Future Generation Computer Systems ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Platform for controlling and getting data from network connected drones in indoor environments

Adrián Arenal Pereira [a], Jordán Pascual Espada [a,*], Rubén González Crespo [b], Sergio Ríos Aguilar [b]

[a] Department of Computer Science, University of Oviedo, Asturias, Spain
[b] International University of la Rioja, La Rioja, Spain

HIGHLIGHTS

- Platform for managing connected drones in indoor environments.
- This platform uses drones as a connected actuators and sensors.
- The server sends UDP messages for move the Drones following a flight plan.
- The platform uses the drone data sensors to estimate the current location in the room.
- System for monitoring a network of drones equipped with environmental sensors.

ARTICLE INFO

Article history:
Received 31 July 2017
Received in revised form 12 December 2017
Accepted 4 January 2018
Available online xxxx

Keywords:
Internet of things
Connected drone
Web services
Drones
Sensors
Internet of drones
Indoor Flight planner

ABSTRACT

Nowadays drones can be used to complete a wide range of different tasks, like patrol, transportation and data collection. Many of these tasks are developed in indoor environments, like industrial premises, factories and buildings. This research work proposes a novel platform to manage drones in indoor environments. The proposed platform raises to manage drones like an internet of connected devices with sensors and actuators. This platform is based on a network of connected drones which communicates with a central server. Drones can be managed by users using a web application. The application allows to define flight plans and to get the drone sensor's data. Drones are connected to the server using a Wi-Fi network, they exchange constantly UDP messages. Using this platform users can design flight plans using an interactive map. Flight plans can be saved and sent to a connected Drone. This platform allows users to manage drones as connected objects, running flight plans and visualizing drones' sensor data in real time. The proposal also can be adapted to many specific industrial uses, including new sensors in the drone like, gas, temperature, radiation, etc. or some actuators like grippers or dispensers.

1. Introduction

Internet of things systems aim to connect and communicate physical devices for many different purposes. Connected objects can work as sensors or/and actuators, through the network they can send or receive data. IoT systems emphasizes the importance of machine-to-machine communication to automate or improve tasks or offer new services [1,2]. Many IoT platforms have been introduced successfully in a lot of fields [3].

Many IoT platforms are based on technologically simple devices, like sensors or small actuators [4]. Other solutions require more complex devices, like robots or drones [5]. Connecting robots to networks for managing or monitoring them is now a widely-used approach [6,7].

Technological development and the cost reduction of drones are encouraging their use for industrial and professional systems [8,9,10]. Many of these systems are based on a direct drone teleoperation, but some of them explore the advantages of joining drones with Internet of things approaches [11]. Controlling drones through the internet opens new possibilities. Also, drones can be used as mobile sensors for getting data in remote areas [12].

Approaches for controlling drones would be classified in: direct teleoperation, specifying flight plants/destination points. The second mechanism usually requires less "attention" or "work" by the user. A user could move simultaneously more than one drone using flight plans but it is difficult to teleoperate more than one drone at the same time. Drones can be managed like other connected objects they can send and receive data through the

---

* Corresponding author.
E-mail address: pascualjordan@uniovi.es (J.P. Espada).

https://doi.org/10.1016/j.future.2018.01.011
0167-739X/© 2018 Published by Elsevier B.V.

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.

network, moving drones in outdoor environments is usually easier than moving then in indoor environments. Most flight plans are based **on** GPS (locations). For most of drones is technically simple move to a certain GPS location, but moving to a location inside a building is much more complex.

This research work proposes a platform for controlling and monitoring connected drones in indoor environments. Connected drones are controlled using indoor flight plans which are defined by users in a web application. Every user action during the design of the flight plan is processed by the application and translated in an automatic communication flow between the server and the selected drone. Proposed approach allows to control one or multiple connected drones in a quick and efficient way. The system is also valid for monitoring tasks, it shows data from drone sensors, and it is designed for including extra external sensor. This feature could allow to create monitoring systems based on mobile connected sensors.

2. Background

There is a wide range of connected objects and electronic devices which are part of IoT systems. Most common connected things are sensors and small embedded devices which usually control sensors and actuators. These kinds of IoT systems are very popular in industrial environments [13], homes and smart cities [14]. IoT related technologies are in a continuous and fast evolution process. There are a lot of future directions and uses for this kind of technologies [15].

Nowadays IoT systems are not limited to connecting simple sensors or actuators, it is also frequent to include connected robots. However, it is not really a new trend, some of these systems for controlling robots though internet were developed more than 20 years ago [16] and they were followed by many other systems which were more complex and powerful [5]. In many cases robots work as sensors and actuators, they can be very suitable devices for performing monitoring tasks [17,18].

For an IoT system connected robots are like other connected devices. Robots have communication capacity, sensors, and actuators, but usually, they have a greater intelligence or autonomy than other simple connected objects. Robots were integrated into a lot of IoT systems, mainly in industrial, medical or military environments [19].

Many IoT proposals include the robot in the system as a set of services which can be used by other connected objects. These services are commonly related to movement, sensing and taking actions [6]. Integration of robots in IoT systems means that the communication and collaboration between things can be used for achieving new goals. Some systems combine robot sensors with external sensor networks for improving some of the robot functionalities [20], like the path planning [21].

Simoens' proposal [7] uses external sensors placed in wearables for improving the accuracy of assistive robots which do interventions for assisting patients. This research work was also one of the firsts in use the specific term "Internet of Robotic Things" which refers to a specific type of IoT systems. There are also many other proposals based on the similar architecture applied to other topics like human detection in case of disasters [22], or robot localization [23]. Some IoT systems use robots like mobile nodes in a network. Communication among robots can be useful to improve tasks [24]. Like Cho's platform for managing smart homes offering robot services through a network or the internet connected robots [25]. Connected robots can also be effective mobile sensors for monitoring indoor places [26].

Some approaches like "Robot Cloud" pose cloud computing architectures for manning groups of robots [27]. Technologies related to robotics also progress very fast, including new features and a cost reduction. Drones would be considered as a kind of mobile robot which can fly, this main feature enables to use them in many new tasks. Sometimes authors use different names to refer to Unmanned aerial vehicle, these names depend on the size, weight and other features (Drones, UAV, etc. [28])

Drones also can include sensors for getting data and receiving orders like an actuator. Drones are used today in a wide range of tasks like logistics tasks, patrol areas, infrastructure maintenance, maps generation using cameras or sensors [29]. Many of the platforms use connected drones as teleoperated vehicles through the Internet, basing the system communication on low level services directly related to the drone basic movements or commands. There are a lot of challenges related to offer more complex services like assign tasks to the drones, agricultural activities, surveillance, deliver merchandise, substances and dangers detection [30].

There are many high quality commercial applications and research projects for connecting drones to the internet and managing them in outdoor environments [11,31]. However, many indoor environments still present difficulties and lack accuracy. There are many challenges related to self-location and movement [32,33]. Drones usually have a lot of internal sensors. They can use these sensors to improve navigation or sharing data with other external systems [34]. Although technically drones can be used for many tasks we must know that they can raise some legal or security problems, especially when they work surrounded by people [35,36].

All proposals are not limited to connecting a drone to an application for managing it. Drones connected to the internet have been used for many years [37]. The next level has been allowed connecting multiple drones to IoT systems and manages them as connected objects. Currently, some authors refer to this kind systems as "Internet of Drones" [38–40]. Drones are joining to many internet of things systems [41]. Some systems propose to combine connected drones with external network sensors for improving the flights [42], or doing agricultural activities [43].

Some IoT Systems use connected drones with high level services (like the move to positions, or complete tasks) for managing and monitoring net of drone, these systems will allow a lot of new features including managing many drones at the same time [38]. There are some theoretical models concerning these kinds of systems, but very few functional platforms. This research work proposes a novel IoT platform for managing connected drones in indoor environments. Proposed platform will provide high level services for designing the flight plans and getting data from connected drones.

3. Proposed platform

The main objective of this platform is to provide a new approach for managing connected drones in indoor environments. In order to achieve this objective, we have designed a proposal composed of the following parts:

- The web application specially designed for manage the drones. Some of the functions of these applications are: defining flight plans and enabling continuous communication with the drones for sending and accomplishing these flight plans. The web application must be executed in a server which is physically placed near the drone, due to the fact that the application must be on the same private Wi-Fi network as the drones.
- A local Wi-Fi network which covers whole the indoor place. The server and the drones must be connected to this network.
- One or more Drones connected to the server. Drones send and receive data from the server. Used drones must have Wi-Fi connection and an Open API for controlling them

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.

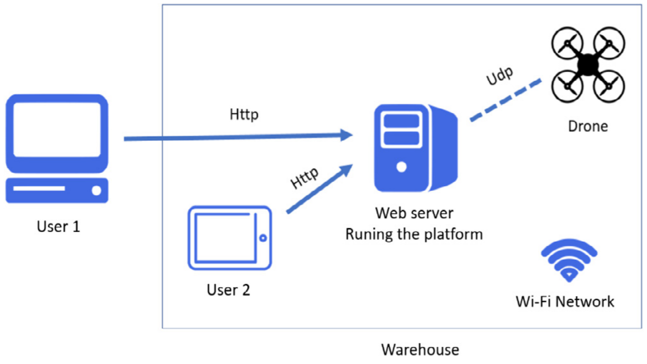


Fig. 1. Platform conceptual scheme.

through a software application. The API allows to send flight commands to the drone and to get drone sensor data. During the design and developed phase of this research work, we have used parrot Drones: Bebop 2 and Bebop.

Web server executes the platform web application, users can access remotely to this application using different devices like tablets or computers. The server must be connected to a local Wi-fi network which covers all the indoor flight area, we can use Wi-fi repeaters if the area is large. Additionally, the server can be connected to the internet, in this case, clients can access from outside the building, but in most of cases it would be better used only a local network for security reasons.

Users define in the web application the flight plan. For executing the flight plan the application asks for the initial location of the Drone. Using UDP protocol the server sends **takeoff** message to the drone. After this initial command the server starts a constant communication flow with the Drone, one message every second. However one message can contain multiple movement commands. The server starts to analyze the defined flight plan and it calculates how the drone can reach the first point in the plan. This process requires sending UDP messages to the drone for changing the drone rotation, speed and flight height. Also, when the server sends the commands it requests the data of the Drone Sensors (compass, distance, battery).

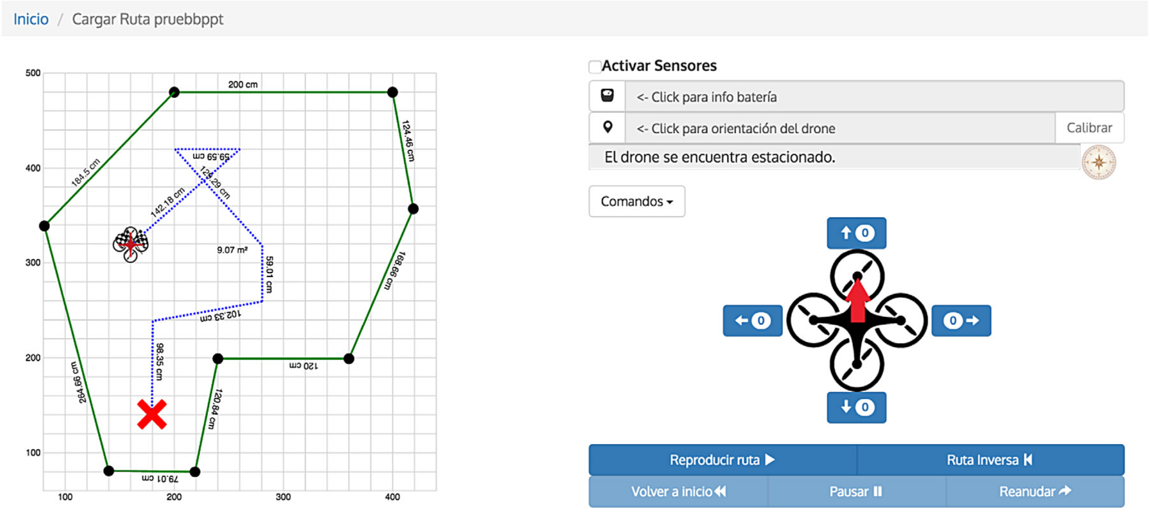
The application knows approximately how far the commands sent move the Drone (this information was obtained in a previous phase, doing multiple flights and analyzing which kind of movements are the most accurate). Combining the known approximations and the drone sensors data the server estimates the new location of the drone. The new location of the drone is shown in the interactive map. When the drone ends to execute movements related to the current point the server, continues executing the process for next points in the flight plan. This process continues until the server finishes the flight plan but the user can cancel the process at any moment or ask the drone to return to the initial location (reverse the flight plan). The conceptual scheme of the platform is shown in Fig. 1.

Users can define the floor in the interactive editor, drawing the walls. These maps are saved in JSON format and can be shared with other users. The map editor contains the measures of the walls for defining an exact representation.

Once the map is defined or loaded the user can define a flight plan. The first step is to put the initial location of the drone. The map is based on a grid of 20 cm squares, this is the minimum movement which the drone can execute accurately (but the platform allows to change this minimum distance, other drones like phantom 4 can do shorter movements) (Fig. 2). The drone speed is constant during the flight, however, sometimes the drone can be stopped for a few seconds to calibrate the location. The user can create a flight plan using the grid, also the user would specify a different flight height for every point in the plan, flight plan points are 3D space points.

When the flight plan is done, a user can connect the platform to the drone. After this if the user launches the flight plan the server starts to process it and send the commands to the drone. Drone sensors information is shown in the right part of the screen, and in the map. The user can see the current location of the drone; it is a real-time monitoring process.

The communication process between the application and the drone is done using UDP (User Datagram Protocol), the Drone is controlled using the API node-bebop contained in the node module 0.6.0 "node-bebop". For sending messages to the drone and the server which runs the applications must be connected to the same WiFi Network. The first message sent to the drone is to establish a connection. When the drone is connected the application sends the **takeoff** command. Some commands like takeoff include a callback message so the application knows when the drone is in the air. Once starting the flight the application starts to send an ordered sequence of commands, some of these commands are: stop, up(value), land, down(value), left(value), forward(value),



El drone se encuentra estacionado.

Fig. 2. Screenshot of the application. In the left part, the user can define the map and the points of the flight plan, this flight plan has 7 key locations/points. The right part shows information about the connected drone.

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.

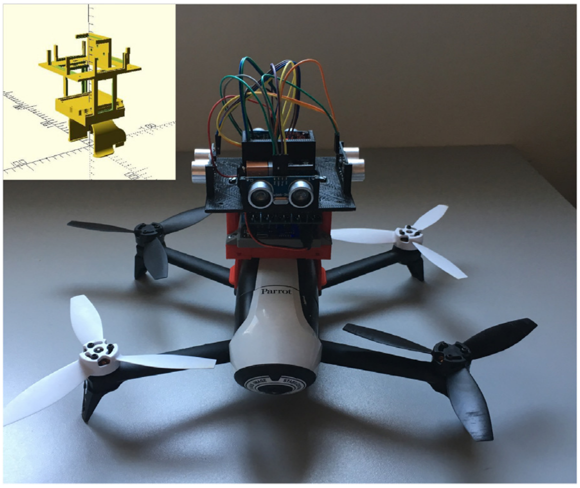


Fig. 3. Parrot bebop drone 2 with external distance sensors supported by an Arduino board with ESP8566 Wi-Fi.

backward(value), clockwise(value), counterclockwise(value). The application divides the flight plan into a small group of movements, every time these movements are executed to the Drone the application updates the location of the drone and it can calculate some corrections in the flight plan.

Commands are not the only communication system; the drone also can start a communication process and send events to the server. If the events are activated they are sent automatically when some states of the drone change, like the battery level, hovering and measurement of sensors.

In some experiments, we have included extra sensors in the Drone, adding an Arduino microcontroller (Wemos D1R2 with ESP8266 Wifi R2, 32 Mb Flash), 5 extra distance sensors HC-SR04 based in ultrasonic sounds are placed on the: right, left, forward, behind and up. A digital compass and a small battery. This Arduino Board was attached to the top part of the drone using a 3D printed structure. All sensors are managed using the digital inputs and outputs of the Arduino board, also the compass require a specific library to obtain the measures (Fig. 3).

The extension board acts like another connected device, the server asks the drone data and the Arduino data in two different requests (two devices have a different local IP). The data provided by the Drone sensor and the Arduino system is merged for improving the knowledge about the environment. Extra sensor data is useful for getting more accuracy in movements, allowing: comparison of movements in respect to one or more points, some triangulations and an anti-crash system. More information about the environment is useful when there are some conditions which can reduce the accuracy of the flight like many open windows, fans or mobile obstacles. However, many types of drone include many internal distance sensors, so this kind of Arduino extension is not necessary.

4. Use case

The platform was tried many times. In this section, there is a description of a use case in which the platform was used for controlling and getting data from a connected drone in 3 flight plans. The platform was installed in an indoor soccer field. A laptop was working as a server, running the main web application. A Parrot bebop 2 Drone 2 was used as a test drone. Main features of the drone are:

- 500 g weight
- Wi-Fi 802.11a/b/g/n/ac
- Signal range: 300 m
- Network: MIMO Dual band
- Wi-Fi: 2.4 and 5 GHz
- Processor: Quad-code GPU.

The laptop was connected to the drone through a Wi-Fi network. We designed 3 flight plans for patrolling the area of the indoor soccer field. (outer edges, zig-zag and spiral Fig. 4).

After designing a flight plan it had been sent to the Drone. At the end of the experiment, the drone successfully completed all of them (Fig. 5). The Drone sent to the platform the internal sensors and battery data, the application sent to the drone the required movement commands to reach the locations. During the execution of the flight plans, it checked that the sensor data showed in the application was right and updated in real time.

5. Evaluation

The proposed platform allows to define and execute indoor flight plans using connected drones. The evaluation process will be divided into two different parts. In the first part, we evaluate the flight plan‘s web application, for checking if users can manage connected drones in an easy way. In the second part, we evaluate the automatic communication process between the application(server) and a drone for executing a set of flight plans, during the flight plan the application(server) starts a bidirectional communication process which implies coordinate all of the drone movements and locations in the defined flight plan.

The web application was evaluated by 6 users, we asked users to do the 5 most common tasks in the application:

1. Load a map of the first floor of a building from an external JSON file.
2. Define a flight plan, based on some indications. The drone must be moved through 10 key locations. User must define a valid flight plan.
3. Save the previous flight plan in the platform. Saved flight plans can be loaded.
4. Connect the software application to the drone and execute the flight plan. The drone ins already turn on. After executing the flight plan user must locate and watch the measurements of the drone sensors during the flight.
5. Delete the previous flight plan in the platform.

We evaluated if users finished these tasks and how long they took. Users did not receive any support or help during the evaluation. They tried to complete these tasks only analyzing the (Fig. 6) application user interface. The following chart shows the average times of beginner users for every task (1–5), these times are compared to the times of an expert.

All beginner users completed the 5 tasks. As expected task 2, define a flight plan, was the most complex. For task 2 average time was 136,1 s. Beginner users needed 39,8% more time to do task 2 and 21,7% for task 3.

Next part was focused on the communication between the application(server) and drones. It had been analyzed the design and execution of 6 different flight plans, which are a significant sample about how the platform works. A descriptive name was assigned to every one of the flight plans.

1. 3 m distance, straight line.
2. 6 m distance, straight line.
3. 6 m distance, 4 direction changes.
4. 12 m distance, 4 direction changes.
5. 6 m distance, 8 direction changes.
6. 12 m distance, 8 direction changes.

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.

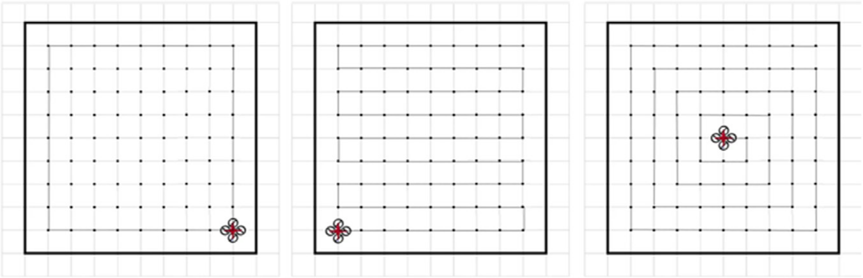


Fig. 4. Flight plans used for patrolling the area: 1 outer edges, 2 Zig-zag and 3 spiral.

Table 1
Data obtained during the design and execution of 6 flight plans.

Flight Plan ID	Key locations	Mouse clicks	Distance	Direction changes	Sent Commands
1	2	3	3	0	19
2	2	3	6	0	34
3	6	7	6	4	38
4	10	11	12	4	72
5	6	7	6	8	42
6	10	11	12	8	76
Total Σ	36	42	45	24	277

Fig. 5. Bebop 2 drone during the platform test.

Fig. 6. Blue bars show the average time for beginner users for doing the tasks. Red bars show the expert user time for the same tasks. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

For every flight plan it had been registered:

- *Key location* in the flight plan. Key locations are specified by the user for defining a flight plan. The application completes the path between every pair of key locations.
- *Mouse clicks*. Number of clicks used by the user for designing the flight plan.
- *Distance* traveled by the drone.
- *Direction changes* during the execution of the flight plan. A direction change is every time the drone turns right, left or backward.
- *Sent commands*. Number of commands sent by the application to the drone. Results are shown in the following table.

Obtained information is shown in Table 1.

Analyzing these data, it was an average of 7694 commands automatically sent from the server to the drone to move to a key location. A user click in the flight planner application was translated into a communication flow of 6595 commands. The application sends an average of 6155 commands to move the drone 1 m accurately.

6. Conclusions and future work

The main objective of this research work was to present a novel IoT platform for controlling and monitoring connected drones in indoor environments. Based on use cases and the evaluation process we can observe that proposed platform can be a valid approach for monitoring drones in indoor environments. All evaluated users completed the tasks and the platform response was satisfactory.

Related to machine-to-machine communication, the platform should promote the automatic communication between server and drones with a low interaction by the user. An average of 6,5 movements commands were sent to the drone for every user click in the application. Flight plans do not have to be defined and executed at the same time so this platform would allow one user to control more than one drone. The monitoring system of the platform had been designed in a generic way, not focused on a specific industry, it allows to include extra sensors using an Arduino board. The Platform can be a solid base to create industrial systems to control drones in patrol/transportation activities and to create monitoring systems based on mobile connected sensors.

Future research lines are related to designing new high-level services, to allow search processes based on sensor information. For example, to do an automatic flight in a delimited area and search locations where the humidity is more than 80%.

References

[1] L. Atzori, A. Iera, G. Morabito, The Internet of Things: A survey, Comput. Netw. 54 (2010) 2787–2805. http://dx.doi.org/10.1016/j.comnet.2010.05.010.

[2] G. Kortuem, F. Kawsar, D. Fitton, V. Sundramoorthy, Smart objects as building blocks for the Internet of things, IEEE Internet Comput. 14 (2010) 44–51. http://dx.doi.org/10.1109/MIC.2009.143.

[3] P. Suresh, J.V. Daniel, V. Parthasarathy, R.H. Aswathy, A state of the art review on the Internet of Things (IoT) history, technology and fields of deployment, in: 2014 Int. Conf. Sci. Eng. Manag. Res., ICSEMR 2014, 2014. doi:10.1109/ICSEMR.2014.7043637.

[4] M. Ashwini, S. Gowrishankar, Siddaraju, Internet of things based intelligent monitoring and reporting from agricultural fields, Int. J. Control Theory Appl. 9 (2016) 4311–4320.

[5] D. Schmid, B. Mäule, I. Roth, Performance teletests for industrial robots by the internet, IFAC Proc. 34 (2001) 147–150. http://dx.doi.org/10.1016/S1474-6670(17)41696-X.

[6] Y. Chen, H. Hu, Internet of intelligent things and robot as a service, Simul. Model. Pract. Theory 1 (2012). http://dx.doi.org/10.1016/j.simpat.2012.03.006.

[7] P. Simoens, C. Mahieu, F. Ongenae, F.D. Backere, S.D. Pestel, J. Nelis, F.D. Turck, S.A. Elprama, K. Kilpi, C. Jewell, A. Jacobs, Internet of robotic things: Context-aware and personalized interventions of assistive social robots (short paper), in: Proc. — 2016 5th IEEE Int. Conf. Cloud Networking, CloudNet, 2016, pp. 204–207. doi:10.1109/CloudNet.2016.27.

[8] K. Ichihara, Technologies and applications in the drone industry, J. Japan Inst. Electron. Packag. 19 (2016) 408–415.

[9] A.B. Rice, Drone technology as applied to the cement industry, in: IEEE Cem. Ind. Tech. Conf., 2016. doi:10.1109/CITCON.2016.7742662.

[10] D. Hill, Researchers have high hopes for drone use in transportation, Civ. Eng. 84 (2014) 38–39.

[11] M. Erdelj, M. Król, E. Natalizio, Wireless sensor networks and multi-UAV systems for natural disaster management, Comput. Netw. 124 (2017) 72–86. http://dx.doi.org/10.1016/j.comnet.2017.05.021.

[12] S. Lentilhac, UAV flight plan optimzed for sensor requirements, IEEE Aerosp. Electron. Syst. Mag. 25 (2010) 11–14. http://dx.doi.org/10.1109/MAES.2010.5442171.

[13] F. Li, J. Hong, A.A. Omala, Efficient certificateless access control for industrial Internet of Things, Futur. Gener. Comput. Syst. 76 (2017) 285–292. http://dx.doi.org/10.1016/j.future.2016.12.036.

[14] T.K.L. Hui, R.S. Sherratt, D.D. Sánchez, Major requirements for building smart homes in smart cities based on Internet of Things technologies, Futur. Gener. Comput. Syst. 76 (2017) 358–369. http://dx.doi.org/10.1016/j.future.2016.10.026.

[15] J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami, Internet of Things (IoT): A vision, architectural elements, and future directions, Futur. Gener. Comput. Syst. 29 (2013) 1645–1660. http://dx.doi.org/10.1016/j.future.2013.01.010.

[16] 96/06132. Remote control and robots: An internet solution, Fuel Energy Abstr. 37 (1996) 434. http://dx.doi.org/10.1016/S0140-6701(97)83534-5.

[17] K.V. Kavya, K.S. Suresh, A. Umamakeswari, A telepresence mobile robot controlling and real time detection using Internet of Things, Indian J. Sci. Technol. 9 (2016). http://dx.doi.org/10.17485/ijst/2016/v9i48/108008.

[18] Y.L. Wang, Q.S. Ma, E.M. Wang, X.L. Wu, Z.L. Chen, Design of monitoring system of the household robot based on Internet of Things, Appl. Mech. Mater. 339 (2013) 163–166. http://dx.doi.org/10.4028/www.scientific.net/AMM.339.163.

[19] C. Turcu, C. Turcu, V. Gaitan, Integrating robots into the Internet of Things, Int. J. Circuits Syst. Signal Process 6 (2012) 430–437.

[20] P.M. Scholl, B. El Majoub, S. Santini, K. Van Laerhoven, Connecting wireless sensor networks to the robot operating system, Procedia Comput. Sci. 19 (2013) 1121–1128. http://dx.doi.org/10.1016/j.procs.2013.06.158.

[21] L. Wei, G. Yuan, X. Dai, Path planning based on warehousing intelligent inspection robot in Internet of Things, Adv. Mater. Res. 267 (2011) 318–321. http://dx.doi.org/10.4028/www.scientific.net/AMR.267.318.

[22] G. Tuna, V.C. Gungor, K. Gulez, An autonomous wireless sensor network deployment system using mobile robots for human existence detection in case of disasters, Ad Hoc Netw. 13 (2014) 54–68. http://dx.doi.org/10.1016/j.adhoc.2012.06.006.

[23] E. Colle, S. Galerne, A multihypothesis set approach for mobile robot localization using heterogeneous measurements provided by the Internet of Things, Rob. Auton. Syst. (2017). http://dx.doi.org/10.1016/j.robot.2017.05.016.

[24] R. Kazala, A. Taneva, M. Petrov, S. Penkov, Wireless network for mobile robot applications, IFAC-PapersOnLine 48 (2015) 231–236. http://dx.doi.org/10.1016/j.ifacol.2015.12.088.

[25] S. Cho, S. Fong, Y.W. Park, K. Cho, Simulation framework of ubiquitous network environments for designing diverse network robots, Futur. Gener. Comput. Syst. 76 (2017) 468–473. http://dx.doi.org/10.1016/j.future.2016.03.016.

[26] C. Yu, X. Chen, Home monitoring system based on indoor service robot and wireless sensor network, Comput. Electr. Eng. 39 (2013) 1276–1287. http://dx.doi.org/10.1016/j.compeleceng.2013.03.002.

[27] Z. Du, L. He, Y. Chen, Y. Xiao, P. Gao, T. Wang, Robot cloud: Bridging the power of robotics and cloud computing, Futur. Gener. Comput. Syst. 74 (2017) 337–348. http://dx.doi.org/10.1016/j.future.2016.01.002.

[28] M. Hassanalian, A. Abdelkefi, Classifications, applications, and design challenges of drones: A review, Prog. Aerosp. Sci. 91 (2017) 99–131. http://dx.doi.org/10.1016/j.paerosci.2017.04.003.

[29] A. Bruzzone, F. Longo, M. Massei, L. Nicoletti, M. Agresta, R. Di Matteo, G.L. Maglione, G. Murino, A. Padovano, Disasters and Emergency Management in Chemical and Industrial Plants: Drones Simulation for Education and Training, in: Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), LNCS, vol. 9991, 2016, pp. 301–308. http://dx.doi.org/10.1007/978-3-319-47605-6_25.

[30] A. Lioulemes, G. Galatas, V. Metsis, G.L. Mariottini, F. Makedon, Safety challenges in using ARDrone to collaborate with humans in indoor environments, in: ACM Int. Conf. Proceeding Ser., 2014. doi:10.1145/2674396.2674457.

[31] S. Chowdhury, A. Emelogu, M. Marufuzzaman, S.G. Nurre, L. Bian, Drones for disaster response and relief operations: A continuous approximation model, Int. J. Prod. Econ. 188 (2017) 167–184. http://dx.doi.org/10.1016/j.ijpe.2017.03.024.

[32] C.E. Palazzi, Drone indoor self-localization, in: Proc. 2015 Work. Micro Aer. Veh. Networks, Syst. Appl. Civ. Use, 2015, DroNet 2015, pp. 53–54 doi:10.1145/2750675.2750677.

[33] D. Hambling, Drone maps unsafe mines to find minerals, New Sci. 234 (2017) 16. http://dx.doi.org/10.1016/S0262-4079(17)30768-6.

[34] K. Geng, N.A. Chulin, Applications of multi-height sensors data fusion and fault-tolerant Kalman filter in integrated navigation system of UAV, Procedia Comput. Sci. 103 (2017) 231–238. http://dx.doi.org/10.1016/j.procs.2017.01.090.

[35] M.H.M. Schellekens, Are internet robots adequately regulated? Comput. Law Secur. Rev. 29 (2013) 666–675. http://dx.doi.org/10.1016/j.clsr.2013.09.003.

[36] D. Wright, Drones: Regulatory challenges to an incipient industry, Comput. Law Secur. Rev. 30 (2014) 226–229. http://dx.doi.org/10.1016/j.clsr.2014.03.009.

[37] D. Lee, C. Ha, Z. Zuo, Backstepping control of quadrotor-type UAVs and its application to teleoperation over the Internet, Adv. Intell. Syst. Comput. 194 (2013) 217–225. http://dx.doi.org/10.1007/978-3-642-33932-5_21.

[38] K.-N. Park, J.-H. Kang, B.-M. Cho, K.-J. Park, H. Kim, Handover management of net-drones for future internet platforms, Int. J. Distrib. Sens. Netw. 2016 (2016). http://dx.doi.org/10.1155/2016/5760245.

[39] M. Gharibi, R. Boutaba, S.L. Waslander, Internet of drones, IEEE Access. 4 (2016) 1148–1162. http://dx.doi.org/10.1109/ACCESS.2016.2537208.

[40] R.J. Hall, An internet of drones, IEEE Internet Comput. 20 (2016) 68–73. http://dx.doi.org/10.1109/MIC.2016.59.

[41] H3 dynamics unveils fixed-wing drone, joins Internet of Things pact, Fuel Cells Bull. 2016 (2016) 5–6. http://dx.doi.org/10.1016/S1464-2859(16)30237-1.

[42] S.-J. Yoo, J. Park, S. Kim, A. Shrestha, Flying path optimization in UAV-assisted IoT sensor networks, ICT Express 2 (2016) 140–144. http://dx.doi.org/10.1016/j.icte.2016.08.005.

[43] J. Polo, G. Hornero, C. Duijneveld, A. García, O. Casas, Design of a low-cost wireless sensor network with {UAV} mobile node for agricultural applications, Comput. Electron. Agric. 119 (2015) 19–32. http://dx.doi.org/10.1016/j.compag.2015.09.024.

Adrián Arenal Pereira, Research scientist at Computer Science Department of the University of Oviedo. B.Sc. from the University of Oviedo in Computer Science Engineering. His research interests include the Internet of Things, drones, robots, ubiquitous computing and emerging technologies, particularly mobile and Web applications.

Pascual Espada, Jordan received a Ph.D. in Computer Science from the University of Oviedo (Spain) in 2011. He is a professor at Computer Science Department of the University of Oviedo (Spain). B.Sc. in Computer Science Engineering and a M.Sc. in Web Engineering from the University of Oviedo. His research interests include the Internet of Things, exploration of new applications and associated human computer interaction issues in ubiquitous computing and emerging technologies, particularly mobile and Web applications. He has been author of published papers in several journals and recognized international conferences and symposiums.

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.

Rubén González Crespo, Ph.D., is the deputy director of the School of Engineering at the Universidad Internacional de La Rioja. Professor of Project Management and Engineering of Web sites. He is honorary professor and guest of various institutions such as the University of Oviedo and University Francisco José de Caldas. Previously, he worked as Manager and Director of Graduate Chair in the School of Engineering and Architecture at the Pontifical University of Salamanca for over 10 years. He has participated in numerous projects $I + D + I$ such as SEACW, GMOSS, eInkPlusPlusy among others. He advises a number of public and private, national and international institutions. His research and scientific production focuses on accessibility, web engineering, mobile technologies and project management. He has published more than 80 works in indexed research journals, books, book chapters and conferences.

Sergio Ríos Aguilar holds a Ph.D. in Economics from University of Granada. He also holds a MSc in Telecommunications from King Juan Carlos University (URJC) and Computer Sciences degree from UOC. He currently works at UPSAM teaching Mobile Development and is conducting research on advanced mobile enterprise information systems.

Please cite this article in press as: A.A. Pereira, et al., Platform for controlling and getting data from network connected drones in indoor environments, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.01.011.