Preliminary Study on Environment Mapping for Nuclear Reactor Dismantling

Sungmoon Joo*, Jonghwan Lee, Ikjune Kim, Dongjun Hyun, Shinyoung Kang,
Kwanseong Jeong, and Byungseon Choi
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, Korea
*smjoo@kaeri.re.kr

1. Introduction

Prediction of time and cost for dismantling of nuclear reactor facilities is critical in the preparation phase of decommissioning. Existing methodologies using prior data are useful for evaluating initial estimates, but these estimates need to be updated using as-built data.

Simulation-based evaluation for the dismantling scenario of the reactor vessel at Kori Unit 1 has been proposed [1]. The simulation-based evaluation potentially yields more realistic estimates, provided realistic as-built data is used. One example is reactor vessel upper internal (RVI) structure cutting (Fig. 1); usually design data (e.g., CAD model) is used in the simulation, however, to make the segmentation and cutting plan more realistic, as-built data is necessary.

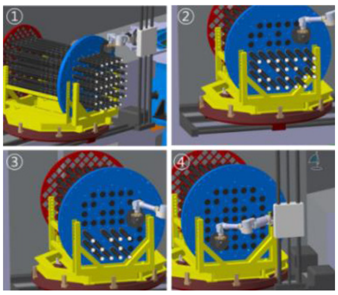

Fig. 1. Cutting Simulation of RVI [1].

This study introduces an algorithm for building as-built environment model using point clouds, and preliminary result is presented.

2. Background Information

This section provides background information for 3D modeling and mapping using point clouds.

2.1 Point Cloud

Point cloud is a set of data points in some coordinate system. In a 3D coordinate system, these points are usually defined by X,Y, and Z coordinates, and often are intended to represent the external surface of an object. Point clouds may be created by 3D sensors such as 3D laser scanners.

2.2 Registration

Often the point clouds are acquired from different view-points. The (point set) registration finds the relative pose (position and orientation) between views in a global coordinate frame, such that the overlapping areas between the point clouds match as well as possible. The overall objective registration is to align individual point clouds and fuse them to a single point cloud.

2.3 Mapping and Localization

Registration algorithms are used in applications such as 3D mapping and localization. The reconstructed map is represented by a set of point clouds which are aligned by means of registration. If the poses where two point clouds were taken from, the result of registration yields a merged point cloud referenced to a global coordinate frame. However, when the poses are unknown, the registration involves the process of finding out the poses, so called localization. The localization requires a loop closure, the problem of recalling revisited (or seen again) scene.

3. Real-time Appearance-Based Mapping

Real-time Appearance-Based Mapping (RTAB-Map) was developed to provide an appearance-based localization and mapping solution independent of time and size, to achieve online loop closure detection for long-term operation in large environment [2]. The idea resides in only using a limited number of locations for loop closure detection so that real-time constraints can be satisfied, while still gain access to locations of the entire map whenever necessary.

The main feature of RTAB-Map is its memory management which enables real-time mapping; memory management, which has been used in robot localization to increase recognition performance in dynamical environment or to limit memory used, is used for online localization and mapping, where new locations are dynamically added over time.

Fig. 2 shows the main concept of RTAB-MAP and its memory management model [2]. The perception module acquires an image and sends it to sensory memory (SM). SM evaluates the image signature to reduce data dimensionality and to extract useful features for loop closure detection. Then SM creates a new location with image signature and sends it to short-term memory (STM). STM updates recently created locations through a process referred to as weight update.

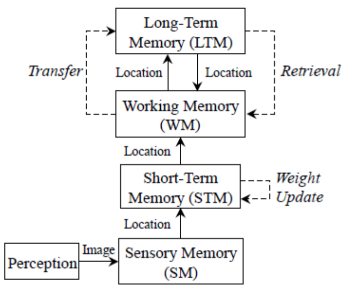

Fig. 2. RTAB-Map Memory Management Model.

Algorithm 1 illustrates the overall loop closure detection process [2].

4. Implementation & Test Results

RTAP-Map algorithm is available as an open source for test and development. Fig. 3 is a map of author's desk area represented by a colored point cloud. Implementation and tests were performed on a PC with Ubuntu 14.04 using Kinect V1 sensor.

Fig. 3. Mapping of Desk Area using RTAP-Map.

Table 1. Algorithm 1

Algorithm 1 RTAB-Map

$time \leftarrow$ TIMENOW() ▷ TIMENOW() returns current time
$I_t \leftarrow$ acquired image
$L_t \leftarrow$ LOCATIONCREATION(I_t)
if z_t (of L_t) is a bad signature (using T_{bad}) **then**
  Delete L_t
else
  Insert L_t into STM, adding a neighbor link with L_{t-1}
  Weight Update of L_t in STM (using $T_{similarity}$)
  if STM's size reached its limit (T_{STM}) **then**
    Move oldest location of STM to WM
  end if
  $p(S_t|L^t) \leftarrow$Bayesian Filter Update in WM with L_t
  Loop Closure Hypothesis Selection ($S_t = i$)
  if $S_t = i$ is accepted (using T_{loop}) **then**
    Add loop closure link between L_t and L_i
  end if
  Join *trash*'s thread ▷ Thread started in TRANSFER()
  RETRIEVAL(L_i) ▷ LTM → WM
  $pTime \leftarrow$ TIMENOW() $- time$ ▷ Processing time
  if $pTime > T_{time}$ **then**
    TRANSFER() ▷ WM → LTM
  end if
end if

5. Conclusion

This study introduces RTAP-Map algorithm for nuclear reactor facility environment mapping to build as-built models, and a preliminary modeling result is presented. The method can be applied to build as-built models of reactor facilities for dismantling, and the as-built data can contribute to more realistic simulation-based evaluation.

Acknowledgements

This work was supported by the nuclear research and development program through the national research foundation of Korea funded by the Ministry of Science and ICT.

REFERENCES

[1] Kim, I., Choi, Hyun, D., Moon, J., Lee, Jeong, K., Kang, S., "Integration of the Unit Modules of the Nuclear Facility Dismantling Simulation System", Proc. of the KRS 2017 Spring Conference, pp. 297-298, May 24-26,2017, Busan.

[2] M. Labbe, F. Michaud, "Appearance-Based Loop Closure Detection for Online Large-Scale and Long-Term Operation", IEEE Transactions on Robotics, Vol. 29, No. 3, pp. 734-745, 2013.