normal construction height calculation module, configured to calculate a normal construction height of airside construction equipment under the normal situation, where a height limit area is an inward horizontal transition surface;

[0054] an emergency construction height calculation module, configured to calculate an emergency construction height of the airside construction equipment under the emergency situation, where the height limit area is a general transition surface;

[0055] a safe construction height display module, configured to superimpose the electronic fence area on a high-resolution image base map of an entire airport to determine whether the airside construction equipment is working in a safe activity area and within a safe height.

[0056] In combination with all the technical solutions described above, the advantages and positive effects of the present disclosure are:

[0057] The present disclosure utilizes Beidou positioning and electronic fence technology based on a high-resolution remote sensing base map to enable the airside construction equipment to be operated in a space with a limited area and height on the airside, which reduces human operation and improves safety efficiency. At the same time, for the airside construction equipment that does not meet requirements of an operation space, it can inform the operator to adjust the position of the airside construction equipment and construction height in time through timely alarm. In the electronic fence area superimposed with high-resolution remote sensing image, it can assist managers to visualize the range of electronic fence in the actual scene, which is convenient for managers to make decisions.

[0058] Advantages of the present disclosure are also reflected in following aspects: the disclosure significantly saves airport personnel coordination costs and communication time, improves construction efficiency, and can be customized to suit the airport, which has significant economic benefits. In the existing technology, there is no method for applying the Beidou positioning and electronic fence technology based on the high-resolution remote sensing base map to schedule the airside construction equipment in the airside area of the airport yet, and the present disclosure supplements the relevant technical gaps. At present, airport construction is in a period of rapid development, there are both the opening of new airports and the reconstruction and expansion of existing airports. The airside construction is not attracted attention when demands are few. With the increase in the density of aircraft landing and taking off at airports, the present disclosure solves the pain point problem that the landing and taking off of aircraft is often affected due to airside construction equipment in the process of airport reconstruction and expansion, which has

significant ecological, economic and social benefits. The present disclosure achieves significant comprehensive benefits at a relatively small cost, which is a great progress in airport management.

BRIEF DESCRIPTION OF THE DRAWINGS

[0059] The accompanying drawings herein are incorporated into and form a part of the specification, which illustrate embodiments consistent with the present disclosure, and are used in conjunction with the specification to explain the principles of the present disclosure;

[0060] FIG. 1 is a flowchart of a method for scheduling the airside construction equipment based on high-resolution remote sensing, BeiDou and electronic fence according to embodiments of the present disclosure;

[0061] FIG. 2 is a schematic diagram of a cross-section of airspace height limit of a device according to an embodiment of the present disclosure;

[0062] FIG. 3 is a picture showing the effect of superimposing an electronic fence area onto a high resolution image base map of an entire airport according to embodiments of the present disclosure;

[0063] FIG. 4 is a schematic diagram of a method for scheduling the airside construction equipment based on high-resolution remote sensing, Beidou and electronic fence according to embodiments of the present disclosure; and

[0064] FIG. 5 is a schematic diagram of an airside construction equipment control system based on high-resolution remote sensing, BeiDou positioning and electronic fence according to an embodiment of the present disclosure.

[0065] In figures: 1, electronic fence area delimitation module; 2, centerline point marking module; 3, normal construction height calculation module; 4, emergency construction height calculation module; 5, safe construction height display module.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0066] In order to make the above objects, features and advantages of the present disclosure more obvious and understandable, the following description of specific embodiments of the present disclosure is given in detail in conjunction with the accompanying drawings. Many specific details are set forth in the following description in order to facilitate a full understanding of the present disclosure. However, the present disclosure is capable of being practiced in many other ways than those described herein, and those skilled in the art may make similar improvements without violating the connotations of the present disclosure, and therefore the present disclosure is not limited by the specific embodiments disclosed below.

[0067] In embodiment 1, as shown in FIG. 1, a method for scheduling an airside construction equipment based on high-resolution remote sensing, Beidou and electronic fence according to an embodiment of the present disclosure includes steps S101-S105.

[0068] In step S101, according to the received airspace information for a normal situation and airspace information for an emergency situation, a system background delimitates an electronic fence area in an airside construction area, which specifically includes:

[0069] (I) A movable area of the airside construction equipment is determined in airport airside area based on both normal situation and emergency situation.

[0070] As acknowledged, the airport tower usually receives emergency airspace information, for example, aircraft forced landing, balloons and flocks of birds in the airspace and other situations that affect the takeoff and landing of aircraft, and reacts to the emergency situation. Upon receipt of the airport emergency by the system, the electronic fence is switched.

[0071] (II) A survey instrument is used to collect the location information of the boundary points of the movable area of the airside construction equipment, including a point A with longitude and latitude coordinates of (lon1, lat1) in a far runway line, a point B with longitude and latitude coordinates of (lon2, lat2) in the far runway line, a point C with longitude and latitude coordinates of (lon3, lat3) in a turning point line between an inward horizontal transition surface and an inward transition surface, a point D with longitude and latitude coordinates of (lon4, lat4) in a turning point line between the inward horizontal transition surface and the inward transition surface, a point E with longitude and latitude coordinates of (lon5, lat5) in a near runway line for emergency situation, a point F with longitude and latitude of (lon6, lat6) in the near runway line for emergency situation, the point G with longitude and latitude coordinates of (lon7, lat7) in a near runway line for normal situation, and a point H with longitude and latitude coordinates of (lon8, lat8) in the near runway line for normal situation.

[0072] (III) Electronic fence area S1 is the area surrounded by four points: the point A (lon1, lat1) in the far runway line, the point B (lon2, lat2) in the far runway line, the point C (lon3, lat3) in the turning point line between the inward horizontal transition surface and the inward transition surface and the point D (lon4, lat4) in the turning point line of the inward horizontal transition surface and the inward transition surface. Electronic fence area S2 is the area surrounded by four points: the point C (lon3, lat3) in the turning point line between the inward horizontal transition surface and the inward transition surface, the point D (lon4, lat4) in the turning point line between the inward horizontal transition surface and the inward transition surface, the point E (lon5, lat5) in the near runway line for emergency situation, and the point F (lon6, lat6) in the near runway line for emergency situation. Electronic fence area S3 is the area surrounded by four points: the

point E (lon6, lat6) in the near runway line for emergency situation, the point F (lon6, lat6) in the near runway line for emergency situation, the point G (lon7, lat7) in the near runway line for normal situation, and the point H (lon8, lat8) in the near runway line for normal situation, as shown in Fig. 2 which illustrates a cross-section of airspace height limit of the device.

[0073] (IV) Based on the mapping information, the electronic fence area is generated in the system background, where S123=S1+S2+S3 is the electronic fence area for normal situation and S12=S1+S2 is the electronic fence area for the emergency situation.

[0074] (V) According to the different situations, different electronic fence areas may be switched on.

[0075] In step S102, according to the electronic fence area, the system background marks points in the near runway centerline and points in far runway centerline, which specifically includes steps 1 and 2.

[0076] In step 1, an electronic fence boundary line is generated based on the collected information of the boundary points of the airside construction equipment activity area.

[0077] The electronic fence is a virtual area, and the simpler the area is, the easier the calculation is. Small areas are generally drawn rectangle, and the airport belongs to the small area with a mall size. Exemplarily, a method for generating the electronic fence boundary line includes: collecting, by the system background, the latitude and longitude of four points in the rectangular area, and then performing calculation on the latitude and longitude of the airside construction equipment acquired in real time and the reported latitude and longitude of the rectangular area, where there are various calculation logics. Two-point localization method can be adopted, in which by taking the electronic fence area S1 (ABDC) in Fig. 2 as an example, it is determined whether point O with longitude and latitude coordinates of (lon0, lat0) at the airside construction equipment is in the electronic fence area S1 by the two points: the point B (lon2, lat2) and the point C (lon3, lat3), which is as follow in detail:

[0078] lon3-lon0>0, lat3-lat0>0;

[0079] lon0-lon2>0, lat0-lat2>0;

[0080] If all four inequalities hold simultaneously, it can be determined that the point O for the airside construction equipment is in the region, otherwise it is determined that the point O for the airside construction equipment is outside the region.

[0081] In step 2, points in the near runway centerline and far runway centerline are marked by the system background.

[0082] Exemplarily, the collected latitude and longitude are labeled in the system background, and the latitude and longitude close to the runway are labeled as near runway points, and the points

far away from the runway parallel line are labeled as far runway points. The so-called line is a virtual connecting line between two points.

[0083] In step S103, under normal situation, the normal construction height of the airside construction equipment is calculated, where the height limit area is the inward horizontal transition surface and the inward transition surface; which Specifically includes steps (1)-(5).

[0084] In step (1), in this case, the electronic fence area is S1+S2+S3.

[0085] In step (2), the near runway line for normal situation, the near runway line for emergency situation, the turning point line and the far runway line are all parallel to the runway centerline. And the near runway line for normal situation is distanced from the near runway line for emergency situation by a known interval of D3, the near runway line for emergency situation is distanced from the turning point line by a known interval of D2, and the turning point line is distanced from the far runway line by a known interval of D1.

[0086] In step (3), in this case, the distance d3 between the point O (lon0, lat0) for the airside construction equipment and the near runway line for normal situation is calculated, and the area in which the airside construction equipment is located is determined. If the airside construction equipment is in area S1, the construction height is below H0. If the airside construction equipment is in area S2 and S3, then the construction height H1 is calculated based on the principle of similar triangles.

[0087] Exemplarily, the lengths of OG, OH, and HG are known based on longitudes and latitudes of the point O (lon0, lat0) for the airside construction equipment ,the point G (lon7, lat7), and the point H (lon8, lat8), and the d3 may be calculated based on the Helen's formula, which is as follow:

[0088] $$p = \frac{OG+OH+HG}{2}$$

[0089] $$d3 = \frac{2\sqrt{p(p-OG)(p-OH)(p-HG)}}{HG}$$

[0090] where OG denotes the distance from the point O of the airside construction equipment to the measurement point G; OH denotes the distance from the point O of the airside construction equipment to the measurement point H; HG denotes the distance from the measurement point H to the measurement point G; p denotes a half of the circumference of △OHG; d3 denotes a height on the side HG of △OHG; and △OHG is a triangle formed by the point O for the airside construction equipment, the measurement point G, and the measurement point H.

[0091] Exemplarily, the area in which the airside construction equipment is located is determined based on the method for generating the electronic fence boundary line.

[0092] In step (4), the allowable construction height limit of the airside construction equipment in airside electronic fence area is deduced from various locations.

[0093] Exemplarily, under the normal situation, the constructable airspace is an area below the inward horizontal transition surface and the inward transition surface in FIG. 2. If the point O for the airside construction equipment is determined in the area S1, the maximum construction height is H_{max}. If the point O for the airside construction equipment is determined in the area S2+S3, according to the principle of similar triangle calculation, the maximum construction height of the areas S2 and S3 under the normal situation is calculated as follow:

[0094] $$h1 = \frac{H \cdot d3}{D2+D3}$$

[0095] It can be understood that the height within the area S2+S3 under the normal situation is within the range above D2+D3 and below the height of the inward transition surface. Where D3 denotes the distance from the near runway line for normal situation to the near runway line for emergency situation, which is a known distance; D2 denotes the distance from the near runway line for emergency situation to the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; H denotes the height of the inward horizontal transition surface under the normal situation, which is a known height; d3 denotes the perpendicular distance from the point O for the airside construction equipment to the near runway line for normal situation; and h1 denotes the maximum construction height of the airside construction equipment in the S2+S3 area at a distance of d3.

[0096] In step (5), based on the height sensor mounted on the top of the airside construction equipment and the allowable construction height limit obtained in step (4), whether the airside construction equipment meets the operational requirements is determined.

[0097] In step S104, in an emergency situation, the height limit area corresponds to a general transition surface, the emergency construction height of the airside construction equipment is calculated as follows.

[0098] In step (i), in this case, the electronic fence area is S1+S2.

[0099] In step (ii), the distance d2 from the point O with latitude and longitude coordinates of (lon0, lat0) for the airside construction equipment to the near runway line for emergency situation is calculated, and the construction height h2 is calculated based on the principle of similar triangles; where the area below the general transition surface is the constructable area under the emergency situation.

[0100] $$p = \frac{OE+OF+EF}{2}$$

[0101] $$d2 = \frac{2\sqrt{p(p-OE)(p-OF)(p-EF)}}{EF}$$

[0102] Where OE denotes the distance from the point O for the airside construction equipment to the measurement point E; OF denotes the distance from the point O for the airside construction

equipment to the measurement point F of; EF denotes the distance from the measurement point E to the measurement point F; p denotes one half of the circumference of △OEF; d2 denotes the height on the side EF of △OEF; and △OEF is the triangle formed by the point O for the airside construction equipment, the measurement point E, and the measurement point F.

[0103] In step (iii), the allowable construction height limit of the airside construction equipment in the airside electronic fence area is deduced from different locations.

[0104] The height of the areas S1 and S2 in an emergency situation is calculated as follow:

[0105] $h2 = \frac{H \cdot d2}{D1+D2}$

[0106] It can be understood that, in an emergency situation, the height within the area S1+S2 is in the range above D1+D2 and below the height of the general transition surface; where D1 denotes the distance from the far runway line to the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; D2 denotes the distance from the near runway line for emergency situation to the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; H indicates the height of the inward horizontal transition surface under the normal situation, which is a known height; and h2 indicates the maximum construction height of the airside construction equipment in the S1+S2 area at a distance of d2.

[0107] In step (iv), based on the height sensor mounted on the top of the airside construction equipment and the allowable construction height limit deduced in step (iii), whether the airside construction equipment meets the operational requirements is determined.

[0108] In step S105, high-resolution remote sensing application and airside construction equipment information feedback, specifically includes:

[0109] (a) superimposing the electronic fence area on high resolution image base map of entire airport in the system, whose effect is shown in Fig. 3;

[0110] (b) determining whether the airside construction equipment is working in a safe activity area and within a safe height by calculation in Step S103 or S104 according to different situations.

[0111] Exemplarily, the latitude and longitude coordinates of the point O of the airside construction equipment acquired in real time and the value of h0 monitored by the height sensor mounted on the top of the airside construction equipment are inputted into height calculation model for electronic fence areas S2 and S3 under normal situation, and the height calculation model of electronic fence areas S1 and S2 under emergency situation, and early warnings are provided for situations that the airside construction equipment is outside the construction area and has exceeded a height limit.

[0112] In embodiment 2, as shown in FIG. 4, a method for scheduling an airside construction

equipment based on high-resolution remote sensing, Beidou, and electronic fence according to an embodiment of the present disclosure includes:

[0113] receiving a command issued by the airdrome control tower in real time; where the command indicates that the airport stands in the emergency situation, or in a situation of construction with suspending air or shipping service, or in a situation of construction without suspending air or shipping service; and

[0114] switching the electronic fence and calculating the activity area of the airside construction equipment and height range of the airside construction equipment based on the command received.

[0115] The re-calculated activity area of the airside construction equipment and height range of the airside construction equipment are fed back to the control tower and to the operator of the airside construction equipment, so that whether the airside construction equipment is currently within the appropriate range is known in time.

[0116] In embodiment 3, as shown in FIG. 5, an airside construction equipment control system based on BeiDou positioning and electronic fence provided by an embodiment of the present disclosure, includes:

[0117] an electronic fence area delimitation module 1, configured to delimit, by the system background, the electronic fence area in the airside construction area according to the received airspace information for a normal situation and airspace information for an emergency situation;

[0118] a centerline point marking module 2, configured to mark, by the system background, points in near runway centerline and far runway centerline according to the electronic fence area;

[0119] a normal construction height calculation module 3, configured to calculate the normal construction height of airside construction equipment, where under the normal situation, the height limit area is an inward horizontal transition surface;

[0120] an emergency construction height calculation module 4, configured to calculate the emergency construction height of the airside construction equipment, where under the emergency situation, the height limit area is a general transition surface;

[0121] an safe construction height display module 5, configured to superimpose the electronic fence area on the high-resolution image base map of the entire airport to determine whether the airside construction equipment is working in a safe activity area and within a safe height.

[0122] In the above embodiments, the description of each embodiment has its own focus, and portions of an embodiment that are not detailed or documented in a particular embodiment can be found in the relevant descriptions of other embodiments.

[0123] The contents of the information interaction and execution process between the above devices/units, since they are based on the same concept as the method embodiments of the present

disclosure, the specific functions and technical effects brought about by them can be specifically referred to in the section of method embodiments, and will not be repeated herein.

[0124] It is clearly understood by the technical personnel in the field to which it belongs that, for the convenience and conciseness of the description, only the division of each functional unit and module described above is used as an example, and that, in actual application, it is possible to assign the above functions to be accomplished by different functional units and modules according to the needs, i.e., to divide the internal structure of the said device into different functional units or modules to accomplish all or part of the above-described functions. The functional units and modules in the embodiments can be integrated in a processing unit, or each unit can exist physically separately, or two or more units can be integrated in a unit, and the said integrated unit can be realized either in the form of hardware or in the form of a software functional unit. In addition, the specific names of the functional units and modules are only for the purpose of facilitating mutual differentiation and are not used to limit the scope of protection of the present disclosure. The specific working process of the units and modules in the above-described system can be referred to the corresponding process in the foregoing embodiment of the method.

[0125] Based on the technical solutions documented in the above embodiments of the present disclosure, the following application examples may further be proposed.

[0126] According to embodiments of the present application, the present disclosure also provides a computer device including: at least one processor, a memory, and a computer program stored in the memory and runnable on the at least one processor, the processor executing the computer program to realize the steps of any of the above respective method embodiments.

[0127] Embodiments of the present disclosure also provide a computer-readable storage medium, the computer-readable storage medium storing a computer program, the computer program being executable by a processor to realize the steps in each of the above method embodiments.

[0128] Embodiments of the present disclosure also provide an information data processing terminal, the information data processing terminal being used to realize, when executed on an electronic device, the provision of a user input interface to carry out steps such as those in each of the above mentioned embodiments of the method, the information data processing terminal not being limited to a cellular phone, a computer, a switch.

[0129] Embodiments of the present disclosure also provide a server, the server being used to , when executed on an electronic device, to provide a user input interface to carry out steps such as those in each of the method embodiments described above.

[0130] Embodiments of the present disclosure also provide a computer program product that, when the computer program product runs on an electronic device, causes the electronic device to

execute in such a way that the steps in each of the above method embodiments can be realized.

[0131] The integrated unit may be stored in a computer-readable storage medium if implemented as a software functional unit and sold or used as a stand-alone product. Based on this understanding, the present application realizes all or part of the processes in the methods of the above embodiments, which may be accomplished through the relevant hardware instructed by a computer program, the computer program, stored in a computer-readable storage medium, realizes the steps of each of the above method embodiments when executed by a processor. Where the computer program comprises computer program code, the computer program code may be in the form of source code, in the form of object code, in the form of an executable file or in some intermediate form, and the like. The computer readable medium may at least comprise: any entity or device capable of carrying computer program code to a photo device/terminal apparatus, a recording medium, a computer memory, a Read-Only Memory (ROM), a Random Access Memory (RAM), an electric carrier signal, a telecommunication signal, and a Software distribution media. Examples include USB flash drives, removable hard drives, disks, or CD-ROMs.

[0132] The foregoing is only a preferred specific embodiment of the present disclosure, but the scope of protection of the present disclosure is not limited thereto, and any modifications, equivalent replacements, improvements, etc., made by any skilled person familiar with the technical field within the scope of the technology disclosed herein and within the spirit and principles of the present disclosure shall be covered within the scope of protection of the present disclosure.

WHAT IS CLAIMED IS:

1. A method for scheduling airside construction equipment based on high-resolution remote sensing, Beidou, and electronic fence, comprising:

according to received airspace information for a normal situation and airspace information for an emergency situation, delimitating, by a system background, an electronic fence area in an airside construction area;

according to the electronic fence area, marking, by the system background, points in near runway centerline and far runway centerline;

calculating a normal construction height of airside construction equipment, wherein under the normal situation, a height limit area is an inward horizontal transition surface and an inward transition surface;

calculating an emergency construction height of the airside construction equipment, wherein under the emergency situation, the height limit area is a general transition surface;

superimposing the electronic fence area on a high-resolution image base map of an entire airport to determine whether the airside construction equipment is working in a safe activity area and within a safe height.

2. The method according to claim 1, the delimitating, by a system background, an electronic fence area in an airside construction area, comprises:

(I) in airport airside area, based on the normal situation and the emergency situation both, determining movable areas, comprising electronic fencing area S1, electronic fencing area S2 and electronic fencing area S3, of the airside construction equipment;

(II) using a survey instrument to collect location information of boundary points of the movable area of the airside construction equipment, including point A in a far runway line, point B in the far runway line, point C in a turning point line between an inward horizontal transition surface and an inward transition surface, point D in the turning point line between the inward horizontal transition surface and the inward transition surface, point E in emergency-situation near runway line, point F in the emergency-situation near runway line, point G in a normal-situation near runway line, and point H in the normal-situation near runway line;

(III) the electronic fence area S1 comprising an area surrounded by the point A in the far runway line, the point B in the far runway line, the point C in the turning point line between the inward horizontal transition surface and the inward transition surface, and the point D in the turning point line between the inward horizontal transition surface and the inward transition surface; and the electronic fence area S2 including an area surrounded by the point C in the turning

point line between the inward horizontal transition surface and the inward transition surface, and the point D in the turning point line between the inward horizontal transition surface and the inward transition surface, the point E in the emergency-situation near runway line, and the point F in the emergency-situation near runway line; and the electronic fence area S3 including an area surrounded by the point E in the emergency-situation near runway line, the point F in the emergency-situation near runway line, the point G in the normal-situation near runway line and the point H in the normal-situation near runway line;

(IV) based on mapping information, generating the electronic fence area in the system background, wherein S123 = S1 + S2 + S3 is the electronic fence area under the normal situation, S12 = S1 + S2 is the electronic fence area under the emergency situation;

(V) switching among the electronic fence area S1, electronic fence area S2, and electronic fence area S3 according to the normal situation and the emergency situation.

3. The method according to claim 1, the marking, by the system background, points in near runway centerline and far runway centerline, comprises:

generating an electronic fence boundary line based on collected information of boundary points of an activity area of the airside construction equipment.

4 .The method according to claim 3, the generating an electronic fence boundary line comprises:

collecting, by the system background, latitudes and longitudes of four points of each of the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3; and then performing calculation on latitudes and longitudes of the airside construction equipment acquired in real time and reported latitudes and longitudes of the electronic fence area S1, the electronic fence area S2, and the electronic fence area S3, and determining whether point O for the airside construction equipment is in the electronic fence area S1, electronic fence area S2, electronic fence area S3 or not.

5. The method according to claim 4, performing calculation on the latitude and the longitude of the airside construction equipment acquired in real time and the reported latitudes and longitudes of the electronic fence area S1, and determining whether the point O for the airside construction equipment is in the electronic fence area S1 or not, comprises:

determining whether the point O for the airside construction equipment is in the electronic fence area S1 through the point B in the far runway line and the point C in the turning point line between the inward horizontal transition surface and the inward transition surface, wherein a latitude and a longitude of the point B in the far runway line is (lon2, lat2), a latitude and a longitude of the point C in the turning point line between the inward horizontal transition surface and the inward transition surface is (lon3, lat3), and the latitude and the longitude of the point O

of the airside construction equipment is (lon0, lat0).

6. The method according to claim 5, the determining whether the point O for the airside construction equipment is in the electronic fencing area S1 comprises:

the longitude of the point C in the turning point line between the inward horizontal transition surface and the inward transition surface lon3 – the longitude of the point O for the airside construction equipment lon0>0, and the latitude of the point C in turning point line between the inward horizontal transition surface and the inward transition surface lat3 – the latitude of the point O of the airside construction equipment lat0>0;

the longitude of the point O of the airside construction equipment lon0 – the longitude of the point B in the far runway line lon2>0, the latitude of the point O for the airside construction equipment lat0 – the latitude of the point B in the far runway line lat2>0;

determining that the point O for the airside construction equipment is within the electronic fence area S1 when four inequalities hold simultaneously.

7. The method according to claim 1, under the normal situation, calculating the normal construction height of the airside construction equipment, comprises:

step (1), obtaining S123=S1+S2+S3, which is the electronic fence area under the normal situation;

step (2), having the normal-situation near runway line, the emergency-situation near runway line, the turning point line, and the far runway line be all parallel to a runway centerline; and the normal-situation near runway line being distanced at a known distance D3, from the emergency-situation near runway line, the emergency-situation near runway line being distanced at a known distance D2, from the turning point line, and the turning point line being distanced at a known distance D1, from the far runway line;

step (3), calculating distance d3 from the point O for the airside construction equipment to the normal-situation near runway line, and determining an area where the airside construction equipment is located; if the airside construction equipment is in the electronic fence area S1, the construction height being below H0; if the airside construction equipment is in the electronic fence area S2 and the electronic fence area S3, then the construction height H1 being calculated according to principle of similar triangles;

obtaining lengths of OG, OH, and HG with the latitude and longitude (lon0, lat0) of the point O for the airside construction equipment and the latitude and longitude (lon7, lat7) of the point G in the normal-situation near runway line, and the latitude and longitude (lon8, lat8) of the point H in the normal-situation near runway line being known, and calculating d3 according to Helen's formula which is expressed as follow:

$$p = \frac{OG + OH + HG}{2}$$

$$d3 = \frac{2\sqrt{p(p - OG)(p - OH)(p - HG)}}{HG}$$

wherein OG denotes a distance from the point O for the airside construction equipment to measurement point G ; OH denotes a distance from the point O for the airside construction equipment to measurement point H; HG denotes a distance from the measurement point H to the measurement point G; p denotes a half of a circumference of △OHG; d3 denotes a height on a side HG of the △OHG; and the △OHG is a triangle formed by the point O for the airside construction equipment, the measurement point G, and the measurement point H;

step (4), deducing an allowable construction height limit of the airside construction equipment in airside electronic fence area according to different locations;

step (5), determining whether the airside construction equipment meets operational requirements based on a height sensor mounted on a top of the airside construction equipment, and the allowable construction height limit deduced in step (4).

8. The method according to claim 7, in step (4), under the normal situation, constructable airspace is an area below the inward horizontal transition surface and the inward transition surface; in response to a determination that the point O for the airside construction equipment is in the electronic fence area S1, a maximum construction height is H_{max}; and whether the point O for the airside construction equipment is in an area S2 + S3 is determined; according to a principle of similar triangle calculation, a height of the electronic fence area S2 and the electronic fence area S3 under the normal situation is calculated as follow:

$$h1 = \frac{H \cdot d3}{D2 + D3}$$

where D3 denotes a distance from the normal-situation near-runway line to the emergency-situation near-runway line, which is a known distance; D2 denotes a distance from the emergency-situation near-runway line to the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; H denotes a height of the inward horizontal transition surface under the normal situation, which is a known height; d3 denotes a perpendicular distance from the point O for the airside construction equipment to the normal-situation near runway line; and h1 denotes a maximum construction height of the airside construction equipment in the area S2+S3 at a distance of d3.

9. The method according to claim 1, under the emergency situation, calculating the emergency construction height of the airside construction equipment, comprises:

(i) obtaining S12=S1+S2, which is the electronic fence area in the emergency situation;

(ii) calculating a distance d2 from latitude and longitude (lon0, lat0) of point O for the airside construction equipment to an emergency-situation near runway line, and calculating a construction height h2 based on principle of similar triangles; wherein an area below the general transition surface is constructable area under the emergency situation;

$$p = \frac{OE + OF + EF}{2}$$

$$d2 = \frac{2\sqrt{p(p - OE)(p - OF)(p - EF)}}{EF}$$

wherein OE denotes a distance from the point O for the airside construction equipment to a measurement point E; OF denotes a distance from the point O for the airside construction equipment to a measurement point F; EF denotes a distance from the measurement point E to the measurement point F; p denotes a half of circumference of △OEF; d2 denotes a height on a side EF of the △OEF; and the △OEF is a triangle formed by the point O for the airside construction equipment, the measurement point E, and the measurement point F;

(iii) deducing an allowable construction height limit of the airside construction equipment in the airside electronic fence area according to different locations;

(iv) determining whether the airside construction equipment meets operational requirements based on a height sensor mounted on a top of the airside construction equipment and the allowable construction height limit deduced in step (iii).

10. The method according to claim 9, in the step (iii), a height of the areas S1 and S2 under the emergency situation is calculated as follow:

$$h2 = \frac{H \cdot d2}{D1 + D2}$$

where D1 indicates a distance between the far runway line and the turning point line between the inward horizontal transition surface and the inward transition surface, which is a known distance; D2 indicates a distance between an emergency-situation near runway line and a turning point line of the inward horizontal transition surface and the inward transition surface, which is a known distance; H indicates a height of the inward horizontal transition surface under the normal situation, which is a known height; and h2 indicates a maximum construction height of the airside construction equipment in the electronic fence area S1+S2 at a distance of d2.