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Iot Based Bomb Defusing And Surveillance Robot

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Abstract

Border Security is most important in any country and many lives are lost due to land mines and bomb blasts. This work focuses on the design and development of a robot based on Internet of things (IOT). The robot is designed to perform bomb defusing, Land mines detection and defusing. It is also used in surveillance at borders. This robot works both autonomously as well as manually. The bomb defusing task is performed based on the image captured by the robot and it will be sent back to the control room with the location to analyze the threat, then the robot is used to defuse the bomb remotely from the control room. The surveillance task is performed to find out the intruders at borders day and night, where the army personnel can't perform the task of surveillance. The images are sent to the control room for analyzing the threat. The robot is designed such that it can detect the land mines using an inbuilt metal detector.

Key words: IOT, Robot, Bomb defusing, Surveillance

1. Introduction

The modern warfare demands the need of the integration of latest technologies. The internet of things (IOT) is one of those technologies and nowadays the IOT is used in many applications like Home automation to automation of Production line in manufacture sector. This technology is used in the development of the most sophisticated devices. The autonomous defense systems must be designed using this technology in boarder surveillance [1]. The protecting the border of any country is important and lacks of people lost their life due to landmines and bombs explode. An estimation of 15,000 to 20,000 people are killed /injured by landmines every year [2]. There is a need of an autonomous system to perform these tasks which are not performed by the individuals. This study will explore the use of IOT in designing and implementing the Robot system that can continuously monitor and defuse the landmines and bombs both autonomously as well as manually [3].

2. System Design

The system design includes two phase involvement- one is the robot and the other one is the user section, i.e., laptop or mobile for controlling the robot [4]. The user section is kept much portable in comparison to other traditional systems. The communication technology used here involves Internet, thus increasing the range and affordability of the device [5]. This is the main phase showcasing the use of the concept of Internet of Things (IOT). We can access our Raspberry Pi console using SSH from any part of the world [6]. Once connected, the user can control the robot using its own portable laptop or mobile from anywhere around the world. Here, portability is also one of the key features in our proposed system [7].

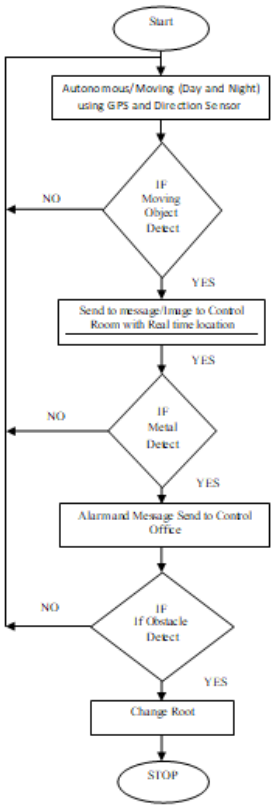

Fig. 1 Algorithm for OIT based robot

At the robot end, we are using a Raspberry Pi minicomputer placed on the robot body or chassis. Wheels are connected to Dc motors of 30rpm and attached to robot chassis. Each motor runs on 12V supply provided by an external power source, i.e., Lithium-ion battery. The motors are interfaced with the Raspberry Pi through relay and motor driver. The Raspberry Pi controls the robot with the help of scripts and programs written in Python language. Besides the manual mode of operation, automated waypoint travelling mode is also enabled in this setup. This is achieved with the help of Google API Directions. The Ultrasonic sensor is also interfaced so that the robot can avoid any obstacles in course of path automatically. The camera is also placed on the body of the robot and programmed in such a way that it can detect any objects and capture the video and image data and email it to the respective authority [8]. The metal detector attached in front of the body can detect any metal objects and hence can send signals to the user. The Algorithm of this study is shown in Fig. 1.

3. Components of IOT based robot

The IOT based robot is the integration of Electronic, Mechanical, Computer Science and information technology. Fig. 2 shows the different components of IOT based robot.

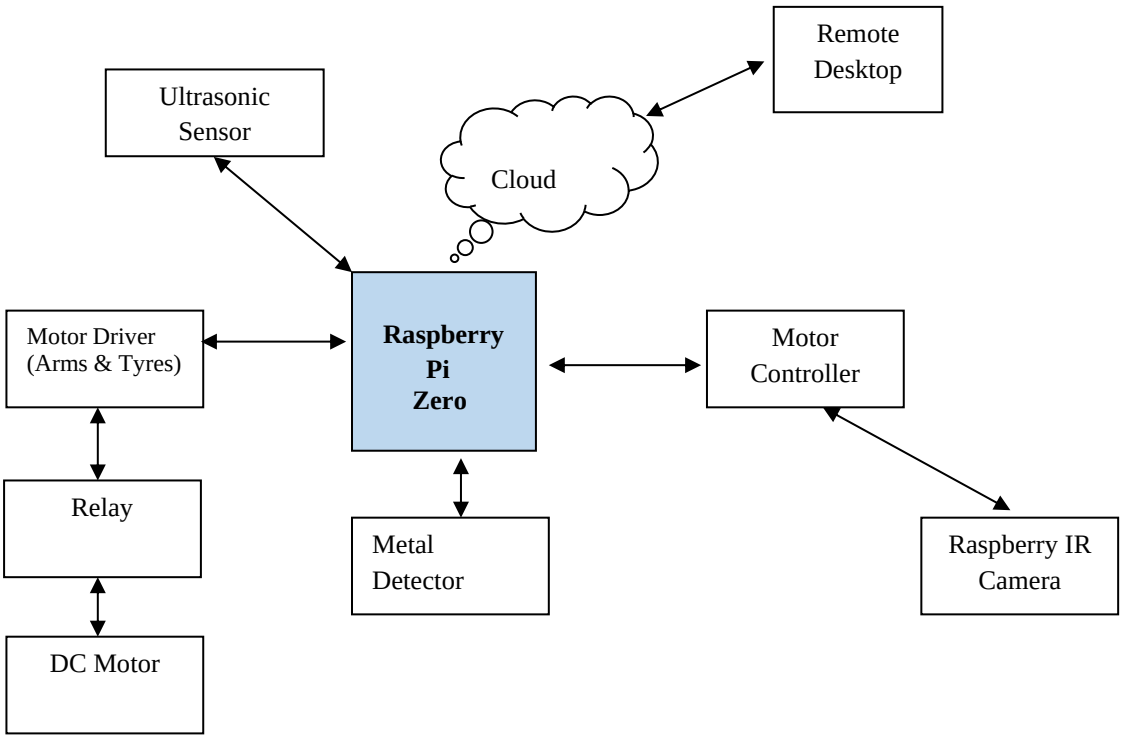

Fig. 2 Components of IOT based robot

These components are discussed under following heads [9].

3.1 Raspberry Pi Zero W

This supports many features such as high speed LAN and so on. This controller is the most advanced controller used along with other components in the robot.

3.2 DC Motors

` The brushless DC motors are used to control the robot arm as well as the robot wheels. It utilizes 12V Dc power supply and rotates at 30rpm speed. The brushless Dc Motors have more advantages than brush DC motors.

3.3 Ultrasonic Sensor

The ultrasonic sensor is used where the need of finding the obstacles and other applications. Ultrasonic waves are used to find the distance. This consists of wave's emitter and receiver. Every object o earth has its own material property. The received signal carries the wave energy based on the emitted signal hit the relevant object.

3.4 Lithium-Ion Battery

Nowadays the Lithium ion batteries are widely used most of the electronic devices; it is because of their loess weight and more energy density. The batteries are costly, but the life is more compared to another batteries.

3.5 Six-Axis Robotic arms

The six axis robotic arm is flexible and can be designed based on the requirements. It moves at 360 degrees. It is having 6 DOF and end effecter is capable of picking and placing. But in our case a tool is attached to dispose the bomb/ Landmines.

3.6 Raspberry Pi IR Camera

It is a Camera module designed for Raspberry Pi. This camera can capture video data in both day and night time. Its can capture the images and send the same to control room on real time bases.

3.7 Motor Driver

Motor derive is the control unit attached to the main control unit. It is used to control the motors attached robot arm as well as chaises of the robot wheels. The motor drive is integrated such a way that it will perform the assigned/programmed part accurately.

3.8 GPS Module

This module is used for automating the movement of the robot using Google API directions and waypoint target setting technique.

3.9 Software Tools

- Python:- Different python libraries are used in this project for running scripts for connection and controlling of robot, sending mail, camera controls, etc.
- Linux:- Linux powered Raspberry Pi is used in this project for connections and interfacing different components and modules together.
- Windows:- Windows platform is being used to run softwares and create code in python.

The assembled prototype of IOT based robot is showed in Fig. 3 and Fig. 4.

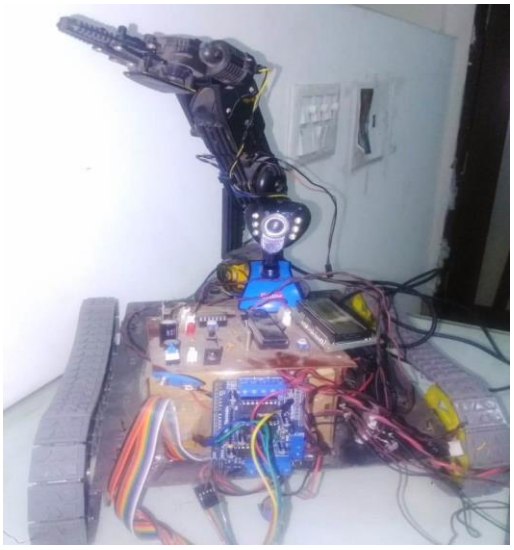

Fig. 3 Assembled Prototype Fig. 4 Prototype testing

4. Conclusions and Future work

In this work a IOT based robot framework is designed and the robot is tested for the feasibility of the robot for the scenario like bomb/landmine disposing and surveillance. The designed system can save lot of lives and it can protect the borders where the individual persons cannot perform the surveillance. The components are used in this are programmed to complete the given tasks exactly. The real time based IOT Robot. The robot is controlled using just a laptop/desktop with internet connections. Automatic monitoring can also be done. Our proposed robot is small in size, thus, maneuvering into area where human access is impossible. This robot can be automated to maneuver the selected path. The metal detector in this robot can help detect objects such as bombs and then can be diffused using its cutter-fitted arms. It would also send email to the host machine with attached images of any camera-detected objects in the path.

In future it is developed by integrating the non lethal weapon surveillance along with the present configuration.

References

1. Kaustubh Gawli, Parinay Karande, Pravin Belose, Tushar Bhadirke , Akansha Bhargava, "Internet of Things (IoT) Based Robotic Arm". ICIATE – 2017, Volume 5 – Issue 01, Pp 1-3.
2. https://www.unicef.org/french/protection/files/Landmines_Factsheet_04_LTR_HD.pdf (Accessed on 10/02/2020)
3. R. S. Batth, A. Nayyar and A. Nagpal, Internet of Robotic Things: Driving Intelligent Robotics of Future - Concept, Architecture, Applications and Technologies, 2018 4th International Conference on Computing Sciences (ICCS), Jalandhar, 2018, pp. 151-160.
4. J. Patoliya, H. Mehta and H. Patel, Arduino controlled war field spy robot using night vision wireless camera and Android application, 2015 5th Nirma University International Conference on Engineering (NUiCONE), Ahmedabad, 2015, pp. 1-5.
5. Wan, J., Tang, S., Yan, H., Li, D., Wang,S., & Vasilakos, A.V.(2016). Cloud robotics: Current status & open issues. IEEE Access, 4, Pp2797-2807.
6. Siegwart, R, Nourbakhsh, I. R., Scaramuzza, D.(2011). Introduction to autonomous mobile robots. MIT press
7. B. Krishna, J. Oviya, S. Gowri and M. Varshini, Cloud robotics in industry using Raspberry Pi, in IEEE Second International Conference on Science Technology Engineering and Management (ICONSTEM), Chennai, India, March 2016, pp. 543-547
8. K. Bekris, R. Shome, A. Krontiris and A. Dobson, Cloud automation: Pre computing roadmaps for flexible manipulation, IEEE Robotics & Automation Magazine, vol. 22, no. 2, pp. 41-50, 2015.
9. Shaik Mahaboob Basha, Abdul Khayyum. S.K, Amarendra.B, Sajid.S.K. Design Of Security Robot in Night Vision Using Wireless Video Camera And Ultrasonic Sensor, Geethanjali Institute of Science And Technology, Nellore, Andhra Pradesh, India.(2015), Vol-2 Issue-5 2017, IJARIIE, Pp 112-116.
10. S. Karnouskos et al., "Experiences in integrating Internet of Things and cloud services with the robot operating system," 2017 IEEE 15th International Conference on Industrial

Informatics (INDIN), Emden, 2017, pp. 1084-1089. Towards the Internet of Robotic Things: Analysis,
11. Architecture, Components and Challenges
12. Towards the Internet of Robotic Things: Analysis,
13. Architecture, Components and Challenge
14. Towards the Internet of Robotic Things: Analysis,
15. Architecture, Components and Challenges
16. azafimandimby, C., Loscri, V., & Vegni, A. M. (2018).
17. Towards efficient deployment in Internet of Robotic Things.
18. In Integration, Interconnection, and Interoperability of IoT
19. Systems (pp

20. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
21. Surveillance Robot for Real-Time Monitoring and Control
22. System in Environment and Industrial Applications.
23. In Information Systems Design and Intelligent Applications (pp.
24. 229-243). Springer, Singapore.
25. Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
26. (2016). Cloud robotics: Current status and open issues. IEEE
27. Access, 4, 2797-28
28. Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
29. (2016). Cloud robotics: Current status and open issues. IEEE
30. Access, 4, 2797-28
31. Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
32. (2016). Cloud robotics: Current status and open issues. IEEE
33. Access, 4, 2797-28
34. Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
35. (2016). Cloud robotics: Current status and open issues. IEEE
36. Access, 4, 2797-28
37. Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
38. (2016). Cloud robotics: Current status and open issues. IEEE
39. Access, 4, 2797-28
40. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
41. Surveillance Robot for Real-Time Monitoring and Control
42. System in Environment and Industrial Applications.
43. In Information Systems Design and Intelligent Applications (pp.
44. 229-243). Springer, Singapore.
45. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
46. Surveillance Robot for Real-Time Monitoring and Control
47. System in Environment and Industrial Applications.
48. In Information Systems Design and Intelligent Applications (pp.
49. 229-243). Springer, Singapore.
50. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
51. Surveillance Robot for Real-Time Monitoring and Control
52. System in Environment and Industrial Applications.
53. In Information Systems Design and Intelligent Applications (pp.
54. 229-243). Springer, Singapore.

55. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
56. Surveillance Robot for Real-Time Monitoring and Control
57. System in Environment and Industrial Applications.
58. In Information Systems Design and Intelligent Applications (pp.
59. 229-243). Springer, Singapore.
60. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
61. Surveillance Robot for Real-Time Monitoring and Control
62. System in Environment and Industrial Applications.
63. In Information Systems Design and Intelligent Applications (pp.
64. 229-243). Springer, Singapore.
65. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
66. Surveillance Robot for Real-Time Monitoring and Control
67. System in Environment and Industrial Applications.
68. In Information Systems Design and Intelligent Applications (pp.
69. 229-243). Springer, Singapore.
70. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
71. Surveillance Robot for Real-Time Monitoring and Control
72. System in Environment and Industrial Applications.
73. In Information Systems Design and Intelligent Applications (pp.
74. 229-243). Springer, Singapore.
75. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
76. Surveillance Robot for Real-Time Monitoring and Control
77. System in Environment and Industrial Applications.
78. In Information Systems Design and Intelligent Applications (pp.
79. 229-243). Springer, Singapore.
80. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
81. Surveillance Robot for Real-Time Monitoring and Control
82. System in Environment and Industrial Applications.
83. In Information Systems Design and Intelligent Applications (pp.
84. 229-243). Springer, Singapore.
85. Nayyar, A., Puri, V., Nguyen, N. G., & Le, D. N. (2018). Smart
86. Surveillance Robot for Real-Time Monitoring and Control
87. System in Environment and Industrial Applications.
88. In Information Systems Design and Intelligent Applications (pp.
89. 229-243). Springer, Singapore.
90. IEEE Robotics & Automation Society: http://www.ieee-
91. ras.org/technical-committees/117-technical-
92. committees/networked-robots/146-networked-robots. (Accessed
93. on June 15, 2018)
94. [3] Strategy Market Research Consulting. Internet of Robotic
95. Things- Global Market Outlook 2017-2023.
96. http://www.strategymrc.com/report/internet-of-robotic-things-
97. market-2017. Accessed on June 15, 2018.
98. [4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.
99. (2016). Cloud robotics: Current status and open issues. IEEE
100. Access, 4, 2797-2807.
101. EEE Robotics & Automation Society: http://www.ieee-

102. ras.org/technical-committees/117-technical-
103. committees/networked-robots/146-networked-robots. (Accessed
104. on June 15, 2018)
105. EEE Robotics & Automation Society: http://www.ieee-
106. ras.org/technical-committees/117-technical-
107. committees/networked-robots/146-networked-robots. (Accessed
108. on June 15, 2018)
109. EEE Robotics & Automation Society: http://www.ieee-
110. ras.org/technical-committees/117-technical-
111. committees/networked-robots/146-networked-robots. (Accessed
112. on June 15, 2018)
113. EEE Robotics & Automation Society: http://www.ieee-
114. ras.org/technical-committees/117-technical-
115. committees/networked-robots/146-networked-robots. (Accessed
116. on June 15, 2018)
117. EEE Robotics & Automation Society: http://www.ieee-
118. ras.org/technical-committees/117-technical-
119. committees/networked-robots/146-networked-robots. (Accessed
120. on June 15, 2018)
121. EEE Robotics & Automation Society: http://www.ieee-
122. ras.org/technical-committees/117-technical-
123. committees/networked-robots/146-networked-robots. (Accessed
124. on June 15, 2018)
125. EEE Robotics & Automation Society: http://www.ieee-
126. ras.org/technical-committees/117-technical-
127. committees/networked-robots/146-networked-robots. (Accessed
128. on June 15, 2018)
129. EEE Robotics & Automation Society: http://www.ieee-
130. ras.org/technical-committees/117-technical-
131. committees/networked-robots/146-networked-robots. (Accessed
132. on June 15, 2018)
133. EEE Robotics & Automation Society: http://www.ieee-
134. ras.org/technical-committees/117-technical-
135. committees/networked-robots/146-networked-robots. (Accessed
136. on June 15, 2018)
137. EEE Robotics & Automation Society: http://www.ieee-
138. ras.org/technical-committees/117-technical-
139. committees/networked-robots/146-networked-robots. (Accessed
140. on June 15, 2018)
141. EEE Robotics & Automation Society: http://www.ieee-
142. ras.org/technical-committees/117-technical-
143. committees/networked-robots/146-networked-robots. (Accessed
144. on June 15, 2018)
145. EEE Robotics & Automation Society: http://www.ieee-
146. ras.org/technical-committees/117-technical-
147. committees/networked-robots/146-networked-robots. (Accessed
148. on June 15, 2018)

149. EEE Robotics & Automation Society: http://www.ieee-
150. ras.org/technical-committees/117-technical-
151. committees/networked-robots/146-networked-robots. (Accessed
152. on June 15, 2018)
153. EEE Robotics & Automation Society: http://www.ieee-
154. ras.org/technical-committees/117-technical-
155. committees/networked-robots/146-networked-robots. (Accessed
156. on June 15, 2018)
157. EEE Robotics & Automation Society: http://www.ieee-
158. ras.org/technical-committees/117-technical-
159. committees/networked-robots/146-networked-robots. (Accessed
160. on June 15, 2018)
161. EEE Robotics & Automation Society: http://www.ieee-
162. ras.org/technical-committees/117-technical-
163. committees/networked-robots/146-networked-robots. (Accessed
164. on June 15, 2018)
165. EEE Robotics & Automation Society: http://www.ieee-
166. ras.org/technical-committees/117-technical-
167. committees/networked-robots/146-networked-robots. (Accessed
168. on June 15, 2018)
169. EEE Robotics & Automation Society: http://www.ieee-
170. ras.org/technical-committees/117-technical-
171. committees/networked-robots/146-networked-robots. (Accessed
172. on June 15, 2018)
173. EEE Robotics & Automation Society: http://www.ieee-
174. ras.org/technical-committees/117-technical-
175. committees/networked-robots/146-networked-robots. (Accessed
176. on June 15, 2018)
177. EEE Robotics & Automation Society: http://www.ieee-
178. ras.org/technical-committees/117-technical-
179. committees/networked-robots/146-networked-robots. (Accessed
180. on June 15, 2018)
181. EEE Robotics & Automation Society: http://www.ieee-
182. ras.org/technical-committees/117-technical-
183. committees/networked-robots/146-networked-robots. (Accessed
184. on June 15, 2018)
185. EEE Robotics & Automation Society: http://www.ieee-
186. ras.org/technical-committees/117-technical-
187. committees/networked-robots/146-networked-robots. (Accessed
188. on June 15, 2018)
189. EEE Robotics & Automation Society: http://www.ieee-
190. ras.org/technical-committees/117-technical-
191. committees/networked-robots/146-networked-robots. (Accessed
192. on June 15, 2018)
193. EEE Robotics & Automation Society: http://www.ieee-
194. ras.org/technical-committees/117-technical-
195. committees/networked-robots/146-networked-robots. (Accessed

196. on June 15, 2018)
197. EEE Robotics & Automation Society: http://www.ieee-
198. ras.org/technical-committees/117-technical-
199. committees/networked-robots/146-networked-robots. (Accessed
200. on June 15, 2018)
201. EEE Robotics & Automation Society: http://www.ieee-
202. ras.org/technical-committees/117-technical-
203. committees/networked-robots/146-networked-robots. (Accessed
204. on June 15, 2018)
205. EEE Robotics & Automation Society: http://www.ieee-
206. ras.org/technical-committees/117-technical-
207. committees/networked-robots/146-networked-robots. (Accessed
208. on June 15, 2018)
209. EEE Robotics & Automation Society: http://www.ieee-
210. ras.org/technical-committees/117-technical-
211. committees/networked-robots/146-networked-robots. (Accessed
212. on June 15, 2018)
213. EEE Robotics & Automation Society: http://www.ieee-
214. ras.org/technical-committees/117-technical-
215. committees/networked-robots/146-networked-robots. (Accessed
216. on June 15, 2018)
217. EEE Robotics & Automation Society: http://www.ieee-
218. ras.org/technical-committees/117-technical-
219. committees/networked-robots/146-networked-robots. (Accessed
220. on June 15, 2018)
221. EEE Robotics & Automation Society: http://www.ieee-
222. ras.org/technical-committees/117-technical-
223. committees/networked-robots/146-networked-robots. (Accessed
224. on June 15, 2018)
225. EEE Robotics & Automation Society: http://www.ieee-
226. ras.org/technical-committees/117-technical-
227. committees/networked-robots/146-networked-robots. (Accessed
228. on June 15, 2018)
229. EEE Robotics & Automation Society: http://www.ieee-
230. ras.org/technical-committees/117-technical-
231. committees/networked-robots/146-networked-robots. (Accessed
232. on June 15, 2018)
233. EEE Robotics & Automation Society: http://www.ieee-
234. ras.org/technical-committees/117-technical-
235. committees/networked-robots/146-networked-robots. (Accessed
236. on June 15, 2018)
237. EEE Robotics & Automation Society: http://www.ieee-
238. ras.org/technical-committees/117-technical-
239. committees/networked-robots/146-networked-robots. (Accessed
240. on June 15, 2018)
241. EEE Robotics & Automation Society: http://www.ieee-
242. ras.org/technical-committees/117-technical-

243. committees/networked-robots/146-networked-robots. (Accessed
244. on June 15, 2018)
245. EEE Robotics & Automation Society: http://www.ieee-
246. ras.org/technical-committees/117-technical-
247. committees/networked-robots/146-networked-robots. (Accessed
248. on June 15, 2018)
249. EEE Robotics & Automation Society: http://www.ieee-
250. ras.org/technical-committees/117-technical-
251. committees/networked-robots/146-networked-robots. (Accessed
252. on June 15, 2018)
253. EEE Robotics & Automation Society: http://www.ieee-
254. ras.org/technical-committees/117-technical-
255. committees/networked-robots/146-networked-robots. (Accessed
256. on June 15, 2018)
257. EEE Robotics & Automation Society: http://www.ieee-
258. ras.org/technical-committees/117-technical-
259. committees/networked-robots/146-networked-robots. (Accessed
260. on June 15, 2018)
261. EEE Robotics & Automation Society: http://www.ieee-
262. ras.org/technical-committees/117-technical-
263. committees/networked-robots/146-networked-robots. (Accessed
264. on June 15, 2018)
265. EEE Robotics & Automation Society: http://www.ieee-
266. ras.org/technical-committees/117-technical-
267. committees/networked-robots/146-networked-robots. (Accessed
268. on June 15, 2018)
269. EEE Robotics & Automation Society: http://www.ieee-
270. ras.org/technical-committees/117-technical-
271. committees/networked-robots/146-networked-robots. (Accessed
272. on June 15, 2018)
273. EEE Robotics & Automation Society: http://www.ieee-
274. ras.org/technical-committees/117-technical-
275. committees/networked-robots/146-networked-robots. (Accessed
276. on June 15, 2018)
277. EEE Robotics & Automation Society: http://www.ieee-
278. ras.org/technical-committees/117-technical-
279. committees/networked-robots/146-networked-robots. (Accessed
280. on June 15, 2018)
281. EEE Robotics & Automation Society: http://www.ieee-
282. ras.org/technical-committees/117-technical-
283. committees/networked-robots/146-networked-robots. (Accessed
284. on June 15, 2018)
285. EEE Robotics & Automation Society: http://www.ieee-
286. ras.org/technical-committees/117-technical-
287. committees/networked-robots/146-networked-robots. (Accessed
288. on June 15, 2018)
289. EEE Robotics & Automation Society: http://www.ieee-

290. ras.org/technical-committees/117-technical-
291. committees/networked-robots/146-networked-robots. (Accessed
292. on June 15, 2018)
293. EEE Robotics & Automation Society: http://www.ieee-
294. ras.org/technical-committees/117-technical-
295. committees/networked-robots/146-networked-robots. (Accessed
296. on June 15, 2018)
297. EEE Robotics & Automation Society: http://www.ieee-
298. ras.org/technical-committees/117-technical-
299. committees/networked-robots/146-networked-robots. (Accessed
300. on June 15, 2018)
301. EEE Robotics & Automation Society: http://www.ieee-
302. ras.org/technical-committees/117-technical-
303. committees/networked-robots/146-networked-robots. (Accessed
304. on June 15, 2018)
305. EEE Robotics & Automation Society: http://www.ieee-
306. ras.org/technical-committees/117-technical-
307. committees/networked-robots/146-networked-robots. (Accessed
308. on June 15, 2018)
309. EEE Robotics & Automation Society: http://www.ieee-
310. ras.org/technical-committees/117-technical-
311. committees/networked-robots/146-networked-robots. (Accessed
312. on June 15, 2018)
313. EEE Robotics & Automation Society: http://www.ieee-
314. ras.org/technical-committees/117-technical-
315. committees/networked-robots/146-networked-robots. (Accessed
316. on June 15, 2018)
317. EEE Robotics & Automation Society: http://www.ieee-
318. ras.org/technical-committees/117-technical-
319. committees/networked-robots/146-networked-robots. (Accessed
320. on June 15, 2018)
321. EEE Robotics & Automation Society: http://www.ieee-
322. ras.org/technical-committees/117-technical-
323. committees/networked-robots/146-networked-robots. (Accessed
324. on June 15, 2018)
325. EEE Robotics & Automation Society: http://www.ieee-
326. ras.org/technical-committees/117-technical-
327. committees/networked-robots/146-networked-robots. (Accessed
328. on June 15, 2018)
329. EEE Robotics & Automation Society: http://www.ieee-
330. ras.org/technical-committees/117-technical-
331. committees/networked-robots/146-networked-robots. (Accessed
332. on June 15, 2018)
333. EEE Robotics & Automation Society: http://www.ieee-
334. ras.org/technical-committees/117-technical-
335. committees/networked-robots/146-networked-robots. (Accessed
336. on June 15, 2018)

337. EEE Robotics & Automation Society: http://www.ieee-
338. ras.org/technical-committees/117-technical-
339. committees/networked-robots/146-networked-robots. (Accessed
340. on June 15, 2018)
341. EEE Robotics & Automation Society: http://www.ieee-
342. ras.org/technical-committees/117-technical-
343. committees/networked-robots/146-networked-robots. (Accessed
344. on June 15, 2018)
345. EEE Robotics & Automation Society: http://www.ieee-
346. ras.org/technical-committees/117-technical-
347. committees/networked-robots/146-networked-robots. (Accessed
348. on June 15, 2018)
349. EEE Robotics & Automation Society: http://www.ieee-
350. ras.org/technical-committees/117-technical-
351. committees/networked-robots/146-networked-robots. (Accessed
352. on June 15, 2018)
353. EEE Robotics & Automation Society: http://www.ieee-
354. ras.org/technical-committees/117-technical-
355. committees/networked-robots/146-networked-robots. (Accessed
356. on June 15, 2018)
357. EEE Robotics & Automation Society: http://www.ieee-
358. ras.org/technical-committees/117-technical-
359. committees/networked-robots/146-networked-robots. (Accessed
360. on June 15, 2018)
361. EEE Robotics & Automation Society: http://www.ieee-
362. ras.org/technical-committees/117-technical-
363. committees/networked-robots/146-networked-robots. (Accessed
364. on June 15, 2018)
365. EEE Robotics & Automation Society: http://www.ieee-
366. ras.org/technical-committees/117-technical-
367. committees/networked-robots/146-networked-robots. (Accessed
368. on June 15, 2018)
369. EEE Robotics & Automation Society: http://www.ieee-
370. ras.org/technical-committees/117-technical-
371. committees/networked-robots/146-networked-robots. (Accessed
372. on June 15, 2018)
373. EEE Robotics & Automation Society: http://www.ieee-
374. ras.org/technical-committees/117-technical-
375. committees/networked-robots/146-networked-robots. (Accessed
376. on June 15, 2018)
377. EEE Robotics & Automation Society: http://www.ieee-
378. ras.org/technical-committees/117-technical-
379. committees/networked-robots/146-networked-robots. (Accessed
380. on June 15, 2018)
381. EEE Robotics & Automation Society: http://www.ieee-
382. ras.org/technical-committees/117-technical-
383. committees/networked-robots/146-networked-robots. (Accessed

384. on June 15, 2018)
385. EEE Robotics & Automation Society: http://www.ieee-
386. ras.org/technical-committees/117-technical-
387. committees/networked-robots/146-networked-robots. (Accessed
388. on June 15, 2018)
389. EEE Robotics & Automation Society: http://www.ieee-
390. ras.org/technical-committees/117-technical-
391. committees/networked-robots/146-networked-robots. (Accessed
392. on June 15, 2018)
393. EEE Robotics & Automation Society: http://www.ieee-
394. ras.org/technical-committees/117-technical-
395. committees/networked-robots/146-networked-robots. (Accessed
396. on June 15, 2018)
397. EEE Robotics & Automation Society: http://www.ieee-
398. ras.org/technical-committees/117-technical-
399. committees/networked-robots/146-networked-robots. (Accessed
400. on June 15, 2018)
401. EEE Robotics & Automation Society: http://www.ieee-
402. ras.org/technical-committees/117-technical-
403. committees/networked-robots/146-networked-robots. (Accessed
404. on June 15, 2018)
405. EEE Robotics & Automation Society: http://www.ieee-
406. ras.org/technical-committees/117-technical-
407. committees/networked-robots/146-networked-robots. (Accessed
408. on June 15, 2018)
409. EEE Robotics & Automation Society: http://www.ieee-
410. ras.org/technical-committees/117-technical-
411. committees/networked-robots/146-networked-robots. (Accessed
412. on June 15, 2018)
413. EEE Robotics & Automation Society: http://www.ieee-
414. ras.org/technical-committees/117-technical-
415. committees/networked-robots/146-networked-robots. (Accessed
416. on June 15, 2018)
417. EEE Robotics & Automation Society: http://www.ieee-
418. ras.org/technical-committees/117-technical-
419. committees/networked-robots/146-networked-robots. (Accessed
420. on June 15, 2018)
421. EEE Robotics & Automation Society: http://www.ieee-
422. ras.org/technical-committees/117-technical-
423. committees/networked-robots/146-networked-robots. (Accessed
424. on June 15, 2018)
425. EEE Robotics & Automation Society: http://www.ieee-
426. ras.org/technical-committees/117-technical-
427. committees/networked-robots/146-networked-robots. (Accessed
428. on June 15, 2018)
429. EEE Robotics & Automation Society: http://www.ieee-
430. ras.org/technical-committees/117-technical-

committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

EEE Robotics & Automation Society: http://www.ieee-

478. ras.org/technical-committees/117-technical-
479. committees/networked-robots/146-networked-robots. (Accessed
480. on June 15, 2018)
481. EEE Robotics & Automation Society: http://www.ieee-
482. ras.org/technical-committees/117-technical-
483. committees/networked-robots/146-networked-robots. (Accessed
484. on June 15, 2018)
485. EEE Robotics & Automation Society: http://www.ieee-
486. ras.org/technical-committees/117-technical-
487. committees/networked-robots/146-networked-robots. (Accessed
488. on June 15, 2018)
489. EEE Robotics & Automation Society: http://www.ieee-
490. ras.org/technical-committees/117-technical-
491. committees/networked-robots/146-networked-robots. (Accessed
492. on June 15, 2018)
493. EEE Robotics & Automation Society: http://www.ieee-
494. ras.org/technical-committees/117-technical-
495. committees/networked-robots/146-networked-robots. (Accessed
496. on June 15, 2018)
497. EEE Robotics & Automation Society: http://www.ieee-
498. ras.org/technical-committees/117-technical-
499. committees/networked-robots/146-networked-robots. (Accessed
500. on June 15, 2018)
501. EEE Robotics & Automation Society: http://www.ieee-
502. ras.org/technical-committees/117-technical-
503. committees/networked-robots/146-networked-robots. (Accessed
504. on June 15, 2018)
505. EEE Robotics & Automation Society: http://www.ieee-
506. ras.org/technical-committees/117-technical-
507. committees/networked-robots/146-networked-robots. (Accessed
508. on June 15, 2018)
509. EEE Robotics & Automation Society: http://www.ieee-
510. ras.org/technical-committees/117-technical-
511. committees/networked-robots/146-networked-robots. (Accessed
512. on June 15, 2018)
513. EEE Robotics & Automation Society: http://www.ieee-
514. ras.org/technical-committees/117-technical-
515. committees/networked-robots/146-networked-robots. (Accessed
516. on June 15, 2018)
517. EEE Robotics & Automation Society: http://www.ieee-
518. ras.org/technical-committees/117-technical-
519. committees/networked-robots/146-networked-robots. (Accessed
520. on June 15, 2018)
521. EEE Robotics & Automation Society: http://www.ieee-
522. ras.org/technical-committees/117-technical-
523. committees/networked-robots/146-networked-robots. (Accessed
524. on June 15, 2018)

525. EEE Robotics & Automation Society: http://www.ieee-
526. ras.org/technical-committees/117-technical-
527. committees/networked-robots/146-networked-robots. (Accessed
528. on June 15, 2018)
529. EEE Robotics & Automation Society: http://www.ieee-
530. ras.org/technical-committees/117-technical-
531. committees/networked-robots/146-networked-robots. (Accessed
532. on June 15, 2018)
533. EEE Robotics & Automation Society: http://www.ieee-
534. ras.org/technical-committees/117-technical-
535. committees/networked-robots/146-networked-robots. (Accessed
536. on June 15, 2018)
537. EEE Robotics & Automation Society: http://www.ieee-
538. ras.org/technical-committees/117-technical-
539. committees/networked-robots/146-networked-robots. (Accessed
540. on June 15, 2018)
541. EEE Robotics & Automation Society: http://www.ieee-
542. ras.org/technical-committees/117-technical-
543. committees/networked-robots/146-networked-robots. (Accessed
544. on June 15, 2018)
545. EEE Robotics & Automation Society: http://www.ieee-
546. ras.org/technical-committees/117-technical-
547. committees/networked-robots/146-networked-robots. (Accessed
548. on June 15, 2018)
549. EEE Robotics & Automation Society: http://www.ieee-
550. ras.org/technical-committees/117-technical-
551. committees/networked-robots/146-networked-robots. (Accessed
552. on June 15, 2018)
553. EEE Robotics & Automation Society: http://www.ieee-
554. ras.org/technical-committees/117-technical-
555. committees/networked-robots/146-networked-robots. (Accessed
556. on June 15, 2018)
557. EEE Robotics & Automation Society: http://www.ieee-
558. ras.org/technical-committees/117-technical-
559. committees/networked-robots/146-networked-robots. (Accessed
560. on June 15, 2018)
561. EEE Robotics & Automation Society: http://www.ieee-
562. ras.org/technical-committees/117-technical-
563. committees/networked-robots/146-networked-robots. (Accessed
564. on June 15, 2018)
565. EEE Robotics & Automation Society: http://www.ieee-
566. ras.org/technical-committees/117-technical-
567. committees/networked-robots/146-networked-robots. (Accessed
568. on June 15, 2018)
569. IEEE Robotics & Automation Society: http://www.ieee-
570. ras.org/technical-committees/117-technical-
571. committees/networked-robots/146-networked-robots. (Accessed

on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023.

http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V.

(2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-

ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.

[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.

IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)

[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.
[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.
IEEE Robotics & Automation Society: http://www.ieee-ras.org/technical-committees/117-technical-committees/networked-robots/146-networked-robots. (Accessed on June 15, 2018)
[3] Strategy Market Research Consulting. Internet of Robotic Things- Global Market Outlook 2017-2023. http://www.strategymrc.com/report/internet-of-robotic-things-market-2017. Accessed on June 15, 2018.
[4] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues.