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Stepwise Algorithms For Person And Object Tracking In Industry 4.0

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Industry 4.0,
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RFID,
IoT,
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Abstract: The data in a tracking event are usually an object that enables tracking, a tracked object, and the time information at which these two objects interact. These data can be obtained using different technologies which are expected to be widely used in Industry 4.0, such as RFID, image processers, ibeacon. These devices send their tracking data to the cloud thanks to the Internet of Things (IoT), which is also considered as one of the components of Industry 4.0. Thus "big data", another component of Industry 4.0, is formed. In this study, how to reduce tracking data without losing its value and then how to convert it into meaningful data by processing step by step are explained with prepared algorithms. By this processed data, traceability reports can be obtained quickly and accurately. The queries used for tracking and the relative time algorithms to evaluate efficiency were shared also in the study. It is aimed that software developers who want to set up tracking systems will benefit from these algorithms. Although studied tracking data is obtained by short-range RFID, these algorithms can be used for different technologies that perform object tracking.

Endüstri 4.0'da Kişi ve Nesne İzleme için Kademeli Algoritmalar

Anahtar Kelimeler
Endüstri 4.0,
Nesne Takibi,
RFID,
Nesnelerin İnterneti,
Nesnelerde Göreceli Zamanlama

Öz: Bir izleme olayındaki veriler genellikle izlemeyi sağlayan bir nesne, izlenen bir nesne ve bu iki nesnenin etkileşimde bulunduğu anki zaman bilgisidir. Bu veriler Endüstri 4.'da yaygın kullanılacağı tahmin edilen RFID, görüntü işleme, ibeacon gibi farklı teknolojiler kullanılarak elde edilebilir. Bu cihazlar, Endüstri 4.0'ın bileşenlerinden biri olarak kabul edilen Nesnelerin İnterneti (IoT) sayesinde izleme verilerini buluta gönderir. Böylece Endüstri 4.0'ın bir diğer bileşeni olan "büyük veri" oluşur. Bu çalışmada izleme verilerinin değer kaybetmeden nasıl azaltılabileceği ve daha sonra adım adım işlenerek nasıl anlamlı veriler haline dönüştürülebileceği hazırlanan algoritmalarla anlatılmıştır. Bu işlenmiş verilerle izlenebilirlik raporları hızlı ve doğru bir şekilde elde edilebilebilmektedir. Çalışmada raporlama için kullanılan sorgular ve ayrıca izleme verilerin birbirleriyle veya planlama verileriyle zaman farklarının çıkarılarak verimlilik değerlerinin ölçülmesi için hazırlanan algoritmalar da paylaşılmıştır. Böylece, izleme sistemleri kurmak isteyen yazılım geliştiricilerinin bu algoritmalardan faydalanmaları amaçlanmıştır. Bu çalışmada kısa mesafeli RFID kullanılarak izleme verileri alınmış olmasına rağmen, nesne takip işlemi gerçekleştiren farklı teknolojiler için de hazırlanan algoritmalar kullanılabilir.

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1. Introduction

With the development of technology, firms want to keep track of everything they use in the industry and use these data in decision-making. Thus, the objects in the industry are equipped with electronic units with sensors and connect to the Internet. So IoT has become widespread. Therefore, one of the most commonly used words in Industry 4.0 studies, which indicates the latest change in the industry, is "IoT"[1]. IoT is defined as the use of the Internet, devices and sensors for communication among people, machines and products [2]. Thanks to IoT, objects are monitored, products are delivered quickly, costs decrease and customer satisfaction increases [3]. The success of IoT applications will enhance by the standardizations of common requirements from different sectors and assurance of low energy security systems [4].

Different technologies such as RFID, ibeacon, GPRS, digital processing can be used for object tracking. RFID is used to search physical objects and has events like following the state changes of object/reader locations [5].

Similarly, the image processing technologies that make face detection and recognition using images obtained via cameras, videos, have started to be used in employee timekeeping and state security applications. In the literature, although the detecting algorithms are used for different objects, identification algorithms are used for only people. The most common of these applications use the face recognition systems with laplacian, eigenfaces or convolution neural networks ([6], [7], [8]). In spite of the different algorithms, all of them aim to recognize the tracked people. Another technology used for tracking is the ibeacon technology. Ibeacons, which work with much lower energy than Bluetooth and Wifi, can be used for location determinations by making calculations over the received data [9]. Regardless of which of these alternatives was used, obtained data is formed of object, time and place information. Therefore, the object tracking model explained in this study can also be applied when working with different technologies.

In the studied application, personnel tracking was done by using RFID. RFID has many advantages and so its usage is increasing [10]. Some of these advantages can be listed as follows: RFID system collects and evaluates data instantly, reduces labor costs, simplifies business processes and improves business efficiency [11]. In addition, RFID provides stock visibility. Thus, the leakage between physical stock and registered stock is prevented and errors and frauds are reduced [12]. On the other hand, due to continuous data flow with RFID, huge amount of data is read. Therefore, there is a need to reduce data volume in RFID studies [13]. In this study, model algorithms were prepared to reduce the volume of tracking data without losing their value and to obtain some reports from these large data.

In the second section of the study, system architecture and application areas of tracking algorithms , in the third section the data accepting and pre-processing algorithms, in the fourth section stepwise methods used for object tracking, in the fifth section the object track reports and in the last section the relative time calculation algorithms are explained.

2. System Architecture and Application Areas of Tracking Algorithms

The monitoring process is possible by the interaction between the tracker object and the tracked object. Each object is assigned a unique ID code to detect object in the track process. Mostly, the tracker object is asked to detect tracked object when it enters a certain area and to send this data for evaluation. On the other hand, in some systems like tracing applications in mobile phone, the tracked object detects the tracker object and sends these data. Especially with the widespread of smart phones, a lot of data like location of navigation , query code of bank operation, are started to be transmitted to different organizations.

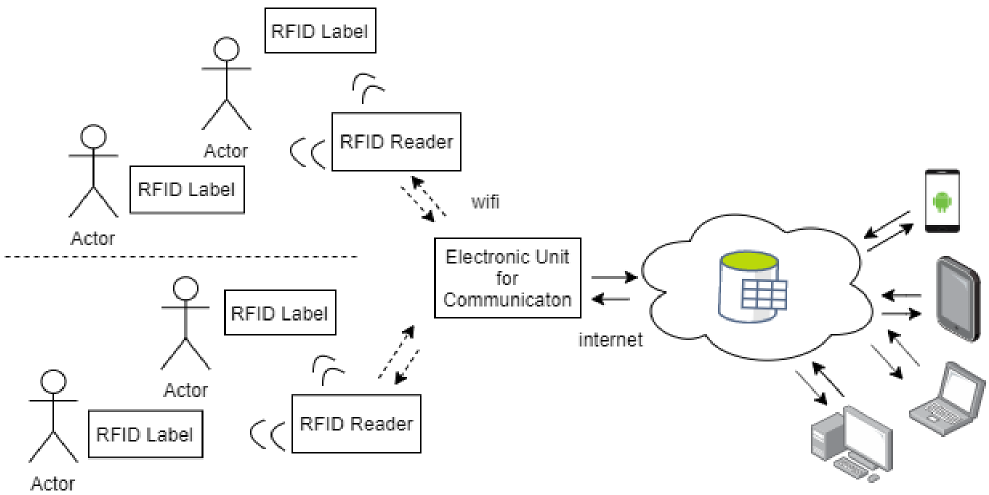

Figure 1. Architecture of the studied application

As a case study, staff movements in a food factory were investigated. First, meetings were held with the human resources manager and the production department manager regarding personnel tracking. Later, a department was selected to see the possible problems. Two short range RFID readers were placed in this department and the entrance and exit movements of the department employees were examined. In this application, RFID readers were used for the tracker objects and RFID tags were used to identify the tracked employees. Since short-range RFID readers were used in the application, these readers were placed near the entrances. As shown in Figure 1, RFID readers send data to the central electronic unit via Wi-Fi and afterwards this data is sent by the electronic unit to the server in the cloud via internet. This data is evaluated on the server. The RFID reader module follows the same path and reaches the evaluated data and transmits these data to the connected object. So this data can be used for identification and authorization.

This work does not deal with the production processes of the tracked object. In production activities, if different materials (objects) come together and a new product (object) occurs, a different algorithm is needed to follow this transformation. In other words, the proposed algorithm can be used as long as the identity code and quantity of the tracked object do not change. In addition, instead of detecting the coordinates of tracked objects, it is aimed to detect the identified places of objects in the study. Although, by using technologies, such as RFID or ibeacon, location coordinate estimates can be made by reading the same tag by more than one reader ([14], [15]), this study is not related with object positions.

The algorithms in this study can be applied to all monitoring technologies. An example of application usage can be the tracking of plate readers placed at different points in a city. In this way, if enough license plate reading devices are installed in the city, it can be observed where the vehicles are located in within a certain period of time. Another application of this algorithm can be tracking of animals that can be found in different locations on a farm. On the other hand, unlike the above examples, the tracked object which use proposed algorithms, may not able to move itself. The clothes having RFID tags in a store can be given as an example of this. Although RFID usage is not widespread at the small to mid-size enterprise (SME) level in current applications, this situation is expected to change in the future. Besides, RFID tags are likely to be used not only for tracing, finding and counting objects, but also for other purposes, such as gathering information on consumer behaviour from stock movements in the store.

3. Simplifying and Matching Tracking Data

RFID readers send the RFID tag numbers to the databases within specific time periods. Thus, the basic data required for object traceability are collected and stored in the databases. These data are device identification number, identification number of the tracked object and time data. If the data sent to the database belongs to an undefined device or undefined object, it is requested to separate this data from the others. This can occur most of the time when unwanted objects are read by the system. Also, sometimes, an RFID card or RFID reader which was not previously defined can be read for the first time from the system for identification. Therefore, in the first step in the database, it is queried whether the RFID card number or device number being read belongs to an identificated object or not.

The device numbers that detect the tracked object are matched with the places of these devices. The place in this matching, identifies the data carrying or containing tracked object instead of specifying a local position [13]. Similarly, the identification numbers from the RFID tags used for the monitored objects were matched with the identification numbers of the objects. The tables used in the initial stage for object traceability are as follows:

UnknownObject (RFIDID, DeviceID, Datetime)
RFIDMove (RFIDID, DeviceID, Datetime, Transmission)
ObjectMove (ObjectID, PlaceID, Datetime)

If "RFIDID" and "DeviceID" data sent to the database do not belong to a previously defined object, the sent data are recorded in "UnknownObject" table, whose data is stored for a short time. If these data belong to defined objects, they are recorded in the "RFIDMove" table, whose data are stored for longer time than previous table. The "UnknownObject" table is used to introduce a new device or a new RFID tag for the first time. Occasionally, an unwanted RFID tag can be read and added to this table. After this step, it is queried whether the previous record of reached RFID tag number (RFIDID value) is read from the same device. "Transmission" value of the data read from the same device in the "RFIDMove" table becomes "False". If the last record for this label identification number does not belong to the same device, its "Transmission" value returns "True" and the location, time, and object number that match these data are saved in the "ObjectTrack" table. If the value is "False", no action is taken because this match suggests that there is no change in the object location. RFIDMove table records which is older than one month is deleted. So this algorithm (Figure 2) reduces data volume.

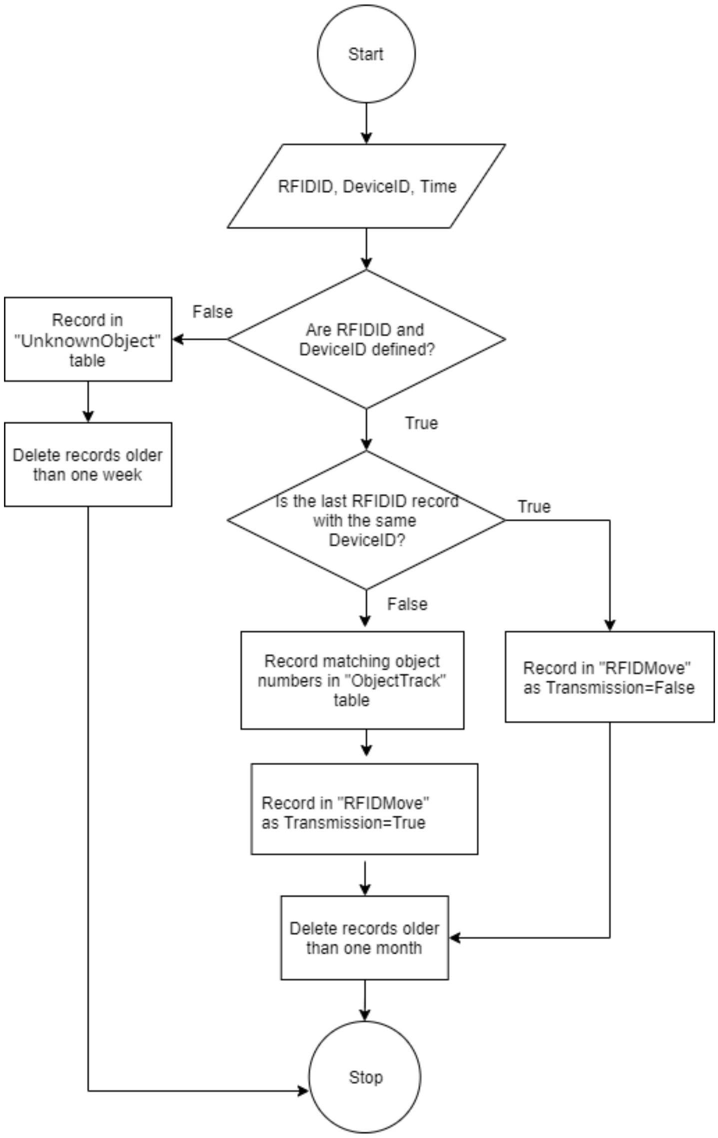

Figure 2. Flowchart for reduction and transmission of tracking data

After this stage, the tracked object can be queried for some reasons like door opening permissions or machine operation permissions. Since query authorizations are done within triggers in databases, permissions can be resulted in a much shorter time than one second after the data is sent.

“RFIDID” and “DeviceID” data detected from the system are matched instantly with “ObjectID” and “PlaceID“ using triggers , and these matching data are added to the “ObjectMove” table. Therefore, it is not a problem to change the "ObjectID" which the "RFIDID" matches, or the "LocationID" which the "DeviceID" matches. Moreover in practice these changes are often made. These changes can occur for many reasons, such as giving the same RFID tag to another product because of being discarded or sold.

4. Data Transformation Algorithms for Object Tracking

Data in RFID applications is dynamic. Since these data indicate the state of the instant readings, data conversion is needed for analysis [16]. In this study, “ObjectMove” tables matching with tracking records are going through transformation processes. In order to query these high volume data instantly, view structures were used. As it is known, view structures do not hold data, they are mostly used for visual purposes. In this study, a high amount of data was processed step by step with view structures and so desired structure was reached.

Data from the RFID reader and subsequently processed into the “ObjectTrack” table may not be in accordance with the time sequence. Even time data of the same object may not be sequential for different reasons, such as power failures. In addition, this data does not show how long the object is in one place and where it is seen afterwards. To deal with these problems, a gradual data transformation was performed using the “view” structures in the database. The "ObjectMove" table can be converted to the "ObjectMoveView" , which is required for quick retrieval of reports, by using 6 view steps.

ObjectMove(ObjectID, PlaceID, Datetime) → ObjectMoveView(ObjectID, StartDatetime, EndDatetime, Time_min, PlaceID)

The views used for this conversion are as follows.

View1: By extracting the first record of each object, object and time data are obtained.

```
Create view [dbo].[WithoutFirstObjMoveView]
as
select ObjectID, Datetime  from ObjectMove o
except
select ObjectID, convert(datetime,min(Datetime)) as Datetime from ObjectMove  group by ObjectID
```

View2: For each record obtained in View1, the nearest historical record with the same object number in this view is found. These records are combined to obtain a view of the object ID, start time and end time data.

```
Create view [dbo].[TimeIntervalView]
as
select  i.ObjectID,  (select  max(p.Datetime) as j from  ObjectMove p
where p.ObjectID=i.ObjectID and   p.Datetime <i.Datetime)  as StartDatetime, i.Datetime as EndDatetime
from
WithoutFirstObjMoveView i
```

View3: By matching “View2” and “ObjectMove” table, places are found. Then these places are added into View2”. In addition, the time between the end time and the start time is calculated for each record.

```
Create view [dbo].[ObjectMoveTimeView]
as
select z.ObjectID, p.PlaceID, z.StartDatetime, z.EndDatetime, convert(int,
datediff(second,z.StartDatetime,z.EndDatetime)) as [Time_sec]
from TimeIntervalView z
join ObjectMove p
on z.ObjectID=p.ObjectID and   p.Datetime =z.StartDatetime
```

View 4: The last time record is found for each object.

```
Create view [dbo].[ObjectMoveLastDatetimeView]
as
select max(Datetime) as LastDatetime, ObjectID from ObjectMove group by ObjectID
```

View 5: Place data is added to the previous view.

```
Create view [dbo].[InstantObjectPlaceView]
as
select distinct v.ObjectID, ph.PlaceID, v.LastDatetime
from ObjectMoveLastDatetimeView v
join ObjectMove ph
on
ph.Datetime=v. LastDatetime
```

View6: The last place and time of the objects are added and the time and place of the movements of the whole time period are displayed.

```
Create VIEW [dbo].[ObjectMoveView]
AS
Select      o.ObjectID , o.StartDatetime, o.EndDatetime, [Time_sec]/60  as Time_min, o.PlaceID
FROM          dbo. ObjectMoveTimeView o
                                   Union
Select a.ObjectID, convert(SmallDatetime, a.LastDatetime), convert (SmallDatetime, getdate()),
convert(bigint,datediff(minute,a. LastDatetime,getdate())), a. PlaceID
FROM DBO.InstantObjectPlaceView a
```

The data types in the “ObjectMove” table and the views derived from this table were selected to use the smallest amount of memory in order to increase processing speed and reduce the memory usage. Therefore, “ObjectID” and “DeviceID” should be defined as integers.

5. Main Reports from Object Tracking Algorithms

"What reports are needed to measure staff movements" were asked to human resource and production department officials in the food factory. In this context, the reports that are thought to be most needed are as follows:

- Instant query of object's places.
  Select ObjectID, PlaceID, max(StartDatetime), EndDatetime from ObjectMoveView
  where (PlaceID =@ObjectID or @ObjectID=0)

- Getting place history of an object between two datetimes.
  Select ObjectID, PlaceID, StartDatetime, EndDatetime from ObjectMoveView
  where StartDatetime>=@qStart and EndDatetime<= @qEnd and (PNo=@ObjectID or @ObjectID=0)

- Distribution of total time of objects according to places between two datetimes.
  Select ObjectID, PlaceID, sum([Time_min]/60) as Hour from ObjectMoveView
  where StartDatetime>=@qStart and EndDatetime<= @qEnd and (PNo=@ObjectID or @ObjectID=0)
  group by ObjectID, PlaceID

6. Relative Time Algorithms

Relative time algorithms compare two time intervals whose have common points. This can be the comparison of the time intervals between two objects or an object time interval can be compared with a plan.

Proposed relative time algorithms were given by drawing the general framework only, because the conditions in the relative calculations of the objects may vary depending on the need. As an example of relative computational comparisons of objects can be given a refrigerant which is switched on and off, and the time of an object which is carried from this refrigerant to another area. Another example can be the machine's working time intervals comparison with operators work time intervals at the machine.

These algorithms compare the start and end times with each other and make judgments about how objects behave according to the result obtained. While making comparisons, measured time was called as object time and the other time was called as plan time to understand easily.

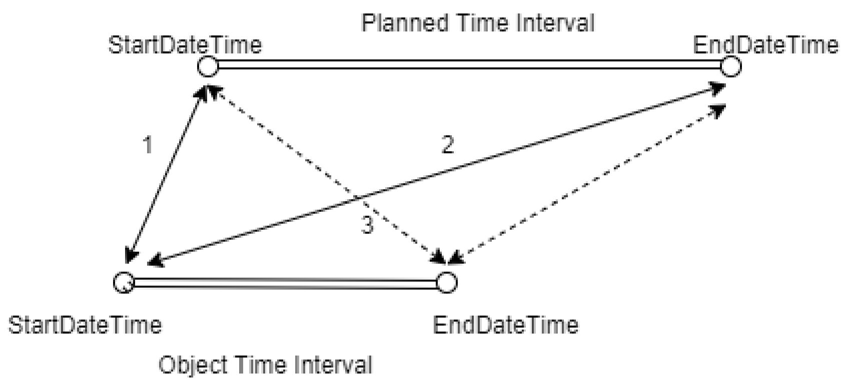

Figure 3. Comparasion between two time intervals

1. Comparison: Is the object tracking start time less than or equal to the plan start time?
2. Comparison: Is the object tracking start time smaller than the plan finish time?
3. Comparison: Is the object tracking end time smaller than the plan start time?
4. Comparison: Is the object tracking end time smaller than the plan end time?

Tablo 1. Classificafication based on comparisons

Comparisons			
1.	2.	3.	4.

Irrelevant Movement Before Plan	1	1	1	1
Early Start and Early End	1	1	0	1
Early Start and Late End	1	1	0	0
Late Start and Early End	0	1	0	1
Late start and late finish	0	1	0	0
Irrelevant Movement After The Plan	0	0	0	0

Traceability of employees is based on time intervals and location. So, the common points in the case study are locations. In the case study, how much the employees fit into working hours was measured. In practice, these plans were prepared periodically. So, it was tried to measure how well the employees act according to the periodical plans. The view structures were used to collectively observe how much the plan was complied with in the case study. It is often necessary to add customizations to these comparisons. For example, an employee can reach his department one minute before the planned time or one hour before. Although both of them are classified under "early started" group, their affects are different actually.

Discussion and Conclusion

With Industry 4.0, it is expected that the human factor in the industry will reduce, inter-object communication will increase and control decisions are taken by the objects. Accordingly, monitoring of objects and evaluation of object movements will become widespread in the future. Regardless of what technology is used, a tracking event is the result of the tracking object, the tracked object, and the interaction between the two. Therefore, similar algorithms can be utilized in object tracking events. In this study, how to track objects and what reports can be obtained by using "tracked object", "tracker object" and "time" data are presented. An algorithm was proposed using flowchart to reduce data volume with triggers. The data obtained using technological equipment were processed to get requested reports quickly. The final data structure was achieved by six steps with the proposed view structures. Hence, the final data structure can be used to get the desired reports and the relative time calculations. Relative time calculations between objects are presented to measure how effectively the objects act. Relative time algorithms can be used by making necessary customizations for calculation of delays, disruptions and incompatibilities. Thus, an infrastructure that can be used as a model for future object tracking studies was prepared. In the future, studies should be carried out in order not to harm the living and nature when these systems are used. Therefore, more detailed studies should be carried out for the side effects of monitoring systems and possible damages should be considered as much as the costs of the systems.

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