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Walking path-planning method for multiple radiation areas

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ABSTRACT

Based on minimum dose path-searching method, walking path-planning method for multiple radiation areas was designed to solve minimum dose path problem in single area and find minimum dose path in the whole space in this paper. Path-planning simulation platform was built using C# programming language and DirectX engine. The simulation platform was used in simulations dealing with virtual nuclear facilities. Simulation results indicated that the walking-path planning method is effective in providing safety for people walking in nuclear facilities.

1. Introduction

In the process of design, operation, decommission of nuclear facilities and nuclear emergency, radiation protection problem cannot be ignored. The effects of radiation cannot be readily detected relying on our senses, which is not safe or efficient. So we can evaluate and plan the walking path to reduce radiation exposure that workers suffered in radioactive environment, take the walking path-planning method for radiation environment as an effective radiation protection measure.

Researches on path-planning technology for nuclear radiation environment are different. The following examples are three typical path-planning methods for nuclear radiation environment:

(1) IFE (Institute for Energiteknikk) and JNC (Japan Nuclear Cycle Development Institute) developed jointly VRdose system which can collect radiation dose data, evaluate the radiation exposure, design work program to reduce radiation exposure to the utmost (Iguchi et al., 2004).
(2) Khasawneh et al. (2013a,b) addressed a localized navigation algorithm for radiation evasion. A well-designed wireless sensor networks infrastructure is distributed in radiation environment to measure radiation level, and then data is transmitted by wireless communication technology.
(3) Hage and Couture (1999) designed path-planning method based on sensor in radiation environment. It is used for mobile robot in radioactive environment to avoid obstacles and continuous radiation exposure.

According to methods above, we can see three characteristics: (1) application environment, includes virtual environment and actual environment; (2) application object, includes people, robots and vehicles; (3) methods, includes path-evaluating and the minimum path-searching.

In view of the above characteristics, we proposed the minimum dose path-searching method which is only used for single area, but not used for multiple areas (Liu et al., 2015). In multiple areas, minimum dose path-searching method is out of work. Therefore, we proposed walking path-planning method for multiple radiation areas to find minimum dose path in the whole space.

The rest of this paper is organized as follows: Section 2 focuses on these methods we proposed. Section 3 briefly introduces the simulation platform. Section 4 describes the simulation experiments for these methods on the simulation platform. Section 5 presents the concluding remarks.

2. Methods

The idea of path-planning methods for radiation environment is as follows: firstly, build a nuclear facility scene; secondly, evaluate some factor in progress of walking path in the scene; thirdly, design walking path to reduce the worker's radiation exposure.

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The hypothesis preconditions of path-planning for radiation environment is as follows: (1) the structure of nuclear facilities and distribution of radioactivity are known and static; (2) walking speed is constant. The research way of the proposed method is to survey environment modeling methods in the first place, the next to select environment model, once more to build environment model, final to design walking path-planning method for multiple radiation areas.

2.1. Environment modeling method

Environment modeling is fundamental and significant, which determines the path-searching method and path-evaluating method. Common environment modeling methods include grid model, visibility graph model and visibility point model.

(1) Grid model

Grid model was proposed by Howden in 1968 (Weigl et al., 1993; Barraquand et al., 1992; Koren and Borenstein, 1991). Three-dimensional (3D) space is transformed into two-dimensional (2D) space which is represented by many grids. Specific path-searching algorithm is based on grid to plan path. The common grid models include square grid and hexagon grid.

(2) Visibility graph model

Visibility graph model was proposed by Tomas Lozano-Perez and Michael A. Wesley in 1979 (Janet, 1995). The target is considered as a point, and then each vertex of obstacle and the target are connected to form a road network. This method is poor in the evaluation, limited and complex in structure.

(3) Visibility point model

Our previous approach (Liu et al., 2014) makes use of visibility point model to plan path in nuclear facilities. The planned path is an optimum in terms of visibility graph model, but not an optimum in terms of the whole scene. The error of calculation is large.

In summary, path-planning in radiation environment is different from path-planning in traffic and game. We need to consider structure of scene and distribution of radioactivity. According to requirements of path-planning and features of radiation environment, single area modeling method and multiple areas modeling method are proposed based on grid model in this paper.

2.2. Single area modeling method

Single area modeling method based on grid is as follows:

(1) 3D scene is mapped to 2D map, as shown in Fig. 1. The black area represents obstacle, the white area represents free space.

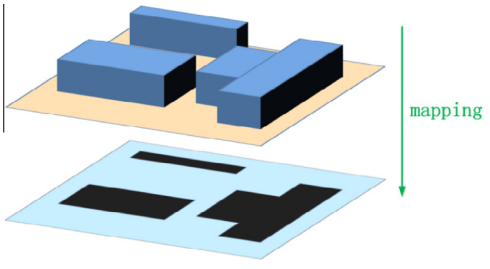

Fig. 1. Progress of 3D scene mapping to 2D scene. The 3D scene is in the upper side, the 2D map in the down side.

(2) 2D scene is discretized by free grids and obstacle grids, as shown in Fig. 2. Arbitrary shape obstacle and equipment is represented by some finite grids.
(3) Dose rate distribution is discretized by grids; dose rate of each grid is represented by average dose rate of all points in elementary grid, as shown in Fig. 3.
(4) In the grid, the walking path is composed of many line segments connected.

2.3. Multiple areas modeling method

Nuclear facilities scene is three-dimensional space, many work areas are not in the same horizontal plane, even non horizontal plane. The single area modeling method is used for a single connected horizontal area, but not used for multiple and connected non horizontal areas. Therefore, we proposed a multiple areas modeling method based on the single area modeling method to solve path problem in multiple areas (whole space). This method includes transverse discretization and longitudinal discretization.

The transverse discretization is similar to single area modeling method. All areas are discretized to build models which are stored in a set and established corresponding relationship. The longitudinal discretization is used for non-horizontal narrow area, such as stair, ladder etc. The space that is discretized by longitudinal discretization is limited and narrow, the path in the space is changeless and unique, so we don't need to plan, just evaluate the path.

Fig. 4 gives an example of longitudinal modeling of the mobile stair, the 3D space is mapped to a 2D plane, and then it is discretized.

Fig. 5 shows flowchart of multiple areas modeling method, main steps are as follows:

(1) All areas that are not in the same plane in 3D workspace, is divided into n discrete areas.
(2) 3D space is mapped to the 2D map by transverse discretization or longitudinal discretization respectively, according to their characteristic.
(3) Add each area environment model to an environment model set, establish the corresponding relation between environment models, constitute a complete environment model.

Multiple areas modeling method takes full advantage of spatial information. Based on the environment modeling, we designed the path-evaluating method and path-planning method.

2.4. Path-evaluating method

Path-evaluating method is mainly used to evaluate factors at one position of walking path in the radiation environment.

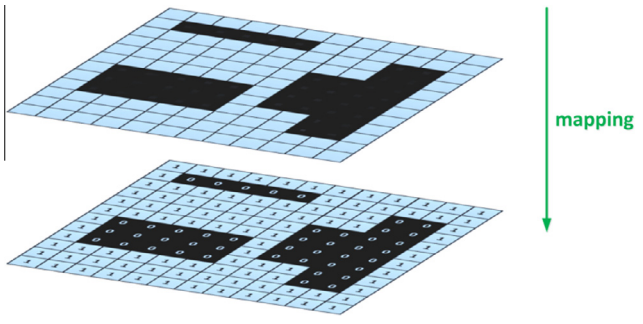

Fig. 2. The discretized 2D scene based on grid. Obstacle grid is represented by "0", free space by "1".

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