Progress in Nuclear Energy 91 (2016) 1–8

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

Dynamic minimum dose path-searching method for virtual nuclear facilities

Meng-kun Li [a], Yong-kuo Liu [a, *], Min-jun Peng [a], Chun-li Xie [b], Shuang-yu Wang [a], Nan Chao [a], Zhi-bin Wen [a]

[a] Fundamental Science on Nuclear Safety and Simulation Technology Laboratory, Harbin Engineering University, Harbin, 150001, China
[b] Traffic College, Northeast Forestry University, Harbin, 150040, China

ARTICLE INFO

Article history:
Received 2 June 2015
Received in revised form
14 March 2016
Accepted 6 April 2016
Available online 18 April 2016

Keywords:
Minimum dose path
Dynamic path
Virtual simulation
Nuclear safety
Nuclear facilities

ABSTRACT

Walking path-planning technology can be taken as a radiation protection measure to reduce radiation exposure to workers in radiation environment, and to guarantee work order and efficiency. Considering the nuclear facilities scene can be dynamic and changeable, we designed a dynamic minimum dose walking path-searching method based on the static minimum dose walking path-planning method earlier, and built path-planning simulation platform for nuclear radiation environment with virtual reality technology to plan walking path and virtual simulation.

1. Introduction

In some radioactive waste workshops and nuclear operation workshops, valve leakage or pipeline rupture leads to leakage of radioactive material. In decommissioning of nuclear facilities, the reactor that has run for decades becomes a strong radiation source, some parts are activated by neutron and polluted by radiation nuclide, even biological shield also has very strong radioactivity. When nuclear accident occurs, workers and the public must be evacuated, an efficient and emergency path-planning method is needed to ensure the operation safety. Worker is not able to discover the ionizing radiation effect through the senses, even if the ionizing radiation effect is harmful to health of worker. When the worker is in radiation environment, radiation protection is essential and the research for radiation protection is necessary. So we have taken path-planning in radiation environment as a radiation protection measure.

So far there have been some researchers who study the path-planning in nuclear radiation field. For example, M. Hage et al. designed the path-planning method based on genetic algorithm using sensor network to collect and deliver messages in radioactive environment (Hage and Couture, 1999). The environment is not complicated and the planned path that could not apply to humans is not in line with people's operating habits.

In recent years, American Alzalloum (2009) addressed the least cost path problem for a radiological contaminated area and found the minimum radiation exposure paths using Dijkstra and Bellman–Ford algorithms. It is heuristic method, but there is a big deviation between two points in path.

Khasawneh et al. proposed a localized navigational guidance algorithm, based on wireless sensor network which is capable of monitoring and guiding the personnel involved as radiation events happen (Khasawneh et al., 2010). They addressed "Radiation Evasion" criterion and "Nearest Exit" Criterion based on the localized navigational algorithm (Khasawneh et al., 2013a, 2013b).

Liu et al. proposed the multi-objective path-planning which is combined multi-objective decision methods with PSO algorithm (Liu et al., 2014). This method solves path problem using quantitative method and qualitative method. Liu et al. designed minimum dose method for walking-path planning of nuclear facilities (Liu et al., 2015). These methods addressed by Liu et al. above are all used in static environment.

In order to ensure safety and health of operator and worker in

* Corresponding author.
E-mail address: LYK08@126.com (Y.-k. Liu).

http://dx.doi.org/10.1016/j.pnucene.2016.04.001
0149-1970/

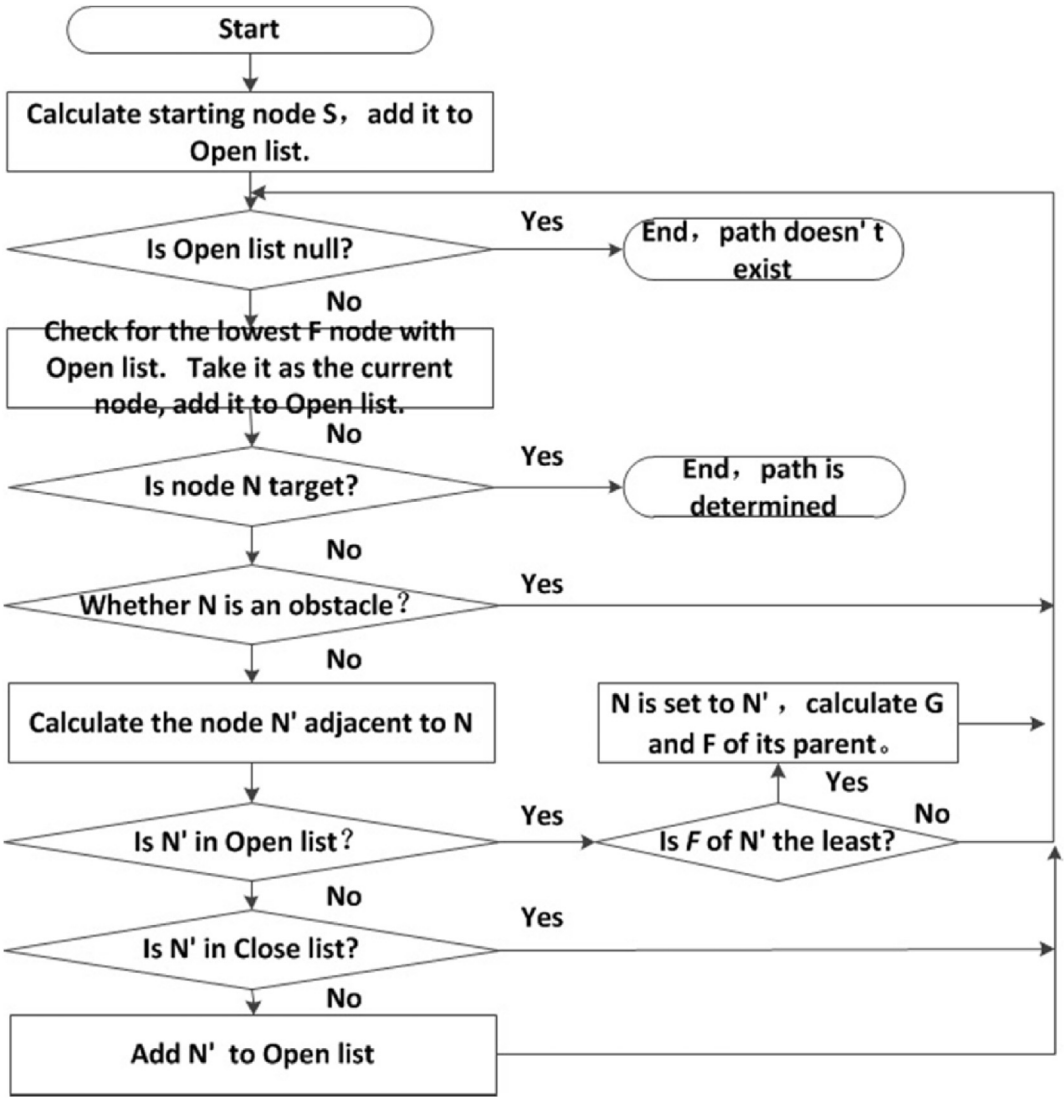

Fig. 1. Flow of static minimum dose path-searching method.

radiation field, reduce impact to workers, the public and environment, advanced virtual simulation is a feasible and effective technical measure. For example, Belgian SCK·CEN developed VISIPLAN software which is a 3D-ALARA planning tool for routine work and interventions in an environment with risk of external exposure (Vermeersch and Vanbosstraeten, 2004). IFE (Institute for Energiteknikk) and JNC (Japan Nuclear Cycle Development Institute) developed jointly VRdose software which is a tool that can display dose-rate distribution and estimates occupational doses for work scenarios in nuclear facilities (Rindahl et al., 2006a, b). Hitachi Corporation built VR-DOSE system for calculation and visualization of radiation field for maintenance support in nuclear power plants (Ohga et al., 2005). Spain developed dose evaluation virtual simulation system CIPRES for refueling task in Cofrentes nuclear power plant (Rodenas et al., 2004). Mól et al. applied game engine for virtual simulation of nuclear facilities (Mól et al., 2008, 2009, 2011; Silva et al., 2015).

As introduced above, recent path-planning researches mainly aimed at static environment, which is pretty idealistic, but real work environment is changeable. So we want to solve path problem in dynamic environment which closes to the actual situation. In this work, path-planning in radiation environment and virtual reality are taken into consideration, we proposed a dynamic minimum dose walking path-searching method, built the path-planning virtual simulation platform for nuclear radiation environment. We hope this research can be helpful for safety of operation in dynamic virtual environment.

The paper is organized as follows: Section 2 describes the proposed method including environment model, static and dynamic minimum dose walking path-searching algorithm. Section 3 presents simulation platform in this work. Section 4 presents two simulation experiments. Section 5 discusses and analysis results of simulation experiments. Finally, Section 6 is dedicated to final conclusion of this work.

2. The proposed methods

The purpose of this paper is to reduce radiation exposure to workers in dynamic virtual radiation environment. The hypothesis preconditions are as follows: (1) Structure of nuclear facilities and radioactivity distribution are known and they are dynamic. (2) The walking speed is constant.

This dynamic method we proposed is innovative, an extension of static method. Both environment model and math model of