E3S Web of Conferences **94**, 01009 (2019) https://doi.org/10.1051/e3sconf/20199401009
*ISGNSS 2018*

# Multi-Thread Based Design of Navigation Algorithm Module in Multi Radio Integrated Navigation System M&S Software

*Jae Hoon* Son[1], *Heyone* Kim [1], *Sang Heon* Oh[2], *Hyoungmin* So[3], and *Dong-Hwan* Hwang[1,*]

[1] Chungnam National University, Department of Electronics Engineering, 34134 Daejeon, Korea
[2] Navcours Co., Ltd, Integrated Navigation Division, 34014 Daejeon, Korea
[3] Agency for Defense Development, 34186 Daejeon, Korea

**Abstract.** A multi-thread based navigation algorithm module is designed in a multi radio integrated navigation system modeling and simulation software in order to efficiently use resources in the software platform of the modeling and simulation software. By adopting the multi-thread architecture, features of navigation algorithms and concurrency of the algorisms can be easily included in the navigation algorithm module. In order to show the usefulness of the multi thread based navigation algorithm module design, a navigation algorithm module in the multi-radio integrated navigation system for GPS, KNSS, Loran-C, eLoran and DME/VOR is implemented in C++ under the Windows operating system. The implementation results show that the thread based design can be useful in the development of multi radio integrated navigation systems.

## 1 Introduction

Navigation outputs can be provided by combining GNSS (Global Navigation Satellite System) with other radio navigation systems even for the outage of GNSS [1-5]. Before a multi radio integrated navigation system, in which GNSS is combined with other radio navigation systems, is operated in real-time, performance evaluations and tests should be performed. Much time and cost can be saved in the evaluation if the M&S S/W (Modeling and Simulation S/W) is used [6].

The can be divided into function modules in order to add new functions and modify the module easily. In M&S S/W, the navigation algorithms should be in an independent module since the navigation algorithms will be running in a real-time multi radio integrated navigation system [1]. The navigation algorithm should contain features of radio navigation algorithm units and integrated navigation algorithms of GNSS and radio navigation systems. In addition to this, the navigation algorithms should be concurrently run.

By using the thread in the operation system, features of the unit navigation system can be included in the navigation algorithm module and concurrency of the algorithms can be easily implemented in the M&S S/W [8-9].

In this paper, a multi thread based navigation algorithm module is designed in a multi radio integrated navigation system M&S S/W. In the navigation algorithm module, a navigation algorithm corresponds to a thread. By doing this, features of navigation algorithms can be independently included in the navigation algorithm module. When a new navigation algorithm needs to be added to the navigation algorithm module, a new thread can be easily generated without modifying other navigation algorithms [7-8].

In the sequel, in section II, the multi thread based navigation algorithm module design is presented. In section III, implementation results of the multi thread based navigation algorithm for GPS, KNSS(Korean Navigation Satellite System), Loran-C (Long range navigation), e-Loran (Enhanced Loran), DME (Distance Measuring Equipment) and VOR (Very high frequency Omnidirectional Radio range) are presented. Finally, in section VI, concluding remark and further studies are presented.

## 2 Multi thread based navigation algorithm module design

### 2.1 M&S S/W

M&S S/W configuration is shown in figure 1. The M&S S/W is divided into navigation algorithm part and GUI (Graphic User Interface) part and navigation environment generation part. Unit navigation algorithm and integrated navigation algorithms are in the navigation algorithm part. The navigation environment generation part generates measurements to the parameter set by the GUI part. The generated measurements are an input of the navigation algorithm part. Through GUI, parameters to send the navigation algorithm part and the navigation environment

[*] Corresponding author: dhhwang@ cnu.ac.kr.

generation part can be set by the user and navigation results can be displayed.

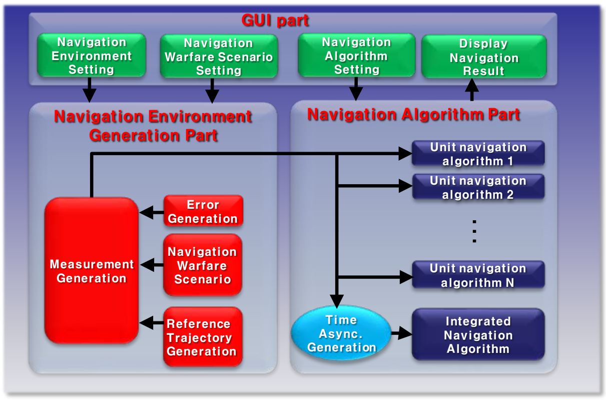
GUI part
Navigation Environment Setting
Navigation Warfare Scenario Setting
Navigation Algorithm Setting
Display Navigation Result
Navigation Environment Generation Part
Navigation Algorithm Part
Error Generation
Navigation Warfare Scenario
Reference Trajectory Generation
Measurement Generation
Unit navigation algorithm 1
Unit navigation algorithm 2
⋮
Unit navigation algorithm N
Time Async. Generation
Integrated Navigation Algorithm

**Fig. 1.** M&S S/W configuration

Since the M&S S/W has many functions and algorithms, the S/W is modularized as shown in figure 2. By doing this, the M&S S/W can be easily modified and more functions can be easily added into the S/W. The navigation algorithm module would be ported into a real-time integrated navigation system without little modification. The M&S S/W in figure 2 consists three function modules and M&S message broker. Each function module does not directly exchange data with other function modules. Instead of sending data to another function module, the function module sends the data to the M&S message broker. The message broker sends the data to another function module. Due to the M&S message broker, each function module does not need to all I/Fs (InterFaces) to exchange with other function modules.

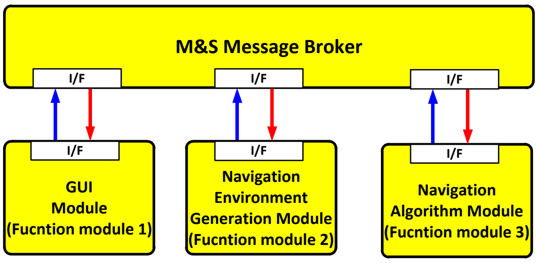
M&S Message Broker
I/F
I/F
I/F
I/F
GUI Module (Fucntion module 1)
I/F
Navigation Environment Generation Module (Fucntion module 2)
I/F
Navigation Algorithm Module (Fucntion module 3)

**Fig. 2.** Message broker based M&S S/W

The structure of the function modules is shown in figure 3. The navigation algorithm module has this structure. The broker is composed of an I/F, an encoder, a decoder, and a procedure. The decoder converts the binary data in the received M&S messages into internal variables for the procedure. The encoder converts the internal variables processed by the procedure into the binary data in the M&S message to transmit. The procedure is a combination of subroutines to carry out functions of the M&S software. Due to the encoder and decoder, variables in the procedure need not be shared with other function modules, i.e., each function module can be independently operated. Programs which have already been developed in other platforms can be reused or easily ported in a function module in the M&S software. In this case, the only thing for the operators and/or developers of the M&S software to do is updating the encoder and decoder.

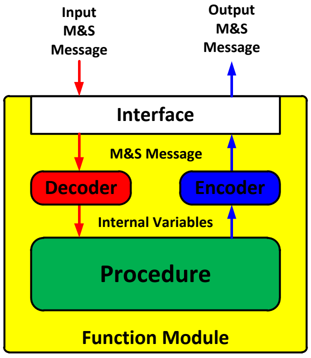

**Fig. 3.** Function module structure of M&S S/W

## 2.2. Multi thread based navigation algorithm module

The navigation algorithm module based on the multi thread is designed for the structure shown in figure 3. It is well known that the thread provides many useful characteristics to the program developers [7-10]. Among the useful characteristics, the scalability, concurrency, and economy are used in the design of the navigation algorithm module. Due to the scalability, a new navigation algorithm can be easily added to the navigation algorithm module by generation a new thread. The threads are to be seen to the user that they are run concurrently. Even though actual thread programs are run in time-sharing mode in a CPU (Central Processing Unit), the operation of the S/W has no problem as long as the running time is short enough. In the navigation algorithm module, a program is included in a thread if it is running independently or its function is clearly different from other program. Due to the scheduler of threads, the program developer can give more throughput.

As mentioned previously, the navigation algorithm module is composed of an I/F, a decoder, an encoder and procedure. The navigation algorithms are in the procedure. The I/F, decoder and encoder are designed in separate threads. Navigation algorithms are also designed in a separate threads as shown in figure 4.

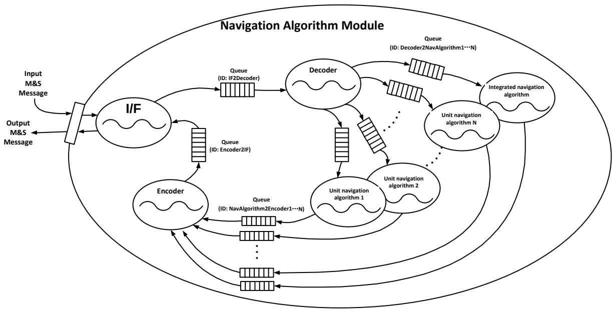
Navigation Algorithm Module
Input M&S Message
Output M&S Message
I/F
Queue (ID: IF2Decoder)
Decoder
Queue (ID: Decoder2NavAlgorithm1⋯N)
Integrated navigation algorithm
Unit navigation algorithm N
Unit navigation algorithm 2
Unit navigation algorithm 1
Queue (ID: Encoder2IF)
Encoder
Queue (ID: NavAlgorithm2Encoder1⋯N)

**Fig. 4.** Multi thread based navigation algorithm module

https://doi.org/10.1051/e3sconf/20199401009

# 3 Implementation result

## 3.1 M&S S/W

The M&S S/W for GPS, KNSS, Loran-C, e-Loran, DME and VOR shown in figure 5 was implemented to show the validity of the design of the multi thread based navigation algorithm module.

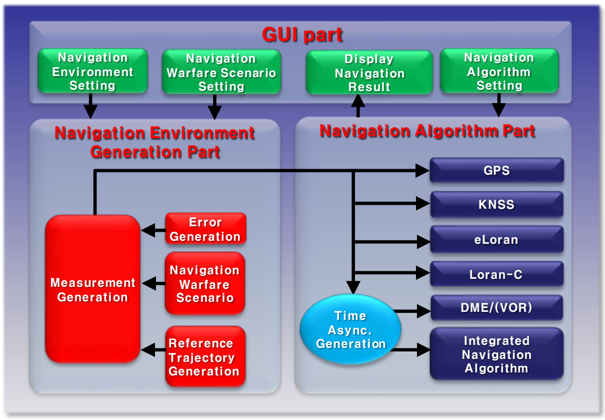
GUI part
Navigation Environment Setting
Navigation Warfare Scenario Setting
Display Navigation Result
Navigation Algorithm Setting
Navigation Environment Generation Part
Navigation Algorithm Part
Measurement Generation
Error Generation
Navigation Warfare Scenario
Reference Trajectory Generation
Time Async. Generation
GPS
KNSS
eLoran
Loran-C
DME/(VOR)
Integrated Navigation Algorithm

**Fig. 5.** Implemented M&S S/W

## 3.2 Navigation algorithm module

If the design method described in section II. 2 is applied to this navigation algorithm module with GPS, KNSS, Loran-C, e-Loran, DME and VOR, the navigation algorithm module has 9 threads and 14 queues as shown in figure 6.

The M&S S/W with the multi thread based navigation algorithm module was implemented in visual C++ under Windows operating system.

The weighted least method was used to estimate navigation results.

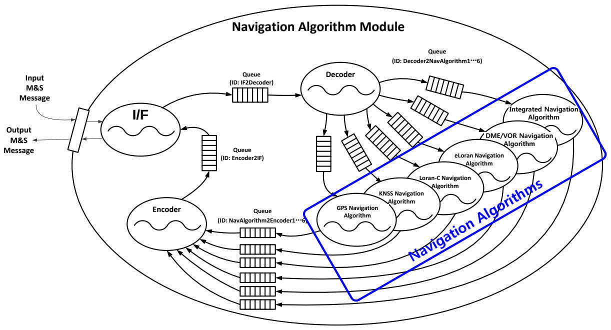
Navigation Algorithm Module
Input M&S Message
Output M&S Message
I/F
Queue (ID: IF2Decoder)
Decoder
Queue (ID: Decoder2NavAlgorithm1…6)
Queue (ID: Encoder2IF)
Encoder
Queue (ID: NavAlgorithm2Encoder1…6)
Integrated Navigation Algorithm
DME/VOR Navigation Algorithm
eLoran Navigation Algorithm
Loran-C Navigation Algorithm
KNSS Navigation Algorithm
GPS Navigation Algorithm
Navigation Algorithms

**Fig. 6.** Implemented thread based structure of the navigation algorithm module

## 3.3 Result

For the trajectory of a vehicle shown in figure 7, the M&S S/W was implemented. It can be seen that the vehicle is moving for 2500s. Initial position of the vehicle is 35.34° of latitude, 126.19° of longitude and 100m of altitude. It also can be observed that the vehicle carries 8-shaped motion and descends after it goes up to 8km of altitude.

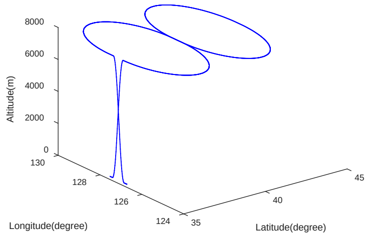

**Fig. 7.** Motion of the vehicle

A result of the integrated navigation algorithm with GPS, KNSS, eLoran, Loran-C, DME, and VOR is shown in figure 8 and figure 9. Numerical values for the navigation result are shown in table 1. The values in table1 are absolute values of errors in 95% probability. For comparison, results for unit navigation algorithms are listed in table1. The results show that the navigation algorithm module designed in multi thread in the M&S S/W is well operated.

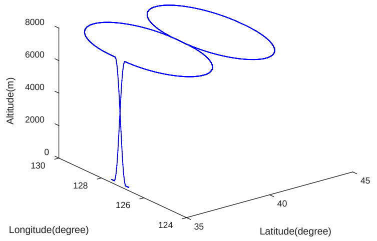

**Fig. 8.** Navigation result

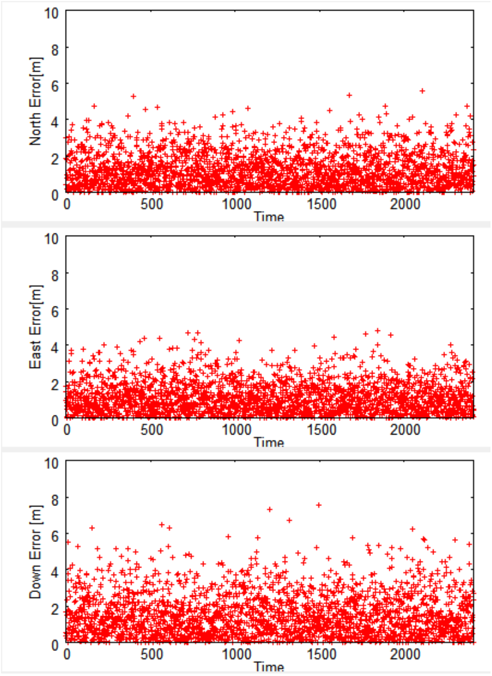

**Fig. 9.** Navigation error

**Table 1.** Navigation result

| Navigation algorithm | North [m] | East [m] | Down [m] |
|---|---|---|---|
| GPS | 2.82 | 2.38 | 3.11 |
| KNSS | 23.79 | 13.31 | 25.5 |
| Loran-C | 162.43 | 130.51 | 1957.08 |
| eLoran | 142.58 | 71.67 | 1438.11 |
| DME/VOR | 1262.76 | 985.60 | 29395.47 |
| Multi Radio Integrated Navigation System | 2.59 | 2.28 | 3.05 |

## 4 Concluding remarks and further studies

In this paper, a multi thread based navigation algorithm module was designed in a multi radio integrated navigation system M&S S/W. In order to show usefulness of the multi thread based navigation algorithm module design, a navigation algorithm module in the multi-radio integrated navigation system for GPS, KNSS, Loran-C, eLoran, and DME/VOR was implemented in C++ under the Windows Operating System. The implementation results showed that the thread based design could be useful in the development of multi radio integrated navigation systems.

As further study, results on the multi thread based approach and addition of fixed and moving pseudolite navigaion system in the navigation module.

This work has been supported by the National GNSS Research Center Program of Defense Acquisition Program Administration and Agency for Defense Development.

## References

1. J. Lee, H. Kim, D.-H. Hwang, S. H. Oh and H. So, Multi-radio Integrated Navigation System M&S Software Design for GNSS Back-up, *Proc. of 2018 IEEE/ION PLANS*, pp. 1026-1033 (2018)
2. H. Kim, J. Lee, S. H. Oh, H. So, D.-H. Hwang, Design of Navigation Environment Generation Module of M&S Software for Integrated Navigation System Performance Evaluation, JPNT, **7**, 2, pp.73-90 (2018)
3. C.-M. Choi, K.-S. Ko, A Study on Development Direction of Navigation System for NAVWAR, JKIICE (in Korean), **19**, 3, pp.  756-763 (2015)
4. H. Kim, J. Lee, W. J. Yoo, S. H. Oh, H. K. Lee, H. So, D.-H. Hwang, Design of Navigation Environment Generation Module of Multi-radio Integrated Navigation System M&S Software for Countermeasure to Navigation Warfare, *Proc. of 2018 IEIE Summer Conference (in Korean)*, pp.791-794 (2018)
5. S. K. Jeong, T. H. Kim, C. S. Sin and S. U. Lee, Technical trends of smart jamming for GPS signal, ETRI Electronics and Telecommunications Trends (in Korean), **27**, 6, pp. 75-82 (2012)
6. A. Maria, Introduction to Modeling and Simulation, *Proc. of 1997 Winter Simulation Conference*, pp.7-13 (1997)
7. W. Stallings, *Operating Systems : Internals and Design Principles*, 4th ed. (Pearson Education International, Upper Saddle River, 2005)
8. A. Silberschatz, P. B. Galvin and G. Gagne, *Operating System Concepts*, 9th ed. (Wiley, River Street Hoboken, 2012)
9. U. K. Park, Development and Performance Evaluation of Dynamic Memory Management Methodology in Multithreaded System, The Journal of Applied Science Technology (in Korean), **11**, 1, pp. 55-76 (2002)
10. J. H. Lee, H. K. Song and T. G. Kim, Analysis and Application of Performance Improvement of a Real-time Simulation Visualization based on Multi-thread Pipelining Parallel Processing, JKSS (in Korean), **26**, 3, pp. 13-22 (2017)