

SPACE DEBRIS COLLISION AVOIDANCE METHOD AND APPARATUS TAKING INTO ACCOUNT ORBIT ALTITUDE ADJUSTMENT TASK

TECHNICAL FIELD

[0001] The disclosure belongs to the field of spacecraft control, and specifically relates to a space debris collision avoidance method and apparatus taking into account a task of orbit altitude adjustment.

BACKGROUND

[0002] Space debris is space junk generated by human space activities. With the increasing frequency of space activities, the number of space debris has increased rapidly, which has posed a serious threat to the safety of human space assets and is a major challenge for human space activities. According to the U.S. Earth orbit in 2016, the number of space debris with a size of more than 10 cm has reached 23,000, the number of debris with a size of 1 to 10 cm is about 500,000, the number of debris with a size of 1 to 10 mm is about 100 million, and the number of debris below 1 mm is tens of billions.

[0003] For space debris above 10 cm, its impact on the spacecraft may cause explosion, disintegration, and completely failure of the spacecraft. However, the orbit of such debris above 10 cm may be monitored, therefore, the collision risk created by such debris may be avoided by changing the orbit of the spacecraft. However, avoiding the risk of collision by changing the orbit of the spacecraft requires the use of valuable spacecraft orbit change propellant resources. For example, the International Space Station consumes about 30kg of propellant each time when implementing the avoidance control.

[0004] Usually, the propellant carried by the spacecraft is mainly used to ensure that the spacecraft runs on its target orbit. When the spacecraft deviates from its designed mission orbit due to various perturbation factors, or when the spacecraft needs to be adjusted to another mission orbit during the flight, this goal may be achieved by implementing the orbit control. For example, in order to overcome the lowering of the orbit of the low-orbit satellite caused by atmospheric damping, it is usually necessary to regularly raise the orbit altitude to maintain the normal operation of the spacecraft. Or, a remote sensing mission needs to be carried out in

another area after completing the earth remote sensing in a specific area, this may be achieved by changing the operating cycle of the spacecraft to adjust its sub-satellite point trajectory. If space debris collision avoidance is only for avoiding the collision of space debris without considering requirements of the mission target orbit of the spacecraft during subsequent flight, a large amount of propellant will inevitably be consumed additionally, and the operating efficiency of the spacecraft will be greatly reduced.

[0005] The information disclosed in the Background section of the application is intended only to enhance the understanding of the background of the present application, and thus should not be construed as an acknowledgment or implication in any way that the information constitutes prior art that is already known to those skilled in the art.

SUMMARY

[0006] The purpose of the embodiments of the present disclosure is to provide a space debris collision avoidance method and apparatus taking into account the task of orbit altitude adjustment, which may solve the problem of wasting propellant and reducing the operating efficiency of the spacecraft in the current space debris avoidance schemes.

[0007] In order to solve the above technical problems, the present disclosure is implemented as follows.

[0008] In a first aspect, embodiments of the present disclosure provide a space debris collision avoidance method taking into account a task of orbit altitude adjustment, including:

[0009] acquiring a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement; and

[0010] controlling the spacecraft with a target control strategy at a second moment, in a case that the collision risk value at a first moment within the target time period is greater than a preset value,

[0011] wherein the second moment is earlier than the first moment;

[0012] wherein the target strategy includes at least one of the following:

[0013] increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control.

[0014] Optionally, before acquiring the collision risk value of the spacecraft and space debris within the target time period, the method further includes:

[0015] acquiring an orbit control strategy corresponding to the continuous orbit change requirement in a case that the spacecraft has the continuous orbit change requirement, and acquiring an orbit control ephemeris forecast based on an orbit determination result in the orbit control strategy;

[0016] wherein acquiring the collision risk value of the spacecraft and space debris within the target time period includes:

[0017] acquiring the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data.

[0018] Optionally, controlling the spacecraft with the target control strategy at the second moment includes:

[0019] determining a target factor based on the first moment;

[0020] determining a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

[0021] executing the target control strategy for the target orbit control arc segment.

[0022] Optionally, after determining the target orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, and before executing the target control strategy for the target orbit control arc segment, the method further includes:

[0023] re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

[0024] executing the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

[0025] re-determining an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

[0026] Optionally, the combining avoidance control includes at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of

times of orbit control, reducing the number of times of orbit control, before controlling the spacecraft with the target control strategy at the second moment, the method further includes:

[0027] determining a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

[0028] re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

[0029] determining the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.

[0030] In a second aspect, embodiments of the present disclosure provide a space debris collision avoidance apparatus taking into account a task of orbit altitude adjustment, including:

[0031] a first acquisition module, configured to acquire a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement; and

[0032] a control module, configured to control the spacecraft with a target control strategy at a second moment, in a case that the collision risk value at a first moment within the target time period is greater than a preset value,

[0033] wherein the second moment is earlier than the first moment;

[0034] wherein the target strategy includes at least one of the following:

[0035] increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control.

[0036] Optionally, the space debris collision avoidance apparatus taking into account the task of orbit altitude adjustment further includes:

[0037] a second acquisition module, configured to acquire an orbit control strategy corresponding to the continuous orbit change requirement in a case that the spacecraft has the continuous orbit change requirement, and acquire an orbit control ephemeris forecast based on an orbit determination result in the orbit control strategy;

[0038] wherein the first determination module is configured to acquire the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data.

[0039] Optionally, the control module further includes:

[0040] a first sub-module, configured to determine a target factor based on the first moment;

[0041] a second sub-module, configured to determine a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

[0042] a third sub-module, configured to execute the target control strategy for the target orbit control arc segment.

[0043] Optionally, the space debris collision avoidance apparatus taking into account the task of orbit altitude adjustment further includes: a first determination module, configured to re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

[0044] wherein the control module further includes a fourth sub-module, configured to execute the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

[0045] re-determine an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

[0046] Optionally, the combining avoidance control includes at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, reducing the number of times of orbit control, the space debris collision avoidance apparatus taking into account the task of orbit altitude adjustment further includes:

[0047] a second determination module, configured to determine a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

[0048] re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

[0049] determine the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.

[0050] In embodiments of the present disclosure, in a case that the spacecraft has a continuous orbit change requirement, a collision risk value of a spacecraft and space debris within a target time period is acquired, and in a case that the collision risk value at a first moment within the target time period is greater than a preset value, the spacecraft is controlled with a target control strategy at a second moment, wherein the second moment is earlier than the first moment, the target strategy includes at least one of the following: increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control. The continuous orbit change requirement of the spacecraft is taken into consideration in the scheme of avoiding the collision of space debris, and the continuous orbit change parameter is taken into consideration when determining the control strategy, which may simultaneously take into account the continuous orbit change mission of the spacecraft and avoid the collision of the spacecraft and space debris, reduce the propellant used for separate orbit change control for avoiding space debris collision, and improve the operating efficiency of the spacecraft.

BRIEF DESCRIPTION OF THE DRAWINGS

[0051] FIG. 1 is a schematic flow chart of a space debris collision avoidance method taking into account a task of orbit altitude adjustment provided by an embodiment of the present disclosure; and

[0052] FIG. 2 is a schematic structural diagram of a space debris collision avoidance apparatus taking into account a task of orbit altitude adjustment provided by an embodiment of the present disclosure.

[0053] The implementation of the purposes, functional features and advantages of the present disclosure will be further described with reference to the embodiments and the accompanying drawings.

DETAILED DESCRIPTION

[0054] In order to make the purposes, technical solutions and advantages of the present disclosure clearer, the technical solutions in the embodiments of the present disclosure will be clearly and completely described below with reference to the accompanying drawings in the embodiments of the present disclosure. The described embodiments are some embodiments of the present disclosure, rather than all embodiments. Based on the embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without making creative efforts fall within the scope of protection of the present disclosure.

[0055] The terms “first”, “second”, etc. in the description and claims of the present disclosure are used to distinguish similar objects, and are not used to describe a specific order or sequence. It should be understood that such used data are interchangeable under appropriate circumstances, so that embodiments of the disclosure may be implemented in sequences other than those illustrated or described herein. Besides, objects distinguished by “first,” “second,” etc. are usually of one type, and the number of the objects is not limited. For example, the first object may be one or plural.

[0056] The space debris collision avoidance method taking into account a task of orbit altitude adjustment provided by embodiments of the present disclosure will be described in detail below with reference to the accompanying drawings through specific embodiments and application scenarios. The following specific embodiments may be combined with each other, and the same or similar concepts or processes may not be described again in some embodiments.

[0057] Embodiment 1

[0058] Referring to FIG. 1, it is a schematic flow chart of a space debris collision avoidance method taking into account a task of orbit altitude adjustment provided by an embodiment of the present disclosure.

[0059] The space debris collision avoidance method taking into account a task of orbit altitude adjustment provided by the present disclosure includes following steps.

[0060] S101, in a case that the spacecraft has a continuous orbit change requirement, a collision risk value of a spacecraft and space debris within a target time period is acquired.

[0061] It should be noted that the orbit of debris of a certain size in space, such as debris above 10cm, may be monitored. In one possible implementation, the collision risk value of the

spacecraft and the space debris is determined by comparing the orbit of the space debris within the target time period with the orbit of the spacecraft within the target time period. For example, the risk value is divided into 0-10, i.e., 10 levels. If the orbit of the spacecraft coincides with the orbit of the space debris, the risk value is considered to be level 10. If the orbit of the spacecraft and the orbit of the space debris are close to a preset distance, the risk value is considered to be level 5. If the distance between the orbit of the spacecraft and the orbit of the space debris is much greater than the preset value, the risk value is considered to be level 0.

[0062] In this embodiment, the target time period is a period of time in the future. The time period may be set by the staff or determined by the history condition of the spacecraft. For example, according to the history record of the spacecraft, it is found that the spacecraft performs the orbit change control to avoid the space debris collision every five days, then the target time period may be set as five days.

[0063] In this embodiment, the continuous orbit change requirement of the spacecraft may be the continuous orbit change operation required for the tasks performed by the spacecraft. For example, the continuous orbit change requirement is the orbit altitude adjustment task, such as the daily routine control process of lowering orbit of the spacecraft (active orbit lowering mission), the normal control process of raising orbit of the spacecraft for overcoming atmospheric damping attenuation (orbit altitude maintenance, that is, irregular orbit raising missions), etc., which is not limited by this embodiment herein.

[0064] S102, in a case that the collision risk value at a first moment within the target time period is greater than a preset value, the spacecraft is controlled with a target control strategy at a second moment.

[0065] The second moment is earlier than the first moment;

[0066] In this embodiment, the collision risk value needs to be determined at every moment within the target time period. When it is found that the spacecraft would have a high risk of collision with space debris at a certain moment in the future (i.e., the first moment), a target control strategy is determined, and the spacecraft is controlled with the target control strategy at the second moment.

[0067] In this embodiment, the second moment needs to be earlier than the first moment. The first moment is the calculated collision moment of the spacecraft and the space

debris. Therefore, the control of the spacecraft needs to be carried out before the collision event occurs, thereby changing the trajectory of the spacecraft, to avoid the collision with space debris. For example, in the orbit altitude maintenance (irregular orbit raising) mission, based on factors such as the imaging resolution and camera focal length of the remote sensing satellite, the satellite needs to fix an altitude range, such as 480 km -520km. Due to the effect of space atmospheric resistance, the satellite orbit altitude attenuates, the orbit needs to be raised irregularly. During the operation of the satellite, it is found that there would be a collision warning on the third day through conventional calculation, therefore, the collision needs to be avoided, and the avoidance may be upward or downward. However, combined with the mission of raising the orbit in the future, for example, on the tenth day, the orbit may be raised on the second day, which avoids the collision warning on the third day and also meeting the task of raising the orbit.

[0068] The target strategy in this application includes at least one of the following: increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control.

[0069] It should be noted that, the target strategy in this application is formulated based on the continuous orbit change requirement.

[0070] A certain experimental satellite mission is taken as an example, after the satellite is put into orbit, it needs to be lowered from an orbit altitude of approximately 1,000km to a target orbit of approximately 800km. However, during the daily routine control process of lowering the orbit, it is found that the satellite would be at risk of colliding with some space debris on the second day if the satellite was controlled to lower the orbit as scheduled. At this time, the control strategy of reducing the amount of orbit control may be adopted, and the orbit lowering control strategy of the current day is adjusted, which reduces the amount of orbit control. In this way, the collision risk on the second day is reduced beyond the collision risk threshold, thereby avoiding the collision risk. Similarly, during the normal controlling process of the low-orbit satellite of raising orbit for overcoming atmospheric damping attenuation, it is predicted that there would be a risk of collision with space debris on the second day, and at the same time, the current orbit was already in a state where it had to be raised as soon as possible.

At this time, the control strategy of increasing the amount of orbit control may be adopted, so the control amount of the raising the orbit is increased. On the one hand, it avoids the collision risk of space debris on the second day, and at the same time, it may maintain a longer period of time without raising the orbit due to increasing the control amount of the raising the orbit. Meanwhile, it may also satisfy that the orbit altitude within a time period meets the acceptable altitude range of the mission target orbit.

[0071] In another embodiment, during the orbit change mission of the satellite, the original control strategy is to perform lowering the orbit once that day. However, in order to avoid a collision event on the second day, the number of times of lowering the orbit today is increased, to allow the satellite to reach a lower altitude, to change the trajectory and avoid the collision event. Similar embodiments include reducing the number of times of orbit control and combining avoidance control, etc., which is not limited by this embodiment herein.

[0072] In embodiments of the present disclosure, in a case that the spacecraft has a continuous orbit change requirement, a collision risk value of a spacecraft and space debris within a target time period is acquired, and in a case that the collision risk value at a first moment within the target time period is greater than a preset value, the spacecraft is controlled with a target control strategy at a second moment, wherein the second moment is earlier than the first moment, the target strategy includes at least one of the following: increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control. The continuous orbit change requirement of the spacecraft is taken into consideration in the scheme of avoiding the collision of space debris, and the continuous orbit change parameter is taken into consideration when determining the control strategy, which may simultaneously take into account the continuous orbit change mission of the spacecraft and avoid the collision of the spacecraft and space debris, reduce the propellant used for separate orbit change control for avoiding space debris collision, and improve the operating efficiency of the spacecraft.

[0073] In a possible implementation, before step S102, step 103 is further included.

[0074] S103, in a case that the spacecraft has the continuous orbit change requirement, an orbit control strategy corresponding to the continuous orbit change requirement is acquired, and an orbit control ephemeris forecast is acquired based on an orbit determination result in

the orbit control strategy.

[0075] When the spacecraft has a continuous orbit change requirement, continuous orbit change planning needs to be carried out, to obtain a control strategy for a number of times of orbit control, and an orbit control ephemeris forecast is performed based on the orbit determination result.

[0076] Step 101 specifically includes: acquiring the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data.

[0077] Optionally, the orbit control ephemeris forecast and space target data are used to perform the collision avoidance calculation, and the risk of collision is determined based on the intersection distance and collision probability.

[0078] The collision risk value herein includes the collision probability of the spacecraft and the space debris or the intersection distance of the spacecraft and the space debris. At this time, the collision risk value being greater than the preset value includes that the collision probability is greater than the first preset value or the intersection distance is less than the second preset value.

[0079] When the collision risk value is evaluated, only the collision probability of the spacecraft and space debris may be considered. For example, the first preset value is 10^{-4} , that is, when the collision probability of the spacecraft and space debris is greater than 10^{-4} , it is considered that the collision risk value exceeds the threshold, and orbit control is required. Alternatively, when the collision risk value is evaluated, only the intersection distance of the spacecraft and the space debris may be considered. For example, the second preset value is 200m. When the distance between the spacecraft and the space debris is less than 200m, it is considered that the collision risk exceeds the threshold, and orbit control is required. Alternatively, both the collision probability and intersection distance may be considered at the same time, and weights may be set for judgment, to improve the accuracy of judgment of the collision risk value.

[0080] In a possible implementation, step 102 may be performed through steps 1021-1023:

[0081] S1021, determining a target factor based on the first moment;

[0082] S1022, determining a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

[0083] S1023, executing the target control strategy for the target orbit control arc segment.

[0084] Specifically, push backwards from the first moment (that is, the theoretical collision moment with the space debris) and search for the orbit control arc segment that may be controlled based on constraints such as measurement and control, lighting, and energy. The target control strategy is performed for the orbit control arc segment.

[0085] In a possible implementation, after step 1022 and before step 1023, steps 1024-1025 may be performed:

[0086] S1024, re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

[0087] S1025, executing the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

[0088] re-determining an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

[0089] Specifically, after searching for the orbit control arc segment that may be controlled, the orbit control strategy after executing the target control strategy is updated, and the orbit control ephemeris forecast is recalculated for collision avoidance calculation, to determine whether the collision risk has been eliminated. If the risk has been eliminated, the latest avoidance strategy is integrated to guide the actual avoidance implementation. Otherwise, return to the strategy formulation and continue to look for the arc segment that may be orbit controlled.

[0090] The strategy of increasing the control amount is taken as an example. Push backwards from the theoretical collision moment, search for the orbit control arc segment that may increase the control amount based on constraints such as measurement and control, lighting, and energy. The orbit control strategy after increasing the amount of orbit control is

updated, and the orbit control ephemeris forecast is recalculated for collision avoidance calculation, to determine whether the collision risk has been eliminated. If the risk has been eliminated, the latest avoidance strategy is integrated to guide the actual avoidance implementation. Otherwise, return to the strategy formulation and continue to look for the arc segment that may increase the amount of control.

[0091] In a possible implementation, the combining avoidance control includes at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, reducing the number of times of orbit control. Before step 102, step 104 is further included:

[0092] S104: determining a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

[0093] re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

[0094] determining the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.

[0095] Specifically, increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control and reducing the number of times of orbit control are single-mode avoidance strategies. The combining avoidance control is a multi-mode strategy formulation. For the multi-mode strategy formulation, a variety of options are added on the basis of the single mode, which may combine increasing the amount of control at a certain time, reducing the amount of control at a certain time, increasing the number of times of orbit control, and reducing the number of times of orbit control, etc., and combine to correct and change the orbit of the spacecraft, thereby achieving the purpose of avoiding the collision risk. For formulation of the multi-mode combining avoidance strategy, when a single mode cannot eliminate the risk of collision, the use of combining avoidance mode is considered to formulate the avoidance strategy.

- [0096]** Embodiment 2
- [0097]** Referring to FIG. 2 it is a schematic structural diagram of a space debris collision avoidance apparatus 20 taking into account a task of orbit altitude adjustment provided by an embodiment of the present disclosure, including:
- [0098]** a first acquisition module 201, configured to acquire a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement; and
- [0099]** a control module 202, configured to control the spacecraft with a target control strategy at a second moment, in a case that the collision risk value at a first moment within the target time period is greater than a preset value,
- [00100]** wherein the second moment is earlier than the first moment;
- [00101]** wherein the target strategy includes at least one of the following:
- [00102]** increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control.
- [00103]** Optionally, the space debris collision avoidance apparatus 20 taking into account the task of orbit altitude adjustment further includes:
- [00104]** a second acquisition module 203, configured to acquire an orbit control strategy corresponding to the continuous orbit change requirement in a case that the spacecraft has the continuous orbit change requirement, and acquire an orbit control ephemeris forecast based on an orbit determination result in the orbit control strategy;
- [00105]** wherein the first determination module 201 is configured to acquire the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data.
- [00106]** Optionally, the control module 202 further includes:
- [00107]** a first sub-module 2021, configured to determine a target factor based on the first moment;
- [00108]** a second sub-module 2022, configured to determine a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

[00109] a third sub-module 2023, configured to execute the target control strategy for the target orbit control arc segment.

[00110] Optionally, the space debris collision avoidance apparatus 20 taking into account the task of orbit altitude adjustment further includes: a first determination module 204, configured to re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

[00111] wherein the control module 202 further includes a fourth sub-module 2024, configured to execute the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

[00112] re-determine an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

[00113] Optionally, the combining avoidance control includes at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, reducing the number of times of orbit control, the space debris collision avoidance apparatus 20 taking into account the task of orbit altitude adjustment further includes:

[00114] a second determination module 205, configured to determine a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

[00115] re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

[00116] determine the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.

[00117] In the embodiment of the present disclosure, the first acquisition module is configured to acquire a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement, and the control module configured to control the spacecraft with a target control strategy at a second moment,

in a case that the collision risk value at a first moment within the target time period is greater than a preset value, wherein the second moment is earlier than the first moment, the target strategy includes at least one of the following: increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control. The continuous orbit change requirement of the spacecraft is taken into consideration in the scheme of avoiding the collision of space debris, and the continuous orbit change parameter is taken into consideration when determining the control strategy, which may simultaneously take into account the continuous orbit change mission of the spacecraft and avoid the collision of the spacecraft and space debris, reduce the propellant used for separate orbit change control for avoiding space debris collision, and improve the operating efficiency of the spacecraft.

[00118] The virtual system in the embodiment of the present disclosure may be an apparatus, or a component, an integrated circuit, or a chip in the terminal.

[00119] In addition, it should be noted that the apparatus embodiments described above are only illustrative and do not limit the protection scope of the present disclosure. In practical applications, those skilled in the art may select some for all modules according to actual needs to achieve the purpose of this embodiment, which is not limited herein.

[00120] Please be noted that, unless stated otherwise directly, all features disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose. Therefore, unless expressly stated otherwise, the disclosed each feature is only one example of a group of equivalent or similar features. Where applicable, further, preferably, much further and more preferably are simple starting for elaborating another embodiment based on the foregoing embodiment. The content after further, preferably, much further and more preferably is combined with the foregoing embodiment, to serve as complete composition of another embodiment. The several further, preferably, much further and more preferably arrangements after the same embodiment may be arbitrarily combined, to form yet another embodiment.

[00121] In addition, as for technical details that are not described in detail in this embodiment, please refer to the intelligent cognition method and system provided by any embodiment of the present disclosure, which will not be repeated herein again.

[00122] The above is only preferred embodiments of the present disclosure and is not intended to limit the present disclosure. Any modification, equivalent substitution, improvement, etc. made within the spirit and principle of the present disclosure shall be included within the protection scope of the present disclosure.

CLAIMS

What is claimed is:

1. A space debris collision avoidance method taking into account a task of orbit altitude adjustment, comprising:

acquiring a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement; and

controlling the spacecraft with a target control strategy at a second moment, in a case that the collision risk value at a first moment within the target time period is greater than a preset value,

wherein the second moment is earlier than the first moment;

wherein the target control strategy comprises at least one of the following:

increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control;

before acquiring the collision risk value of the spacecraft and space debris within the target time period, the method further comprising:

acquiring an orbit control strategy corresponding to the continuous orbit change requirement in a case that the spacecraft has the continuous orbit change requirement, and acquiring an orbit control ephemeris forecast based on an orbit determination result in the orbit control strategy;

wherein acquiring the collision risk value of the spacecraft and space debris within the target time period comprises:

acquiring the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data;

wherein controlling the spacecraft with the target control strategy at the second moment comprises:

determining a target factor based on the first moment;

determining a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

executing the target control strategy for the target orbit control arc segment;

wherein the target time period is a period of time in the future set by an operator or determined by history conditions of the spacecraft,

the first moment is a calculated collision moment of the spacecraft and the space debris;

the target factor is a constraint condition of measurement and control, lighting, and energy.

2. The space debris collision avoidance method taking into account the task of orbit altitude adjustment according to claim 1, after determining the target orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, and before executing the target control strategy for the target orbit control arc segment, the method further comprising:

re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

executing the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

re-determining an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

3. The space debris collision avoidance method taking into account the task of orbit altitude adjustment according to claim 1, wherein the combining avoidance control comprises at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, reducing the number of times of orbit control, before controlling the spacecraft with the target control strategy at the second moment, the method further comprising:

determining a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

re-determining the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

determining the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.

4. A space debris collision avoidance apparatus taking into account a task of orbit altitude adjustment, comprising:

- a first acquisition module, configured to acquire a collision risk value of a spacecraft and space debris within a target time period, in a case that the spacecraft has a continuous orbit change requirement; and

- a control module, configured to control the spacecraft with a target control strategy at a second moment, in a case that the collision risk value at a first moment within the target time period is greater than a preset value,

- wherein the second moment is earlier than the first moment;

- wherein the target control strategy comprises at least one of the following:

- increasing an amount of orbit control, reducing an amount of orbit control, increasing a number of times of orbit control, reducing a number of times of orbit control and combining avoidance control,

- the apparatus further comprising:

- a second acquisition module, configured to acquire an orbit control strategy corresponding to the continuous orbit change requirement in a case that the spacecraft has the continuous orbit change requirement, and acquire an orbit control ephemeris forecast based on an orbit determination result in the orbit control strategy;

- a first determination module, configured to acquire the collision risk value of the spacecraft and space debris within the target time period based on the orbit control ephemeris forecast and space data;

- the control module further comprising:

- a first sub-module, configured to determine a target factor based on the first moment;

- a second sub-module, configured to determine a target orbit control arc segment that is able to execute the target control strategy in a target orbit of the spacecraft based on the target factor;

- a third sub-module, configured to execute the target control strategy for the target orbit control arc segment;

wherein the target time period is a period of time in the future set by an operator or determined by history conditions of the spacecraft,

the first moment is a calculated collision moment of the spacecraft and the space debris;

the target factor is a constraint condition of measurement and control, lighting, and energy.

5. The space debris collision avoidance apparatus taking into account the task of orbit altitude adjustment according to claim 4, further comprising:

a first determination module, configured to re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the target control strategy and the target orbit control arc segment;

wherein the control module further comprises a fourth sub-module, configured to execute the target control strategy for the target orbit control arc segment, in a case that the re-determined collision risk value is less than or equal to the preset value;

re-determine an orbit control arc segment that is able to execute the target control strategy in the target orbit of the spacecraft based on the target factor, in a case that the collision risk value is greater than the preset value.

6. The space debris collision avoidance apparatus taking into account the task of orbit altitude adjustment according to claim 4, further comprising:

wherein the combining avoidance control comprises at least two of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, reducing the number of times of orbit control,

a second determination module, configured to determine a second target strategy in a case that the collision risk value at the first moment within the target time period is greater than the preset value, wherein the second target strategy is at least one of increasing the amount of orbit control, reducing the amount of orbit control, increasing the number of times of orbit control, and reducing the number of times of orbit control;

re-determine the collision risk value of the spacecraft and the space debris within the target time period based on the second target strategy;

determine the target control strategy being the combining avoidance control in a case that the re-determined collision risk value is greater than the preset value.