A Preliminary Study for Knowledge-Based Management for Nuclear Activities using Open-Source Satellite Imagery

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1. Introduction

Kyung Hee University has established a Center for International Nuclear Policy and Peace Studies (CINPAPS) for conducting the researches mainly related to nuclear activity monitoring using open-source intelligence (OSINT). Satellite imagery, available from OSINT, can be used as a means for nuclear activity monitoring. In the United States, various non-governmental think-tanks, such as the Institute for Science and International Security (ISIS) and 38 North, provide satellite imagery analysis publicly available on their websites [1, 2]. Various computer-based image processing techniques are employed to analyze satellite images, but some subjective judgement is necessary to interpret the ultimate and implicit phenomena. In Korea, however, there is a shortage of analysis experts and organizations with highly related knowledge and experience for nuclear activity monitoring in non-governmental sector.

This study attempts to create a kind of knowledge-base that incorporates evidence of nuclear activities for satellite imagery analysis to augment experts' decisions. This paper introduces an ongoing study aimed at building this knowledge-base. Fig. 1 shows the overall concept and flow of this study. First, we explore some websites that provide satellite imagery analysis of nuclear activities. Next, web crawling technique is employed to collect satellite images and existing analysis cases on the websites [3]. Then, we itemize the evidence of nuclear activities by classifying and analyzing them. Finally, we propose the applicability of this knowledge-base.

2. Satellite Imagery analysis for Monitoring Nuclear Activities

Satellite imagery is utilized as one of the tools for nuclear activity monitoring because it allows observation of geographically inaccessible areas [4, 5]. This section briefly outlines a general process for its analysis and discusses the elements required for each process. You can see the procedure in 'Applicability' part of Fig. 1.

The first step is to get satellite imagery. In addition to high-quality optical imagery with high-resolution (<1m), thermal infrared or Synthetic Aperture Radar (SAR) imagery that are not affected by night or clouds can be used. By specifying the imagery type and resolution for the region and time of interest, it is possible to purchase or acquire images from commercial satellite companies, etc. The second step is the image processing of the acquired satellite imagery. This step typically involves computer-based image preprocessing and analysis. Various image processing technologies using image processing software have been developed, and there are various studies applying them to nuclear activity monitoring. Most research deals with object and change detection techniques. These techniques aim to identify specific objects and their changes [6]. The final step is to interpret the analysis results from the previous step. Computer-based image analysis techniques can help to identify the object itself, or to identify changes in structure and position. However, it is up to the analyst to give meaning (i.e., interpretation) to these changes. The most important part of the analysis is to identify and utilize a variety of direct and indirect evidence for inference. For this reason, satellite analysis specialists for nuclear activity monitoring should be very knowledgeable and experienced.

3. Development of Knowledge-Base for Monitoring Nuclear Activities using Satellite Imagery

A database of expert analytical knowledge mentioned in Section 2 will be useful for future analyses. This section introduces the process for building such a database. Fig. 1 illustrates this process.

3.1 Think-tanks for Satellite Imagery Analysis

Various think-tanks that operate nuclear activity monitoring based on the interpretation of OSINT are in operation [7]. OSINT exists in various forms such as news, paper, satellite imagery, and the like. Attention in this study is the use of open-source satellite imagery for nuclear activity monitoring. Among the various think-tanks, there are two organizations providing analysis using satellite imagery: ISIS and 38 North. ISIS is a US science institute dealing with international security issues, and 38 North is a program at the US Stimson center, specializing in North Korean intelligence analysis. The two have in common that they provide publicly available analysis results in the form of articles on their websites. Here, experienced analytical

specialists acquire satellite imagery of the region of interest and analyze and present their opinions. As such, the articles they provide are the result of inference from the knowledge of experienced domain experts with years of experience.

3.2 Data Collection

To build a database, it is necessary to first acquire a large amount of data. The aforementioned websites provide periodic updates of various analysis cases along with satellite imagery. Therefore, there is a need to continuously collect a large amount of only the necessary information up-to-date on the website. Web crawling, a technology that collects content on the Web in an automated way, makes this possible. A crawler created by programming can call a web page to extract only the data we need.

In this paper, we collected satellite imagery and analytical articles related to nuclear activities on web sites using web crawling technology. For the collection, the crawler was programmed as follows: First, the crawler loads websites where the desired information exists, then retrieve a list of articles by setting search words based on countries and regions of interest. It then lists their dates and titles, automatically retrieves each one, and requests satellite imagery and analysis results within the article. Satellite imagery is stored as images, and the analysis results are stored in text files. As a result, we have a basic database divided by year and region. This database can be updated continuously using the crawler.

3.3 Database Construction

A knowledge-base can be defined as data that has been systematically accumulated for easy access to knowledge in a specific field. When you encounter a problem that requires expert judgment, you can use this knowledge-base to help you solve the problem. The knowledge-base is constructed by gathering knowledge from experts and editing it in a defined format, and is required to be constantly updated, maintained and managed. In this study, knowledge-base was constructed by extracting and itemizing the basis of nuclear activity inference from the contents analyzed by satellite imagery experts. Fig. 2 shows the structure of this knowledge-base. For analysis, classification criteria were set by country and region / date / type of nuclear facilities or nuclear activities / evidence. Here, the types of nuclear facilities and activities are listed as possible facilities and activities that can be considered in the nuclear cycle. Above all, the most important thing is to list the evidence. Inferences are based on physical characteristics such as existence, size, and shape of topographic features. In addition to these physical properties, the structural changes of the features considering the temporal information and the changes in the operation of the facility can be used as evidence. On the other hand, some internal activities may be difficult to identify. At this time, circumstantial evidence that can be inferred from observed facts, such as workers or large vehicle movements, can also be considered. Based on these, the data obtained in the previous step was analyzed, and the analysis results for the items were extracted and organized. The generated knowledge-base can be used as an image processing condition or reasoning ground in satellite imagery analysis. The results of the analysis can be updated again and continue to accumulate in the knowledge-base.

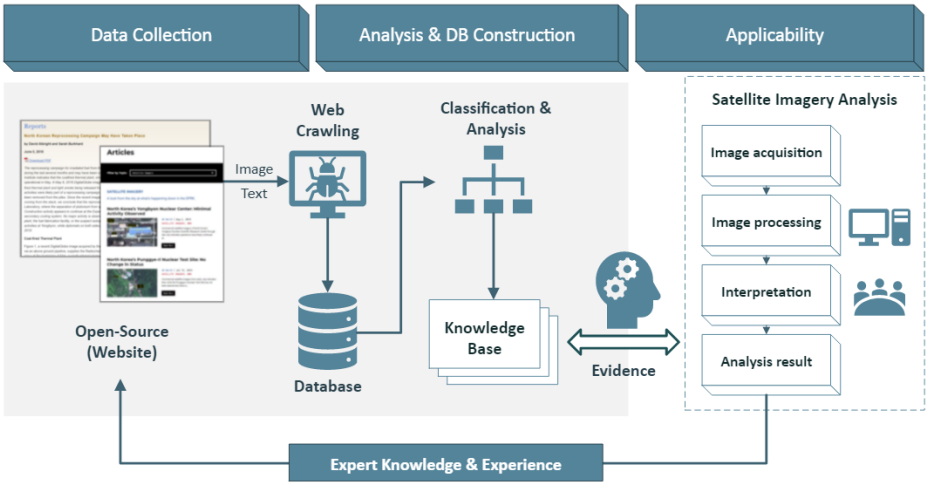

Fig. 1. Knowledge-based management for nuclear activity monitoring using open-source satellite imagery

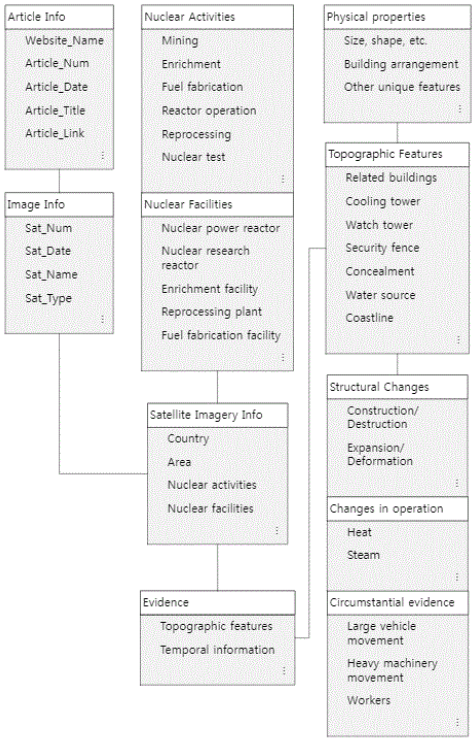

Fig. 2. Structure of the evidence knowledge-base on nuclear activity

4. Conclusions

This study describes the current state of building a knowledge-base that contains evidence of nuclear activity on satellite imagery. With the knowledge and experience of the analyst and the speed of the analysis, satellite imagery would be of high value as a means of nuclear activity monitoring. Recently, as a variety of satellite imagery analysis platforms using artificial intelligence have been developed, it is possible to identify changes and detections of objects in a plurality of satellite images. If images of suspected or unspecified areas are available, they can be used to perform monitoring of unidentified areas. At this point, the knowledge-base being built in this study can help detect nuclear activities by providing the criteria used to identify objects and changes. This is because labeling is important for effective AI application. Finally, we plan to use all of these to develop a semi-automated inference algorithm that will enable faster and more efficient analysis.

This study also emphasizes the use of open-source. Of course, there will be limits to the availability or accuracy it has, but it has the advantage of bringing together collective intelligence at an affordable price. This study attempted to suggest the possibility of such a group research system.

5. Acknowledgement

This study was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea. (No. 1803028)

REFERENCES

[1] ISIS [Internet]. URL: http://isis-online.org/.
[2] 38 North [Internet]. URL: https://www.38north.org/.
[3] R. Mitchell, Web Scraping with Python, 2nd Edition, O'Reilly Media, 2018.
[4] R. S. Kemp, Environmental Detection of Clandestine Nuclear Weapon Programs, Annual Review of Earth and Planetary Sciences, Vol. 44:17-35, 2016.
[5] KINAC, 2017 Final Report on Technological Information Analysis on the Nuclear Activities of Surrounding Countries, KINAC/RR-017/2017, 2018.
[6] B. Jasani, I. Niemeyer, S. Nussbaum, B. Richter and G. Stein, International Safeguards and Satellite Imagery: Key Features of the Nuclear Fuel Cycle and Computer-Based Analysis, Springer, Berlin, 2009.
[7] J. Lee, J. Son and J. Whang, A Preliminary Study for Establishing a Monitoring System for Undeclared Nuclear Programs using Open-Source Information, Transactions of the Korean Nuclear Society Autumn Meeting, Yeosu, Korea, October 25-26, 2018.