Door-Opening Drones

Subjects: Others

Contributor: Javeed Shaikh-Mohammed, Yousef Alharbi, Abdulrahman Alqahtani

Doorknob accessories, wheelchair-mounted door-opening accessories, door-opening robots, and door-opening drones—were used to group the various technologies for manually opening doors. Drones are unmanned aerial vehicles (UAVs) with a wide range of applications, including product delivery, asset inspection, search and rescue, law enforcement and military services, disaster management, and emergency medical services. Drones are emerging as safe alternatives to humans in applications involving inaccessible environments or dangerous scenarios. In cases of medical emergencies, when a person is stuck in remote locations and an ambulance is unable to reach a patient in time, medical drones are being used for emergency medical services. Door-opening drones are unmanned aerial vehicles (UAVs) equipped with the capability to open doors.

Keywords: door-opening ; drones

1. Introduction

According to the latest data from the World Health Organization (WHO), around 1.3 billion people, or about 16% of the world's population, are estimated to live with some form of disability [1]. According to the United Nations (UN), around 80% of people with disabilities live in developing countries, and around 20% of the world's poorest people have some kind of disability [2]. According to the International Labour Organization (ILO), employment rates are lower for people with disabilities compared to non-disabled people, with employment rates for people with disabilities in some countries below 30% [3].

Wheelchairs are one of the most widely used assistive devices by people with disabilities. However, according to the WHO, it is estimated that only 5–15% of people worldwide who require a wheelchair have access to one [4]; in other words, around 20 million people worldwide need wheelchairs but do not have them [5]. Even those people who have access to a wheelchair face several accessibility challenges in their daily lives. Some of the challenges faced by wheelchair users are maneuvering through narrow doorways or passages, building entrances that lack ramps, high door thresholds, and accessing manual doors.

Narrow doorways require complex maneuvering skills for wheelchair users to enter without bumping into the door frame. Opening inward swinging doors (or pulling doors backward) requires backing up and proper positioning of the wheelchair with respect to the door, which could be a difficult task for some wheelchair users, especially in tight spaces with higher chances of collisions with walls. Also, high door thresholds (over 20 mm) increase the risk of tipping. Wheelchair users also need to apply greater force than other individuals to open several types of doors. Heavy fire doors, for instance, may be difficult to open and may close too quickly. Some wheelchair users may experience difficulty operating certain types of door handles, particularly if they have limited hand use.

2. Door-Opening Drones

Drones are unmanned aerial vehicles (UAVs) with a wide range of applications, including product delivery, asset inspection, search and rescue, law enforcement and military services, disaster management, and emergency medical services [6][7][8][9][10][11]. Drones are emerging as safe alternatives to humans in applications involving inaccessible environments or dangerous scenarios [12]. In cases of medical emergencies, when a person is stuck in remote locations and an ambulance is unable to reach a patient in time, medical drones are being used for emergency medical services [9][13]. Door-opening drones are unmanned aerial vehicles (UAVs) equipped with the capability to open doors.

The Lemur-2 drone by BRINC has a blade attachment to break glass and is able to push doors that are ajar [14]. The drone could be user-operated or in autonomous mode. The onboard 3D LIDAR sensor makes real-time floor plans. Lemur-2 was developed for use by law enforcement personnel and is National Defense Authorization Act (NDAA) compliant. Although Lemur-2 is able to break glass panes to access buildings, it lacks the ability to turn doorknobs.

A team of researchers at Purdue University has developed a drone called the BoomCopter that is able to open and close doors, flip switches, and attach sensors to walls. The BoomCopter was designed to perform tasks in environments that would be considered dangerous or inaccessible to humans. The BoomCopter (see the illustration in **Figure 1**) utilizes a tri-rotor design, allowing it to hover in the same way as the more common quad-rotor design [15][16].

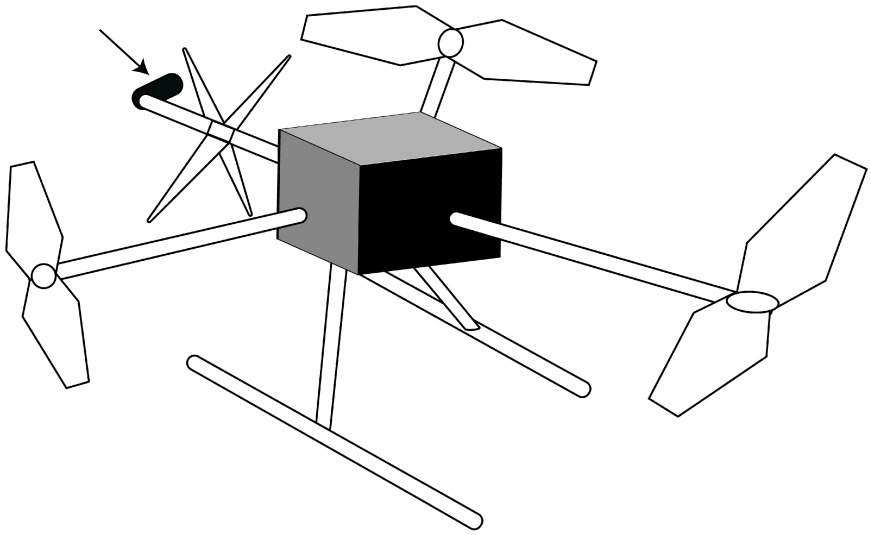

Figure 1. Illustration of a remote-controlled drone equipped with an end-effector (indicated with an arrow), which assists the drone operator in turning doorknobs and opening manual doors.

The BoomCopter drone features a horizontal robotic arm with a propeller mounted at 90 degrees to move the drone back and forth as it hovers. The robotic arm is equipped with different end-effectors to accomplish specific tasks. The BoomCopter can be operated either remotely by a user or autonomously using on-board sensors, cameras, and processors. For autonomous mode operation [17], the BoomCopter drone could be trained to recognize items such as door handles using computer vision techniques and be able to open doors. Another group demonstrated the capability of a drone to push a rolling cart and a door [18]. In a related study, a team from ETH Zurich demonstrated a planning and control method that enables drones to manipulate articulated objects with the least amount of operator-provided priors [19]. Recently, the group presented a reinforcement learning method for drones to learn motion behaviors for a manipulation task such as a door-opening task [20].

The tiny drones known as FlyCroTugs provide an intriguing example of drone technology in action. Researchers from Stanford University and Ecole Polytechnique Federale de Lausanne (EPFL) created the FlyCroTugs, which are tiny drones that collaborate to carry out activities in hazardous or unreachable places for humans. By coordinating their movements, the quadrotor FlyCroTugs drones can lift or transport heavy objects up to 40 times their own weight. These tiny drones can attach to different surfaces and apply force via the winches and replaceable adhesives on their bases. The ability of two FlyCroTugs to coordinate their activities in order to open doors was demonstrated [11][21][22][23]. While the second tiny drone fixed itself to the ground and pulled open the door, the other tiny drone turned the doorknob. FlyCroTugs' ability to anchor is made possible by the drone's base using replaceable adhesives. The adhesives could contain ridged silicone (inspired by Gecko feet) to cling onto glass and microspines for slicing through tough surfaces such as stucco, carpet, or rubble [22].

Table 1 lists the technical specifications of the door-opening drones. **Table 2** summarizes the door-opening drones. The Lemur-2 drone is commercially available and costs around USD 10,000 to 20,000 [24]. The BoomCopter, FlyCroTug, or other drones discussed here are still in the research and development phase and are not available on the market.

Table 1. Technical specifications of drones that open doors autonomously.

Specification	Lemur-2	BoomCopter	FlyCroTug
Weight (kg)	**1.5**	**2.3–2.9**	**0.1**
Dimensions (L/W/H) (″)	**13/16/4**	**23.6/27.6/11.4**	**4/4/-**
Propeller design	**Quadcopter**	**Tricopter with a horizontally mounted reversible propeller**	**Quadcopter**

Specification	Lemur-2	BoomCopter	FlyCroTug
Payload (kg)	0.45	1.86–1.2	0.02 (flight) ~4 (tugging)
Flight time (min)	20	13–21.4	5
Flight range (km)	-	8.8–14.4	-
Sensors	Forward and downward LiDAR (Light Detection and Ranging) sensor; dual tracking cameras (daytime, night vision, thermal)	GPS module; force sensor; sonar sensor; camera; flight management unit (FMU)	Autopilot module (inertial measurement unit, barometer)

L—Length, W—Width, H—Height.

Table 2. Drones that open doors autonomously.

Door opening AT	Features	Commercial Availability	Cost
Single drone	Attachment breaks glass; Drone can push doors already ajar	Yes	USD 10k–20k
Single drone	Attachment turns doorknobs and pulls or pushes door	No	–
Swarm of tiny drones	One drone turns doorknob; Another drone pulls the door	No	–

References

1. World Health Organisation. Disability. Available online: https://www.who.int/news-room/fact-sheets/detail/disability-and-health (accessed on 7 June 2023).
2. United Nations. Factsheet on Persons with Disabilities. Available online: https://www.un.org/development/desa/disabilities/resources/factsheet-on-persons-with-disabilities.html (accessed on 7 October 2023).
3. International Labour Organization. Disability and Work. Available online: https://www.ilo.org/global/topics/disability-and-work/lang--en/index.htm (accessed on 8 August 2023).
4. World Health Organization. Guidelines on the Provision of Manual Wheelchairs in Less Resourced Settings; World Health Organization: Geneva, Switzerland, 2008; ISBN 978-92-4-154748-2.
5. World Health Organisation. Wheelchair Service Training Package—Basic Level; World Health Organization: Geneva, Switzerland, 2012; ISBN 978-92-4-150347-1.
6. Choi, H.-W.; Kim, H.-J.; Kim, S.-K.; Na, W.S. An Overview of Drone Applications in the Construction Industry. Drones 2023, 7, 515.
7. Daud, S.M.S.M.; Yusof, M.Y.P.M.; Heo, C.C.; Khoo, L.S.; Singh, M.K.C.; Mahmood, M.S.; Nawawi, H. Applications of Drone in Disaster Management: A Scoping Review. Sci. Justice 2022, 62, 30–42.
8. Moshref-Javadi, M.; Winkenbach, M. Applications and Research Avenues for Drone-Based Models in Logistics: A Classification and Review. Expert Syst. Appl. 2021, 177, 114854.
9. Rosser Jr, J.C.; Vignesh, V.; Terwilliger, B.A.; Parker, B.C. Surgical and Medical Applications of Drones: A Comprehensive Review. JSLS J. Soc. Laparoendosc. Surg. 2018, 22, e2018.00018.
10. Shahmoradi, J.; Talebi, E.; Roghanchi, P.; Hassanalian, M. A Comprehensive Review of Applications of Drone Technology in the Mining Industry. Drones 2020, 4, 34.
11. JEREMY HSU Tiny Drones Team Up to Open Doors—IEEE Spectrum. Available online: https://spectrum.ieee.org/tiny-drones-team-up-to-open-doors (accessed on 4 August 2023).
12. National Safety Council Drones—National Safety Council. Available online: https://www.nsc.org/workplace/safety-topics/work-to-zero/safety-technologies/drones (accessed on 4 August 2023).
13. Sigari, C.; Biberthaler, P. Medical Drones: Disruptive Technology Makes the Future Happen. Der Unfallchirurg 2021, 124, 974.

14. BRINC LEMUR 2. Available online: https://brincdrones.com/lemur-2/ (accessed on 10 October 2023).
15. Mechanical Engineering—Purdue University Boomcopter Is a Drone That Can Open Doors. Available online: https://engineering.purdue.edu/ME/News/boomcopter-is-a-drone-that-can-open-doors (accessed on 4 August 2023).
16. Mechanical Engineering—Purdue University Boomcopter: The Drone That Can Open Doors. Available online: https://www.youtube.com/watch?v=3Q1dXuMWzTw (accessed on 4 August 2023).
17. McArthur, D.R.; An, Z.; Cappelleri, D.J. Pose-Estimate-Based Target Tracking for Human-Guided Remote Sensor Mounting with a UAV; IEEE: Piscataway, NJ, USA, 2020; pp. 10636–10642.
18. Lee, D.; Seo, H.; Jang, I.; Lee, S.J.; Kim, H.J. Aerial Manipulator Pushing a Movable Structure Using a DOB-Based Robust Controller. IEEE Robot. Autom. Lett. 2020, 6, 723–730.
19. Brunner, M.; Rizzi, G.; Studiger, M.; Siegwart, R.; Tognon, M. A Planning-and-Control Framework for Aerial Manipulation of Articulated Objects. IEEE Robot. Autom. Lett. 2022, 7, 10689–10696.
20. Cuniato, E.; Geles, I.; Zhang, W.; Andersson, O.; Tognon, M.; Siegwart, R. Learning to Open Doors with an Aerial Manipulator. arXiv 2023, arXiv:2307.15581.
21. The Verge Micro-Drones with Winches Can Open Doors and Lift 40 Times Their Own Weight. Available online: https://www.theverge.com/2018/10/24/18018984/micro-drones-winches-lift-40-times-own-weight-stanford-epfl (accessed on 4 August 2023).
22. IEEE Spectrum “FlyCroTug” Drones Work Together to Open a Door. Available online: https://www.youtube.com/watch?v=GhrpWggIbSM (accessed on 4 August 2023).
23. Estrada, M.A.; Mintchev, S.; Christensen, D.L.; Cutkosky, M.R.; Floreano, D. Forceful Manipulation with Micro Air Vehicles. Sci. Robot. 2018, 3, eaau6903.
24. Davis, B. BRINC Aims Lemur 2 and BRINC Ball at Police, SWAT. Available online: https://insideunmannedsystems.com/brinc-aims-lemur-2-and-brinc-ball-at-police-swat/ (accessed on 21 October 2023).