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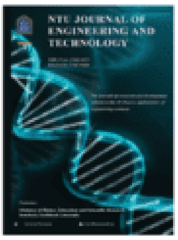

Integration of DeepSORT and RFID Technology for Enhanced Human Tracking

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ABSTRACT

Human activity tracking enhances safety and reduces the risk of people getting lost or kidnapped. This paper presents a human tracking system using the YOLOv8n detection model, DeepSORT tracking algorithm, and RFID technologies on low-power devices like the Raspberry Pi.
The passive RFID tags, which do not require batteries, make the system lightweight and maintenance-free. The Raspberry Pi Model V3 camera, with an 8-megapixel Sony IMX219 sensor, captures video at 640x480p90 resolution.
The YOLOv8n algorithm was trained on 2292 images, achieving an accuracy of 0.992 for mAP50 and 0.902 for mAP50-95. After integrating it with DeepSORT, the system achieved MOTA = 0.973684 and MOTP = 0.438766 at 30 fps.
In real time, tracking for 20 frames yielded MOTA = 1.0 and MOTP = 0.13. The UHF RFID reader detected tags at a distance of 1.5 meters.

Introduction

Recently, object tracking has gained great importance, and has become one of the most important topics in computer vision [1]. Human tracking technologies offer many benefits, but there are some risks and concerns associated with them, including privacy, informed consent, chilling effects, and ownership of tracking data [2]. Occlusion issues, motion blur, and lighting changes in video sequences are among the reasons that lead to tracking failure [3].

The issue of missing persons is considered one of the most important issues of concern to the Iraqi environment. The reason for this is that the missing person may be a friend or relative who disappeared as a result of the conflicts and unrest that this country experienced. The number of missing persons in Iraq over the past five decades ranges from 250,000 to more than one million individuals [4]. One of the groups most affected by the loss of security is children, as they live in an environment full of excessive violence. The Times newspaper reported that 265 Iraqi children were kidnapped during the first nine months of 2009, and that security forces were only able to return 30% of them [5].

Therefore, the spread of tracking technologies that enable a person to know the individual's location and his or her travel path is of great importance in maintaining the security and safety of citizens [6]. Deep learning has greatly advanced the field of people tracking in various applications such as security, surveillance, crowd or congestion evaluation, and many others [6]. The authors of this study propose a tracking method based on computer vision and RFID technologies. Passive UHF RFID Tag is small in size and does not require a battery.

Literature Review

In 2010, Xiaodong Lin et al. [7] developed an RFID-based system to locate missing children in large public areas like theme parks. The system involves a collaboration between control rooms, storage nodes, and strategically placed RFID readers. When a child wearing a passive RFID tag approaches a reader, the reader processes the data and ensures the child's identity privacy through the REACT approach. Simulations demonstrated that the system's performance improved with more users, enhancing the ability to find lost children.

In 2012, Kanchan kamble [8] proposed a GPS is used for determining the location, and the method of communication may be a satellite, land radio cellular link between the automobile and the receiver of a radio, a satellite, or close cellular tower. The transmitter's GSM modem transmits the automobile's location from a far-off location to the mobile device making the request. Latitude and longitude will be sent to the proprietor via a message. Additionally, utilizing RS232 cable, the data is transmitted to the pc for output. Finally, the accurate location of the car will be traced utilizing software that graphs a point (or tiny circle) as the vehicle on a map of the city that has been scanned.

In 2015, Zahida Kawther [9] developed a centralized control system using GPS, GPRS, and an Arduino UNO microcontroller to locate lost pilgrims during Hajj. The system uses GPS-equipped mobile phones or wristband trackers for children and the elderly. When a pilgrim is reported missing, the system queries their passport number or GPS ID via a graphical user interface, displaying their location on a Google map. This approach enhances safety during large-scale events like Hajj by using affordable GPS technology.

In 2016, Trupti, Patil, Karhe [10] develop a system of tracking for each young child who goes the school. A child system for tracking will monitor the child's movements whenever they go outside the home. Additionally, if a youngster is weeping, it will notify the parents. As a result, parents do not need to constantly watch over their children's movements because the system will notify them if their youngster leaves the designated region. The system will not only provide Location of the child but also provide information whether child is crying or not and if child requires emergency help through the text message.

In 2020, Widodo, et al, [11] suggested a research for a tank-based army robot prototype that uses a PID controller for object detection and tracking to simulate shooting the object enemy utilizing computer vision. Unmanned Ground Vehicle (UGV), or robots used for military uses, are typically utilized to increase a soldier's ability. Instead of soldiers shooting at one other on the field of battle in the future, war will be fought between operators and machines.

In 2020, Sharooq A. and A. Mural [12] developed an RFID-based system to enhance student safety in schools. The system includes ARDUINO, RFID devices, GSM modem, GPS, LCD display, and buzzer. GPS tracks the child's location, while RFID confirms identity. Parents receive real-time location updates via SMS, and are notified if any safety issues arise. The system displays the pupil's name and ID on an LCD screen, and sends the data to parents' phones. By accessing the school database, parents can monitor their child's activities from home.

In 2023, Taha A., et al, [13] proposed one important technique to decrease kidnap and disappearing kids is with the use of contemporary technology. The GPS and GSM technologies can be employed to tracking a little one. Since not all families have the same standard of living, a cheap child tracker system is suggested here. Additionally, this suggested strategy operates in real-time. The offered strategy makes it feasible for preventing kidnappings affordably.

Methodology of Software Part

YOLOv8

The success of Yolov8 stems from the updates to previous Yolo versions, as this version is considered a distinctive model that provides better accuracy and a faster detection process. YOLO v8 was announced it in January 2023 by Ultralytics [14]. YOLOv8 has different models with like: Nano-sized, Small-sized, Middle-sized, Large-sized, and Extra-large sized [15]. The figure 1 illustrates the architecture of yolov8 which composed of Backbone, Neck, and Head.

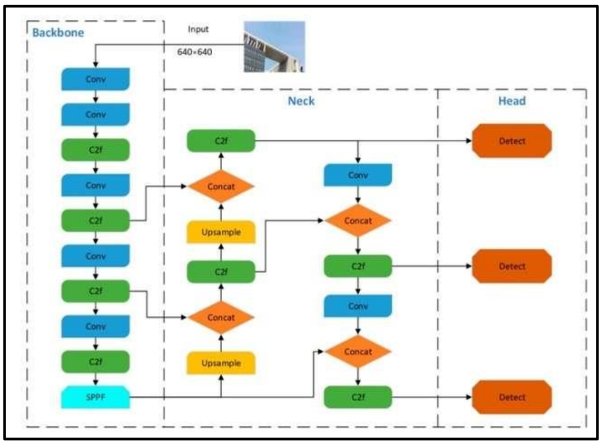

Figure 1. Structure of YOLOv8 [15].

Backbone: responsible for extracts the features of image with the various resolutions.

Neck: Collect and merge the features of images for the various resolutions.

Head: the final stage for detection object, which would generates last predictive based on object resolutions [16].

DeepSORT

The abbreviation of DeepSORT is Simple Online and Real-time Tracking with a Deep association metric [17]. DeepSORT approach it is the high level algorithm of identification and tracking objects, it is considered strong and fast [18]. The detection and tracking the objects walk together, side by side. Detection the object means a process identifying the wanted object in a frame, whilst during the tracking operation there is a trajectory for every object in the video. Figure 2 shows in generally form the stages of the detection and tracking any object [19].

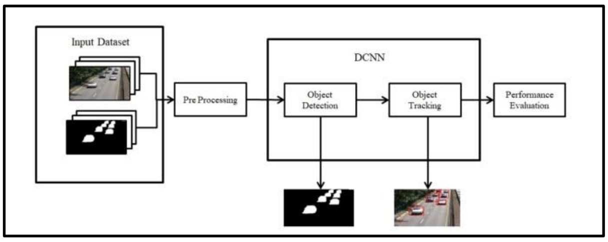

Figure 2 Stages of Process of Objects Detection and Tracking [19].

After the detection process done on the input's video, a tracking process begin, at the first stage a Kalman filter would process the frames of the video then the DeepSORT approach completed the process, the last stage is the Hungarian assignment, these process are illustrated in figure 3 for multi-object tracking.

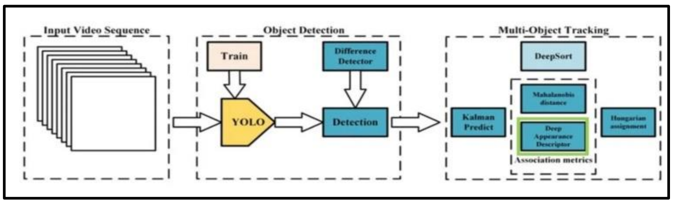

Figure 3 The Flowchart of Detection and Tracking an Object [18].

Kalman filter used for prediction the location of object in the prior frame. While Hungarian algorithm uses both location of the object and appearance information's for matching process, after that the tracking process would complement [20].

Methodology of Hardware Part

UHF RFID Reader

The Dioche Brand UHF RFID Reader, shown in Figure 4, is ideal for a variety of applications requiring long-range and effective tag scanning since it has a long reading distance and high-speed reading capabilities.

Figure 4 UHF RFID Reader.

The key characteristics of this kind are listed in Table 1[21].

Table 1 Features of UHF RFID Reader [21]

feature	Description
Brand	Dioche
Special Feature	Waterproof
Read Range	0-6 meters
Reliable Distance	3 meters
Frequency	902-928 MHz
Communication	USB,RS232,Wiegand26/34/96
Power Supply	12 v DC
Antenna	Built-in Circularly Polarized Antenna
Support Protocol	18000-6c passive tags
Model	R16-0-5m/0-16.4ft Close-Range Integrated Reader
Weight	3.83 pounds
Product Dimension	8.46"L x 8.46"W x 1.97"H
Data Rates	115200 bps (default 9600 bps)
Power Range	(0.1-1) W

RFID Tag

The solution using a passive RFID tag, which does not contain a battery and has a low cost, is considered the most suitable solution for tracking objects [22].

Figure 5 shows the ALN-9662, it's a passive tag, which works at 860-960 MHz, other features of it showing in Table 2 [23].

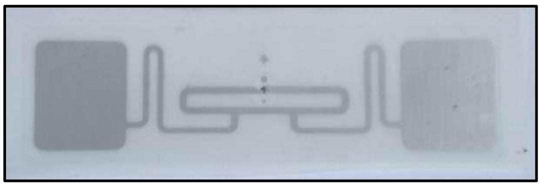

Figure 5 ALN-9662 RFID Tag.

Table 2 The Features of RFID Tag ALN-9662 [23]

Tag Classification		General Tag
Compliance Standard		EPC Class1 Gen2
Operating Frequency		860-960MHz
Operating Mode		Passive
Data Transfer Rate		Up to 640 kbps
Manufacture		Aluminum etching
Antenna Dimension		70mm x 17mm
Storage Temperature		-40 to 85 °C Non-condensing
Operating Temperature		-40 to 65 °C Non-condensing
Recommended Storage		30%~85%(Limits)
ESD(HBM)		2,000V±
Chip IC type		Alien Higgs-3
memory	EPC	96 EPC Bits, Extensible to 480 Bits
	User	512 User Bits
	TID	64 Bit Unique TID
	Password	32 Bit Access and 32 Bit Kill Password
	EEPROM data retention	10 years
	EEPROM write endurance	100,000 cycles

RS232 to TLL Converter

It's a male connector of serial type DB9 from ANMBEST Brand in figure 6 illustrate the outside look for it, with weight of 0.07 kilograms and has only one port for provide bidirectional data communication in range of 300 to 115200 bps.

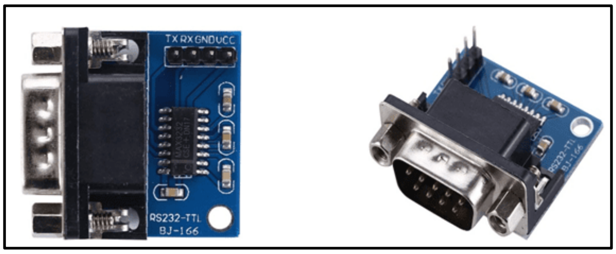

Figure 6 The Outside Look of the RS232 to TTL Converter [24].

Raspberry Pi 3Model B+

Raspberry pi is a small single board developed by Raspberry Pi Foundation in United Kingdom. Due to its small size, high speed and its power consumption is low, raspberry pi 3 model B+ board as shown in figure 7 this board works at 1.4 GHz 64-bit quad-core.

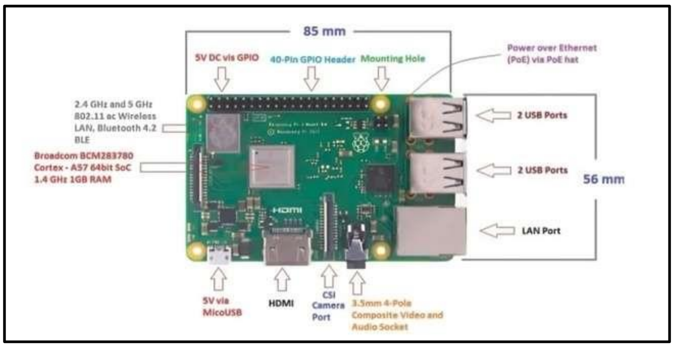

Figure 7 Raspberry Pi 3 Model B+ [25].

Raspberry Pi Camera V2

Raspberry pi camera v2 which released in 2016 with 8-megapixel with dimensions of 25x23x9 mm and 3 g and comprises of Sony IMX219 is compatible with raspberry pi 3 model B+ as shown in figure 8.

This camera uses for capturing images and videos, with 3280x2464 pixels for images and multiple resolutions for video at 1080p30, 720p60 and 640x480p90. Raspberry pi camera is connected directly to raspberry pi 3 model B+ through CSI interface, this interface used only for this purpose.

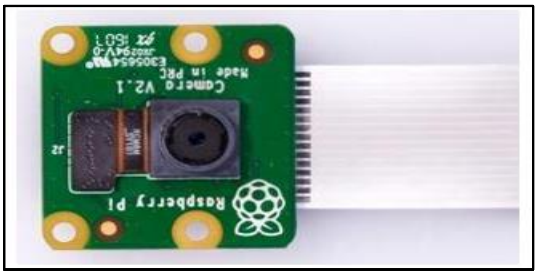

Figure 8 Raspberry Pi Camera v2 [26].

PC Computer

A 8th Generation Intel® Core™ i7-8565U Processor and a graphic card is Nvidia MX130 2GB DDR5 and 15.6 inches size of screen and type of panel is full HD 1920x1080 as shown in figure 9 [27].

Figure 9 PC Computer.

Methodology of Hardware and Software Integration

The proposed system integrates both hardware components and software processes to track human movement and associate it with RFID data.

Figure 10 shows the hardware components for the proposed system, the system consists of a UHF RFID reader that captures the identity information from RFID tags attached to people or objects, and the captured data is converted through an RS232 to TTL converter to a Raspberry Pi 3 Model B+ controller. Besides, video frames are captured using a Raspberry Pi camera. And display the results on the personal computer.

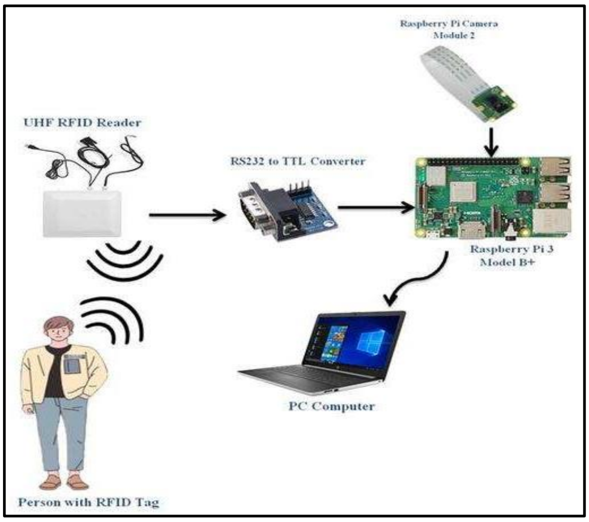

Figure 10 Schematic of Proposed System.

Figure 11 shows the flowchart of the whole system at the software level, the system processes video frames using the YOLOv8 algorithm to detect objects, and tracks them using the DeepSORT algorithm. The process begins with capturing frames via the camera, followed by reading the RFID data. The YOLOv8 algorithm is then used to detect and locate objects in the video. If objects are detected, bounding boxes are extracted and the objects are tracked using the DeepSORT algorithm. The RFID data is then combined with the annotated frames and saved for display or analysis.

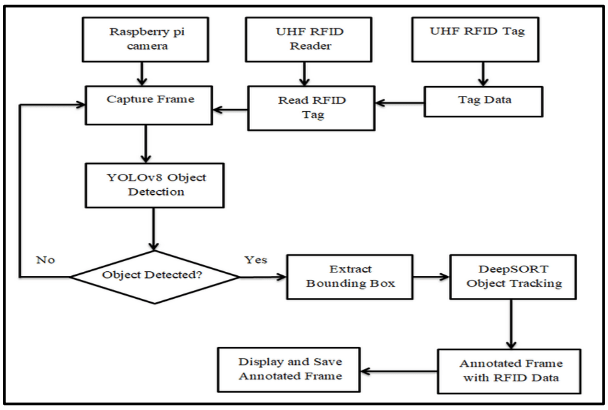

Figure 11 Flowchart of the Proposed System.

Metrics of Object Tracking

MOTA (Multi-Object Tracking Accuracy)

MOTA has score range from (−∞, 1); it said that the system has poor performance when MOTA in negative values, and 1 it means best performance.

$$MOTA=1-\frac{\sum_t(FN_t+FP_t+IDS_t)}{\sum_t GT_t} \quad (1)$$

Where:

FN: False Negative
FP: False Positive
IDS: number of ID switches.
GT: number of ground truth objects

MOTP (Multi-Object Tracking Precision)

MOTP has score range from (0, ∞); where 0 means perfect performance and ∞ means worse performance.

$$MOTP=\frac{\sum_{k=1}^{N}\sum_{i=1}^{c_k} d_{i,k}}{\sum_k^N c_k} \quad (2)$$

Where:

k = 1 to N: This represents the frames in the sequence, where N is the total number of frames.

c_k: Number of correct detected object at frame k

$d_{i,k}$: Means the distance between detected object I in frame k and the corresponding ground truth object [28].

Results and Discussions of Tracking Algorithm

To track the detected object(s), DeepSORT performs this process. The figure 12 shows the tracking system's output of several frames use a 5 second video downloaded from internet with a frame rate of 30fps. The tracking algorithm assigned each element a unique number that remained constant for that element throughout the video frames.

Figure 12 Results of DeepSORT Algorithm
(a) At Frame 6, (b) At Frame 66, (c) At Frame 132 and (d) At Frame 153.

In the context of tracking, confidence scores for detected objects may remain relatively stable within a frame. The reason for this is that the tracking algorithm uses temporal information from multiple frames to preserve the identity of the tracked objects.

The figure 13 provides a clear visualization of how the model's tracking confidence varies across video frames. The curve shows the confidence degrees for two different path IDs (1, 2) in the video frames. The confidence degrees for the two path identifiers (1, 2) range between 0.3 and 0.9. There is a noticeable decrease in confidence at frames 40 and 140, while it is relatively stable between frames 50 and 130 and mostly ranges above 0.7. Fluctuations in confidence scores indicate causes such as occlusion and rapid movements of objects. High confidence scores in the middle frames indicate stable and reliable tracking during those frames.

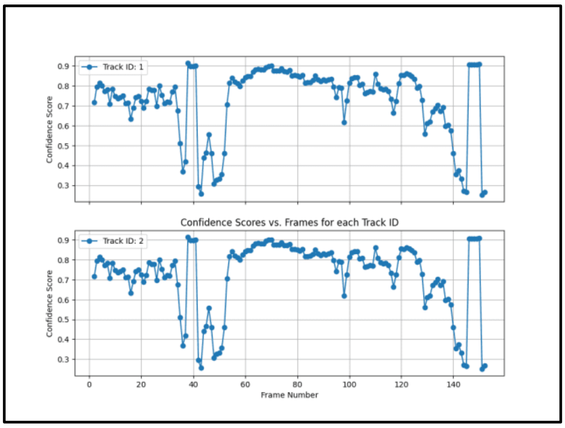

Figure 13 Confidence Score with Frames for each ID Track

Where:

X-axis: Frame Number (progress of the frame)

Y-axis: Confidence Score

Figure 14 indicates the final MOTA and MOTP results of the tracking system.

```
          mota       motp
acc  0.973684  0.438766
Final MOTA: 0.9736842105263158
Final MOTP: 0.43876627063908824
```

Figure 14 MOTA and MOTP for the whole Frames

Figure 15 shows the degrees of MOTA and MOTP along the video frames. The MOTA score is close to 1.0 almost along the length of the tires, which indicates a high level of tracking accuracy. MOTA decreases slightly in the last frames due to changes in lighting and rapid movements of objects. The MOTP score ranges between 0.4 and 0.5 across the video frames. Fluctuations in the MOTP score indicate differences in the accuracy of the bounding boxes across different frames.

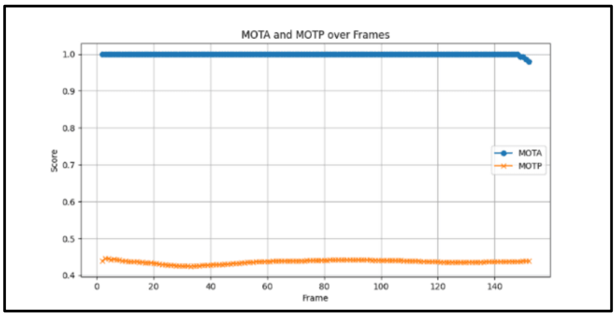

Figure 15 MOTA and MOTP over Frames

Where:

X-axis: Represents the progression of video frames.

Y-axis: Represents the MOTA and MOTP scores.

Testing the Tracking System in Real-Time

Figure 16 shows the interconnections of hardware components that implemented for tracking person(s) in real world, it's consist of Personal Computer (PC), Raspberry Pi 3 Model B+, Raspberry Pi Camera Module V2, RS232 To TTL Converter, UHF RFID Reader and Passive UHF RFID Tag(s).

Figure 16 Interconnections of Hardware Components

Testing the Tracking System in Real-Time without RFID Technology

To test the system in real time to track the detected human object, utilized the DeepSORT algorithm to give each object a unique number that accompanies it throughout the period of its presence within the system area. Figure 17 shows a number of frames for 20 fps, The ID of the item, in addition to the class, and the extent of confidence that this element belongs to this class.

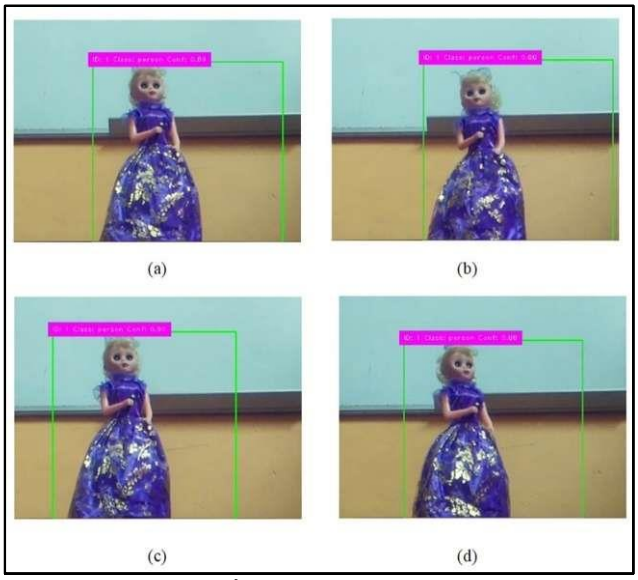

Figure 17 Results of Tracking Model in Real-Time (a) At Frame 3, (b) at Frame 7, (c) At Frame 11 and (d) at Frame 15.

Testing the System in Real World with RFID Technology

As the tracking system start, the raspberry pi camera v2 capture the video in real time which is connected to raspberry pi 3 model B+, the video will process by YOLO and DeepSORT as an individual frames. UHF RFID Reader connect to raspberry pi 3 model B+ through RS232 to TTL Converter, so it will reads UHF RFID Tag(s) and send its reading to raspberry pi 3 model B+ through RS232 to TTL Converter, then the raspberry pi 3 model B+ will associated this reading with its object and show that on raspberry pi camera. Figure 18 shows the results of real time tracking system. It is worth noting that the distance between the UHF RFID reader and the UHF RFID tag was 1.5 meters.

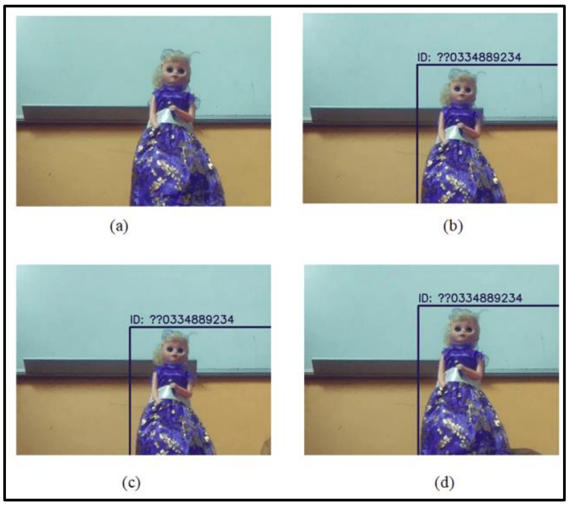

Figure 18 Real-Time Object Tracking at Different Frames
(a) Frame 1, (b) Frame 8, (c) Frame 11 and (d) Frame 19.

The accuracy performances (MOTA and MOTP) for 20 frames were 1.0 and 0.13 respectively.

Conclusion

In this work, a prototype for human tracking using Raspberry Pi 3 Model B+ and RFID technologies is presented. The simplicity of the mechanical part of the proposed system and its integrated part make the system easy and available. The proposed system for people detection and tracking was implemented on a personal computer and then deployed on low-power devices such as the Raspberry Pi Model P+, supported by a Raspberry Pi Model V2 camera. The camera continuously takes pictures of the scene. The UHF RFID reader reads the UHF RFID tag continuously. The proposed system was based on three stages: the first is to detect people with the help of the trained YOLOv8 algorithm, the second is to track them with the help of the DeepSORT algorithm, and the third is to prepare the system to work in real-time. The system's accuracy results confirm its effectiveness in tracking people. Environmental factors such as overlap and lighting can hinder the performance of the RFID reader and the camera.

References

[1] Wu,Y., Lim, J. and Yang, M.H.(2013) Online object tracking: A benchmark, in Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 3102 pp.2411–2418.doi / 01.0011 : , CVPR.2013.312.

[2] Hucklesby,A. and Macnish,K. Tracking People Network Briefing Paper 2 The Ethics of Tracking People ”,Arts and Humanities Research Council,University of Leeds 3101.

[3] Zhang, L. and Fan, H. (2023) Visual object tracking: Progress, challenge, and future ,Innovation ,vol. 4, no. 2. Cell Press, Mar. 13, 2023 . doi 01.0101 : j.xinn.2023.100402 .

[4] ICMP Missing Persons in Iraq: Short Guide for Families of the Missing,” International Commission on Missing Persons. Accessed: May 06, 2024. [Online]. Available : https://www.icmp.int/?resources=missing-persons-in-iraq-short guide-for-families-of-the-missing.

[5] “انتهاكات الولايات المتحدّة الأمريكية لحقوق أطفال ونساء العراق,” *الاتحاد العام لنساء العراق بالاشتراك مع الاتحاد النسائي العربي العام*, جنيف, Nov. 2010. Accessed: May 06, 2024. [Online]. Available : https://www.ohchr.org/sites/default/files/lib-docs/HRBodies/UPR/Documents/session9/US/GFIW_GeneralFederationofIraqiWomen.pdf.

[6] Deepika, C., and Sowmiya, A. (2023) Person Identification And Tracking Using Deep Learning *IJARIIE-ISSN(O)-2395-4396* ,Vol. 9, No. 2, PP. 871–878, 2023 .

[7] Lin, X., Lu, Kwan, R., D. and Shen, X. (2010) REACT: An RFID-based privacy-preserving children tracking scheme for large amusement parks, *Computer Networks* ,vol. 54, no. 15, pp. 2744–2755, Oct. 2010 ,doi : /10.1016j.comnet.2010.05.005.

[8] Kamble, K. P. (2012) Smart Vehicle Tracking System ,*International Journal of Distributed and Parallel systems* ,vol. 3, no. 4, pp. 91–98, Jul. 2012 ,doi/10.5121 :ijdps.2012.3410.

[9] Parveen, Z., and Aldhlan, K (2016) . Missing Pilgrims Tracking System Using GPS, GSM and Arduino Microcontroller ”,*International Conference on Recent Advances in Computer Systems (RACS 2015* ,(pp. 23–27, 2016 ,doi : /10.2991racs-15.2016.4.

[10] Trupti, M., Chaudhari, R., Patil, D. A. J., and Karhe, M. R. R., (2016) RFID and GPS based child tracking system with voice recognition for

security ",*International Journal of Scientific Development and Research* ,vol. 1, no. 12, pp. 179–184, 2016, [Online]. Available : www.ijsdr.org.

[11] Budiharto, W., Irwansyah ,E ., Suroso, J. S., (2020) and A. A. S. Gunawan, "Design of object tracking for military robot using pid controller and computer vision ",*ICIC Express Letters* ,vol. 14, no. 3, pp. 289–294, 2020 ,doi : /10.24507icicel.14.03.289.

[12] Ahamed, S., and Murali, A. (2020) RFID BASED SCHOOL CHILDREN TRACKING AND SAFETY ENHANCEMENT SYSTEM ", *Journal of Engineering Sciences* ,vol. 11, no. 7, pp. 986–991, 2020, [Online]. Available : www.jespublication.com .

[13] Taha, T. A., Hussain, A. S. T., Desa, H., Taha, F. H., and Bektaş, Y. (2023) Child tracking system using smartphone ",*Bulletin of Electrical Engineering and Informatics* ,vol. 12, no. 5, pp. 2745–2752, 2023 ,doi : /10.11591eei.v12i5.5161.

[14] Wang, G., Chen, Y., An, P., Hong, H., Hu, J., and Huang, T. (2023). UAV-YOLOv8: A Small-Object-Detection Model Based on Improved YOLOv8 for UAV Aerial Photography Scenarios. *Sensors*, *23*(16), 1–27. https://doi.org/10.3390/s23167190.

[15] Zhai, X., Huang, Z., Li, T., Liu, H., and Wang, S. (2023). YOLO-Drone: An Optimized YOLOv8 Network for Tiny UAV Object Detection. *Electronics (Switzerland)*, *12*(17), 1–21.https://doi.org/10.3390/electronics12173664.

[16] Kateb, F. A., Monowar, M. M., Hamid, M. A., Ohi, A. Q., & Mridha, M. F. (2021). FruitDet: Attentive feature aggregation for real-time fruit detection in orchards. *Agronomy*, *11*(12). https://doi.org/10.3390/agronomy11122440.

[17] Liu, W., and Zhang, L. (2022). Academic Journal of Science and Technology Aerial Traffic Statistics Based on YOLOv5+DeepSORT. *Academic Journal of Science and Technology*, *3*(3), 198–201.

[18] Lingineni, D., Dusi, P., Jakkam, R. S., and Yada, S. (2023). Object Detection and Tracking Using DeepSORT. *Lecture Notes on Data Engineering and Communications Technologies*, *142*, 303–312. https://doi.org/10.1007/978-981-19-3391-2_23.

[19] Kumar, C. K., and Rawal, K. (2022). A Brief Study on Object Detection and Tracking. *Journal of Physics: Conference Series*, *2327*(1). https://doi.org/10.1088/17426596/2327/1/012012.

[20] Luo, H., and Zeng, Z. (2023). Real-time Multi-Object Tracking Based on Bi-directional Matching. *ArXiv.Org*, *abs/2303.08444*. https://doi.org/10.48550/ARXIV.2303.08444.

[21] Card Reader, UHF Passive Electronic Tag RFID Reader for Parking System Access Control Waterproof Passive Electronic TAG RFID Integrated Card Reader Access Control Readhead 5m(Can connect to Internet) [Online].Available:https://www.amazon.com/Passive-Electronic-Waterproof-Integrated networking/dp/B07YZ8NW22.

[22] Xunxun, W. (2010). *Design of Passive UHF RFID Tag Antennas and Industry Application*.

[23]*AZ-9662*. (n.d.). [Online]. Available: https://www.idmart.com.tw/download/Inlay/AZ9662/AZ-9662%20Dry%20inlay%20datasheet%20v1.0.pdf.

[24] 5PCS MAX3232 3.3V to 5V DB9 Male RS232 Serial Prot to TTL Converter Module Root Connector for Arduino Raspberry Pi and Microcontrollers [Online]. Available: https://www.amazon.com/ANMBEST-Converter-Connector-Raspberry-Microcontrollers/dp/B0B1CRS8LG.

[25] Arabboev, M., Begmatov, S., Nosirov, K., Shakhobiddinov, A., Chedjou, J. C., and Kyamakya, K. (2021). Development of a Prototype of a Search and Rescue Robot Equipped with Multiple Cameras. *International Conference on Information Science and Communications Technologies: Applications, Trends and Opportunities, ICISCT 2021*. https://doi.org/10.1109/ICISCT52966.2021.9670087.

[26] Raspberry Pi Camera Module V2-8 Megapixel,1080p (RPI-CAM-V2) [Online]. Available: https://www.amazon.com/Raspberry-Pi-Camera-Module-Megapixel/dp/B01ER2SKFS.

[27] HP Notebook 15-da1071ne Product Specifications [Online]. Available: https://support.hp.com/us-en/document/c06289744.

[28] Aguilar, C., and Ortner, M. (2022). Josiane Zerubia. Small Object Detection and Tracking in Satellite Videos With Motion Informed-CNN and GM-PHD Filter. *Frontiers in Signal Processing*, *2*. https://doi.org/10.3389/frsip.2022.827160ï.