Term Project Proposal - ITM Artificial Intelligence

Accurate target location tracking with deep learning approach

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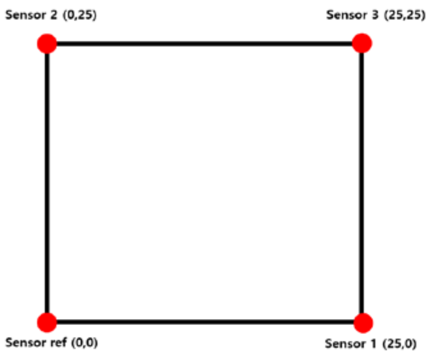
1. **What is the problem that you will be investigating? Why is it interesting? Why do you choose this topic?**

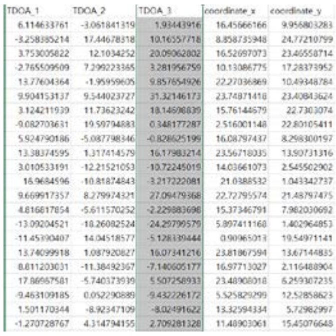
With the development of IT technology, unmanned systems are gradually being promoted in many fields. In particular, in unmanned stores such as Amazon Go, when a customer puts items in a shopping cart and goes straight to the exit without a checkout process, the product that purchased are identified and automatic payment is made. This technology is possible because many sensors and cameras in the store can be used to determine what products a customer has in their shopping cart. However, these sensors and cameras are expensive to purchase and for operate. In order to reduce cost, many technologies have been studied for accurately locating the target even in a narrow room but there are many obstacles.
Recent preliminary studies have tried to obtain accurate TDOA (difference in signal propagation time of different transmitters (also called tags) measured at receivers (anchors)) through several algorithms, especially deep learning. However, this method simply inferred the correct TDOA value and tracked the location using the hyperbolic equation, and did not use deep learning for the entire process. In addition, the method of estimating the position through TDOA is essential to find the intersection of the hyperbolic equations, but this process needs a lot of computer resources to solve these complex nonlinear equations.
Therefore, to solve these problems, we will build a deep learning model that estimates the exact coordinates of the target by using the TDOA values extracted from the rough space. In particular, we will build a CNN model by converting each TDOA measurement into a TDOA image. We expect that it will be possible to accurately and quickly determine the location of the target even in complex spaces such as unmanned convenience stores and indoor gyms.

2. **What dataset are you using? If needed, how do you plan to collect it? Please describe the dataset as much as you can.**

While training the model, we will use the TDOA and tag coordinate value data measured from real experiments. In the test, a virtual coordinate space as shown in Figure 1 was defined using 4 anchors, tags, and a Central Computing Unit (CCU). The TDOA measurement was made in the environment where the tag moves, and the target moves randomly and generates position coordinate log data every 0.1 seconds. Using these data, data as shown in Figure 2 was created. In the generated data, we will add additional noise to the TDOA value or change it to a 0 value to assume a rough environment. From the official announcement of the measuring device in Figure 3, the noise will be a value that more than the mechanical limit of the device which is 10cm.

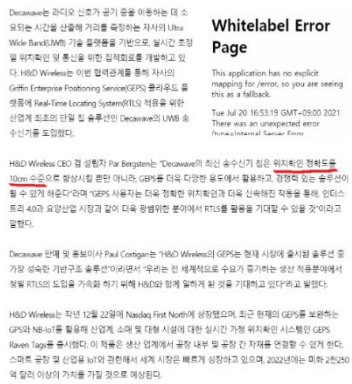


<Fig1. Virtual coordinate space>



TDOA_1	TDOA_2	TDOA_3	coordinate_x	coordinate_y
6.114633761	-3.061841319	1.93443916	16.45666166	9.956803283
-3.258385214	17.44678318	10.16557718	8.858735948	24.77210799
3.753005822	12.1034252	20.09062802	16.52697073	23.46558714
-2.765509609	7.299223365	3.281956759	10.13086775	17.28373952
13.77604364	-1.95959605	9.857654926	22.27036869	10.49348784
9.904153137	9.544023727	31.32146173	23.74871418	23.40843624
3.124211939	11.73623242	18.14698839	15.76144679	22.7303074
-9.082703631	19.59794883	0.348177287	2.516001148	22.80105411
5.924790186	-5.087798346	-0.828625199	16.08797437	8.298300197
13.38374595	1.317414579	16.17983214	23.56718035	13.90731316
3.010533191	-12.21521053	-10.72245019	14.03661073	2.545502902
16.9684596	-10.81874843	-3.217222081	21.0388532	1.043342737
9.669917357	8.279974321	27.09479368	22.72795574	21.48797475
4.816817854	-5.611570252	-2.229883696	15.37346791	7.982030692
-13.09204521	-18.26082524	-24.29799579	5.897411168	1.402964853
-11.45390407	14.04518577	-5.128339444	0.90965013	19.54971141
13.74099918	1.087920827	16.07341216	23.81867594	13.67144835
8.811203031	-11.38492367	-7.140605177	16.97713027	2.116488904
17.86967581	-5.740373939	5.507258933	23.48908018	6.259307235
-9.463109185	0.052290889	-9.432226172	5.525829299	12.52858623
1.501170344	-8.92347109	-8.02491622	13.32594334	5.72982997
-1.270728767	4.314794155	2.709281328	11.48903061	15.45076648

<Fig2. Examples of measured data>



Decawave는 라디오 신호가 공기 중을 이동하는 데 소요되는 시간을 산출해 거리를 측정하는 자사의 Ultra Wide Band(UWB) 기술 플랫폼을 기반으로, 실시간 초정밀 위치확인 및 통신을 위한 집적회로를 개발하고 있다. H&D Wireless는 이번 협력관계를 통해 자사의 Griffin Enterprise Positioning Service(GEPS) 클라우드 플랫폼에 Real-Time Locating System(RTLS) 적용을 위한 산업계 최초의 단일 칩 솔루션인 Decawave의 UWB 송수신기를 도입했다.

Whitelabel Error Page

This application has no explicit mapping for /error, so you are seeing this as a fallback.

Tue Jul 20 16:53:19 GMT+09:00 2021
There was an unexpected error

H&D Wireless CEO 겸 설립자 Par Bergsten는 "Decawave의 최신 송수신기 칩은 위치확인 정확도를 10cm 수준으로 향상시킬 뿐만 아니라, GEPS를 더욱 다양한 용도에서 활용하고, 경쟁력 있는 솔루션이 될 수 있게 해준다"라며 "GEPS 사용자는 더욱 정확한 위치확인과 더욱 신속해진 작동을 통해, 인더스트리 4.0과 요양산업 시장과 같이 더욱 광범위한 분야에서 RTLS를 활용을 기대할 수 있을 것"이라고 말했다.

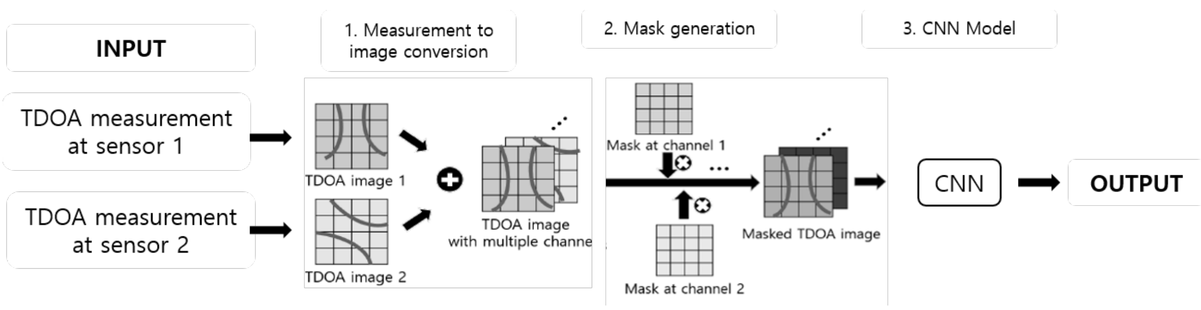
Decawave 판매 및 홍보이사 Paul Costigan는 "H&D Wireless의 GEPS는 현재 시장에 출시된 솔루션 중 가장 성숙한 기반구조 솔루션"이라면서 "우리는 전 세계적으로 수요가 증가하는 생산 적용분야에서 정밀 RTLS의 도입을 가속화 하기 위해 H&D와 함께 일하게 된 것을 기대하고 있다"라고 말했다.

H&D Wireless는 작년 12월 22일에 Nasdaq First North에 상장됐으며, 최근 현재의 GEPS를 보완하는 GPS와 NB-IoT를 활용해 산업계, 소매 및 대형 시설에 대한 실시간 가정 위치확인 시스템인 GEPS Raven Tags를 출시했다. 이 제품은 생산 업계에서 공장 내부 및 공장 간 자재를 연결할 수 있게 한다. 스마트 공장 및 산업용 IoT와 관련해서 세계 시장은 빠르게 성장하고 있으며, 2022년에는 미화 2천250억 달러 이상의 가치를 가질 것으로 예상된다.

< Fig3. official article of device peformance>

3. What method or algorithm are you proposing? If there are existing implementations, will you use them and how? How do you plan to improve or modify such implementations?

As mentioned earlier, we will train the CNN model by imaging the TDOA value. We propose a TDOA image based target tracking model to provide robust target tracking results in cluttered environment. Fig. 4 represents the overall procedure of model, which is composed of three steps; (i) measurement to image conversion (ii) mask generation (ii) CNN model for estimation. When TDOA measurements are obtained at CCU, each TDOA measurement is converted into image. Then, a mask is created to deal with measurement errors, where the value of mask can be determined by human (based on observation of environments) or deep learning architecture. By combining and treating TDOA images with masks as input data, we train a CNN model with fully connected layer to estimate target position. In section 4 about reference paper, there was similar subject but used LSTM model. However, we are going to convert TDOA to image and use CNN to predict precise target tracking result.



<Fig 4. System architecture for our proposed tracking model>

4. What reading do you examine to provide context and background? What papers (previous works) do you refer to?

1) Convolutional Neural Networks for Position Estimation in TDoA-Based Locating Systems (Niitsoo et.al 2018)

In this paper, they present a model to determine the exact location by combining TDoA and CNN deep learning model. Unlike in single-path scenarios, it is difficult to calculate accurate TDoA in multi-path scenarios. To overcome this problem, this paper solved the problem using CNN deep learning. The above paper differs from our goal to solve the communication uncertainty of the sensor due to obstacles. But the fundamental purpose of accurate location estimation using TDoA and CNN models is the same, I think this is a paper has many references, such as the model structure.

2) DeepTAL: Deep Learning for TDOA-Based Asynchronous Localization Security With Measurement Error and Missing Data (Xue et.al 2019)

Similar to our subject, this paper proposed an improved target location measurement algorithm using deep learning to overcome various errors such as data omissions due to obstacles, sensor errors, and network attacks. LSTM is applied to achieve stronger learning and better representation of target states and TDOA predictions. Experiments using the proposed algorithm showed that the accuracy was efficiently improved even in the case of measurement error or data omission. Although the definition of the problem to be solved is similar, they have successfully solved the problem using an LSTM network, unlike our approach of using a CNN network.

5. How will you evaluate your results? Qualitatively, what kind of results do you expect (e.g., plots or figures)? Quantitatively, what kind of analysis will you use to evaluate and/or compare your results? (e.g., what performance metrics)?

The difference between the model and the true value will be counted and expressed as a bar plot. By measuring the coordinates of the tag obtained through the trained model and the coordinate distance of the actual tag, we will train the model by reducing the distance difference, and evaluate how accurately the tag was measured by using distance difference. In addition, we will compare the three-layer FCNNs model with TDOA values input and tag coordinates output to see how more effective our proposed algorithm is in a rough environment where errors occur frequently.