DRONE COMMUNICATION WITH NAIVE HUMANS

By

NEELESH IDDIPILLA

Bachelor of Technology in Electronics and Communication Engineering

Gitam University

Vishakhapatnam, India

2014

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
AUGUST 2019

DRONE COMMUNICATION WITH

NAIVE HUMANS

Thesis Approved:

Dr. Christopher Crick

Thesis Adviser

Dr. Blayne Mayfield

Dr. Johnson Thomas

ACKNOWLEDGEMENTS

I would first like to thank my adviser Dr. Christopher Crick for his support and assistance he gave me throughout my research. His door is always open whenever I faced any trouble in going forward with my research. He consistently steered me through the right direction whenever I asked for his assistance.

I would also like to thank my committee members Dr. Blayne Mayfield and Dr. Johnson Thomas for their valuable support and time.
Finally, I would like to thank all the participants who were involved in the survey, family and friends for their support.

Name: Neelesh Iddipilla

Date of Degree: August 2019

Title of Study: DRONE COMMUNICATION WITH NAIVE HUMANS

Major Field: COMPUTER SCIENCE

Abstract: In recent times, drones have become ubiquitous and are tackling problems in such diverse areas as construction, disease control and product delivery. With the rise of drone usage in areas frequented by humans, natural human-drone interaction has become an important phenomenon to study. Designing behaviors for effective drone communication with humans is complex but necessary, especially if drones are to operate in human environments.

We present research on drone communication with naive humans, that is, with people interacting with drones who are not themselves participating in whatever task with which the drone is engaged. Drones need to be able to communicate warnings and requests for assistance from humans that they just happen to encounter, and we are attempting to establish design methodologies for creating behaviors that can be interpreted by such naive humans.

We have performed a user study (N=21) and presented the results. The results suggest that our approach works and most of the participants can recognize a drone's intentions from its demonstrations.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

The capability and affordability of drones are growing rapidly. Despite the rapid growth very few amounts of research are being done to give them the ability to communicate. Drones are becoming increasingly autonomous and so is the need to design behaviors for them to effectively communicate with humans.

Since drones can easily go to places which are very difficult for a human to reach, giving the drones ability to communicate well increases the human capabilities. As drones are flying objects, they have the advantage to communicate effectively to large number of people with a single gaze.

If drones were to become autonomous and were to operate in human environments as companions designing such behaviors is necessary. These behaviors can also be used in indoor environments.

In this project out focus is limited to on how drone can communicate help and danger with humans using its own flight capabilities. Because we believe those are the two primary areas to focus to bridge the gap of drones being social.

Drones make lot of noise and fly in high altitudes, so adding speakers to convey their intentions is not a suitable option. Adding led lights [6] and other visual devices like projectors [7] to convey their intentions might not be suitable in all times of day.

Also, additional devices add extra weight and drains the battery life of the drone. Due to the above-mentioned reasons we believe that drone using its own body flight capabilities for communication is viable and more suitable option.

Motivated by the above mentioned challenges we designed behaviors using the drone flight capabilities such as its speed, yaw, pitch and roll to communicate its intentions with humans.

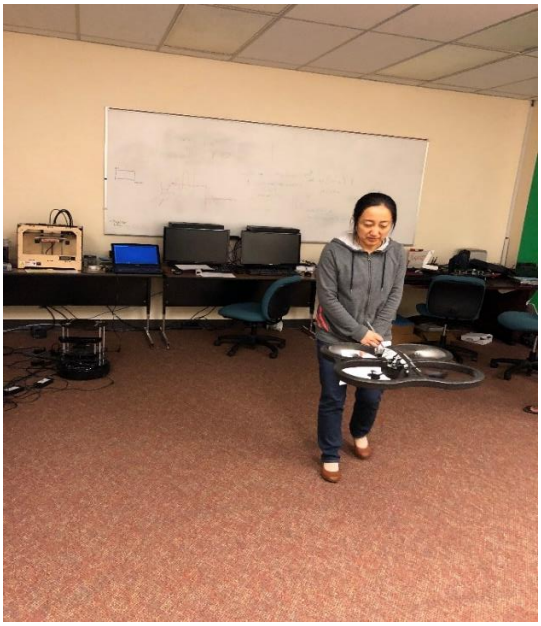


Figure 2.1 Participant observing drone demonstration

In the above figure 1.1 a participant is observing drone demonstration to understand the intention of the drone. Most participants felt comfortable with the drone and moved closer to it.

Total of seven demonstrations have been designed and studied. The seven experiments have control group experiments also. These experiments are designed to confuse users and see whether they can realize the difference between experimental group experiments and control group experiments.

We have performed experiments with a total of twenty-one participants. Each participant is only shown five demonstrations randomly. The results suggest that our approach works, and people can realize the drone intentions.

CHAPTER II

RELATED WORK

A lot of work is focused on how to make drone understand what humans are intending. This is done using gestures [13]. For example, Nagi et al [15] used hand gestures simple hand gestures to give the directions to the drone. What we are doing differently in our project is other way around studying how drones can effectively communicate their intentions, knowledge and actions using its flight capabilities.

Some prior work has been done by Sharma on communication affect via flight path using Laban Effort System [18]. Laban Effort System focuses on space, weight, time and flow.

In our project we are not interested in the factors weight, space or time. We are more interested on yaw, pitch, roll and speed of the drone.

Drone communicating its emotions with humans was studied previously [14]. Cauchard et al [21] studied the emotion encoding into drones using their flight paths, their work also defined a range of personality traits that can be encoded into a quadcopter. Malliaraki [14] suggested five emotional states for the drone using its movements. Drone communication about their knowledge, intentions and actions rather than emotions with humans is our interest.

Conventional media output ways like screens and projectors are attached to drones. For example, midair displays or pervasive flying screens are studied to display evacuation instructions to people in emergency situations by Schneegas et al [23].

Knierim et al [12] attached a projector a drone to deliver mobile in situ projected navigation instructions. The navigation directions are projected on the road and user could use them to move one place to another without the use of smartphone.

But using the traditional media output devices like screens and projectors have limitations such as extra weight and additional power needed to make them work. So, we have explored communication using the drone flight capabilities.

No additional devices are used for communication other than its own flight capabilities in our work.

A small amount of work has been done to study aspects like comfortable distance with drone [8], user perceptions of drones, privacy and security [6].

Different user interfaces [3][4][9] for interacting with drones have been developed and studied. These interfaces are used for making the drone understand human more.

Prior work has been done on designing the drone safely [1] so humans could touch and interact with them freely. This can make the users more comfortable with drones but does not convey any of its intentions.

A variety of work has been done to explore role of drone in various ways like search and rescue [7] and package delivery [10] etc.

Previously a study has been conducted on how drones could be used as a companion for pedestrians in the interest of their safety [11].

Human robot interaction for a service robot to convey its feedback through a screen has been previously built.

A user study with 200 users has been done in Germany to investigate perception of drone usage (Lidynia et al) [14]. Szafir et al [20] Performed an explorative study on Assistive free-flyers (AFFs) communication to effectively communicate intent that used a manipulated flight path, rated modified flight motions.

Exchange of forces is also studied for humans to interact with drones through the employment of a sensor ring, Rajappa et al [18].

Our work does not focus on building interfaces for humans to interact with the drones.

Design spaces have also been explored for robot communication of flight directionality to nearby users by Szafir et al [21].

Mueller et al [22] used a drone to motivate users to do jogging. Our work enables drones to communicate any warnings ahead of their path while jogging but does not motivate.

CHAPTER III

RESEARCH METHOD

3.1 Experimental Setup:

Ardrone 2.0 and ROS are used for the demonstration of the experiments. All the users are presented with the five demonstrations randomly out of seven demonstrations mentioned in Table I. Even though each user is presented with only five demonstrations, these demonstrations are same for all the users. Two categories of tasks have been studied, which are Help and Danger. For Help category the drone communicates with humans that the drone or its owner is in trouble and needs immediate help. For Danger category the drone asks humans not to move ahead and stops the human from the facing the danger.

3.2 Procedure:

Out of seven demonstrations five belong to experimental group and two of them belong to control group. Experimental group demonstrations are designed for a single purpose it is either help or danger. While the control group experiments are to confuse the subjects and see how they are realizing them. Control group experiments resemble like experimental group experiments in many ways but are not designed to convey either help or danger. For example, one of the control group experiments is U turn which resembles both like follow me and a barricade to stop people from moving forward.

The goal of control group experiments is trying to find out how people consider them as both danger and help. Table I describes the implementation of the demonstrations using yaw, roll, pitch and z velocity. Table I also shows the values of the parameters for the implementation of tasks.

Each participant is informed to consider front camera side of drone as front and rear as back for each demonstration. Before giving the Likert scale survey we have asked each subject to write their demonstrations in words. Since all the experiments are conducted indoors, we have asked the subject to imagine the following scenario for each demonstration.

“Imagine you are walking on a street then a drone comes and does this demonstration in front of you”.

The participants have been given with a Likert scale survey with questions asking them whether the user can understand and agree what the drone is trying to communicate. The survey form consists of four questions and five categories strongly agree, agree, Neutral, disagree and strongly disagree for each question.

We have given same questions for each demonstration.

The below are given questions:

1. “To what extent do you think the drone is asking for assistance or help?”
2. “To what extend do you think the drone is indicating danger ahead?”
3. “To what extent do you think Drone is trying to scare you?”
4. “To what extent do you think drone is trying to befriend you?”

Demonstration	Yaw	Roll	Pitch	Z velocity	Movement
L Symbol	used	-	used	-	Moves little forward and turns left
Cross symbol (X)	-	used	used	used	From a certain height slides toward left and again reaches certain height and slides right.
Help using Pitch	used	-	used	-	Moves forward while nodding up and down, wait for a while, turn around 180 degrees and moves forward.
Help using roll	used	used	used	-	Moves forward while shaking both sides, wait for a while, turn around 180 degrees and moves forward.
intimidate	-	-	used	-	Moves forward very fast towards a person and comes back and does the same again
Danger using Yaw	used	-	-	-	Turns left and then immediately right.
U turn	used	-	used	-	Moves forward and immediately turn left continuously making a semi-circle pattern.

Table 3. 1: Parameters used and implementation of each Demonstration

3.3 User Study:

All the participants are aged from 17 to 30 years old and consists of both male and female. All the participants in the experiments have seen a drone before. Every experiment is conducted in an indoor environment without any external wind from the environment.

Help demonstrations
Help using Pitch
Help using roll

Table 3.2: Help Demonstrations

Danger demonstrations
Cross symbol
Intimidate
Danger using Yaw

Table 3.3: Danger Demonstrations

Control group demonstrations
L Symbol
U turn

Table 3.4: Control group Demonstrations

3.4 Prior Interview Survey Sheet:

The below figure 3.1 is the interview sheet is given to participants first for collecting the responses. The responses are the first impressions that came into their mind after seeing the demonstration done by the drone.

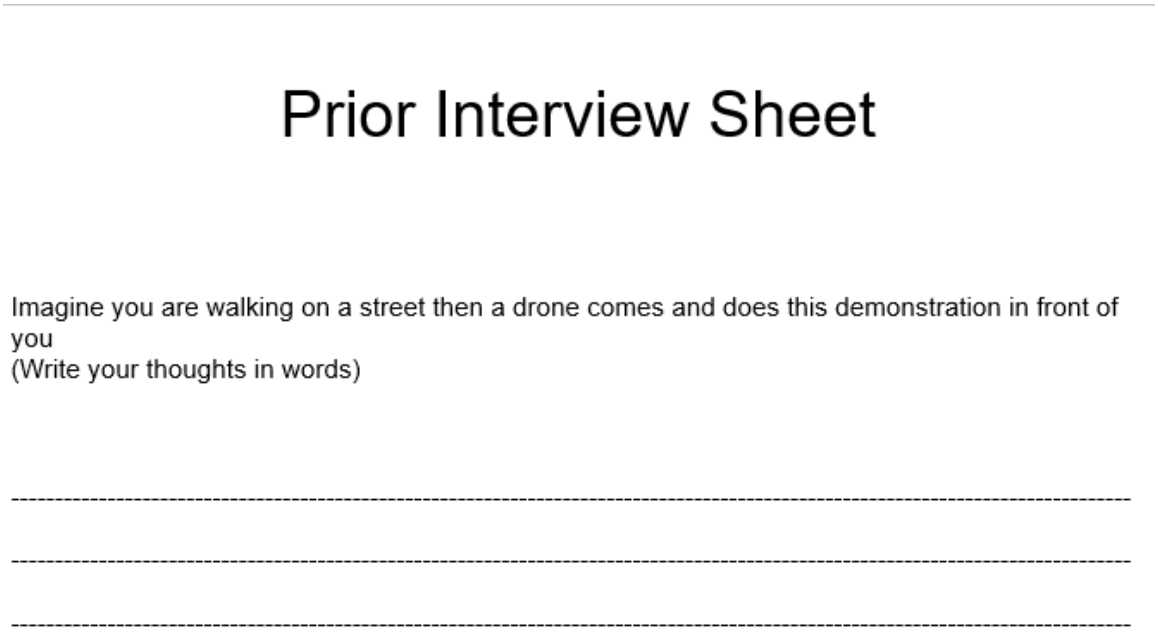
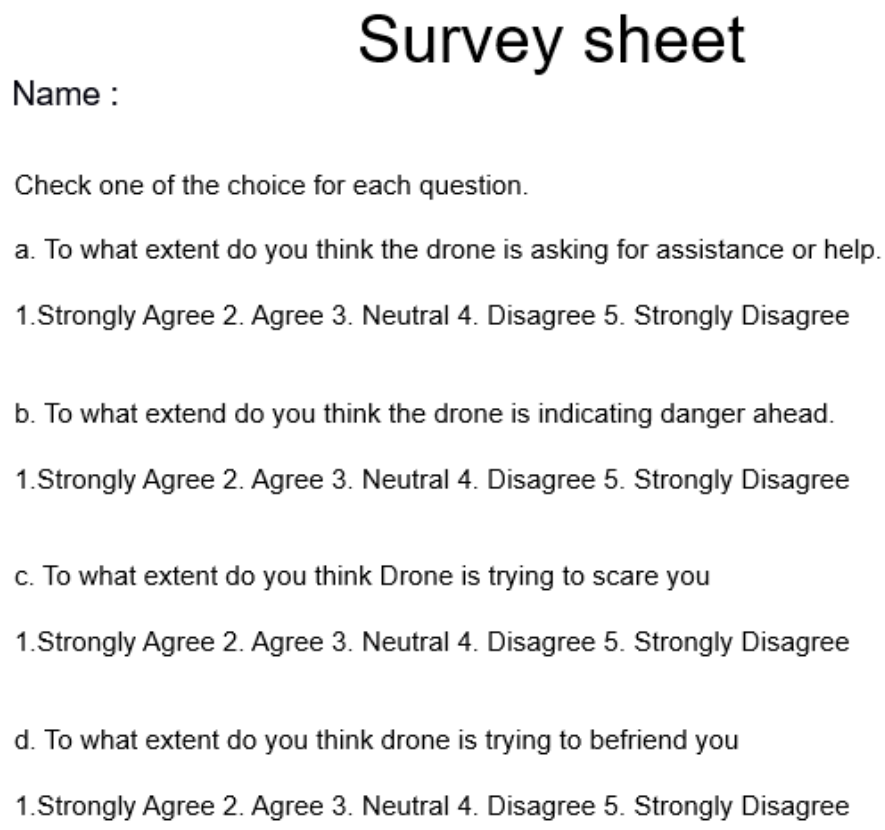


Figure 3.1 Prior Interview Survey Sheet

We have given this to study to what extent the users are able to comprehend the demonstration without the help of the Questionnaire.

3.5 Questionnaire given to participants:

The below figure is the questionnaire given to participants after each demonstration. This questionnaire is same for all experiments and it is given after getting the feedback from the prior interview sheet.



Survey sheet

Name :

Check one of the choice for each question.

a. To what extent do you think the drone is asking for assistance or help.

1.Strongly Agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

b. To what extend do you think the drone is indicating danger ahead.

1.Strongly Agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

c. To what extent do you think Drone is trying to scare you

1.Strongly Agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

d. To what extent do you think drone is trying to befriend you

1.Strongly Agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

Figure 3.2 Questionnaire given to participants

The responses are encoded in form likert scale for each question to the corresponding question.

This is used to measure to what extend the users attributed each demonstration to danger warning and requesting help.

CHAPTER IV

RESULTS

The below results are collected for a total of twenty-one participants. Total seven behaviors are designed and each participant is shown five demonstrations in random order. All the results are represented in form of error bars with mean and standard errors.

Figure 4.1 and Figure 4.2 represents the results for the demonstrations for danger.

4.1 Danger Using X:

From the figure 4.1 we can see that cross-symbol (X) demonstration communicates danger ahead very well. The total users participated for the symbol X is 21.

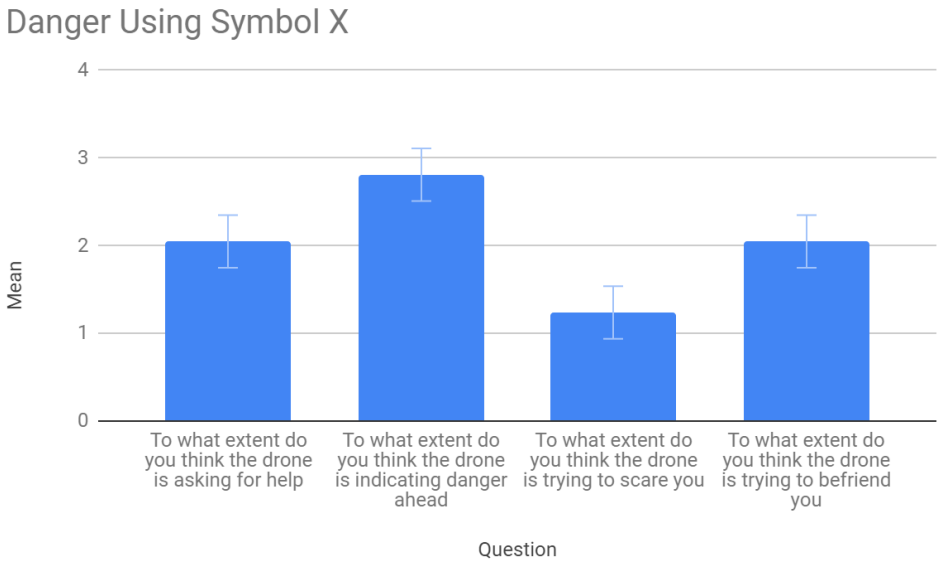


Figure 4.1: Cross Symbol(x)

Few responses we got from the prior interview with users before giving survey sheet:

“Trying to stop further movement I;e stops moving forward ”

“The drone warns me that there is some work in progress going ahead so to be careful. It performed a X sign in air.”

4.2 Danger Using Intimidate:

Figure 4.2 represented below shows that intimidate demonstration can be used for making people stay away from danger ahead by intimidating them.

The demonstration Danger Using Intimidate is shown to a total number of 19 users

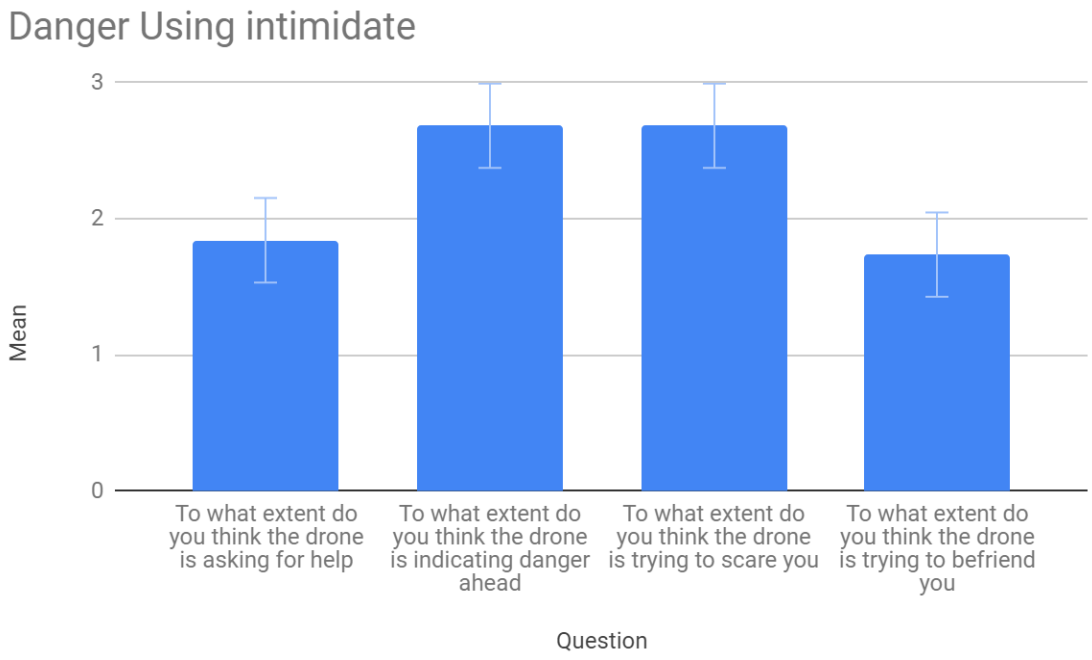


Figure 4.2: Danger using Intimidate

Few responses we got from the prior interview with users before giving survey sheet:

a. “It seems aggressive. It wants me to run away?”
b. “Trying to alert and show something”
c. “Go back don’t go further”

4.3 Danger Using YAW:

The below figure 4.3 shows the results for the demonstration danger using yaw. Even though we have designed this behavior for conveying danger Figure 4.3 represented below shows that demonstration can be used for asking people that drone needs help instead of danger.

The demonstration Danger Using YAW is shown to a total number of 17 users.

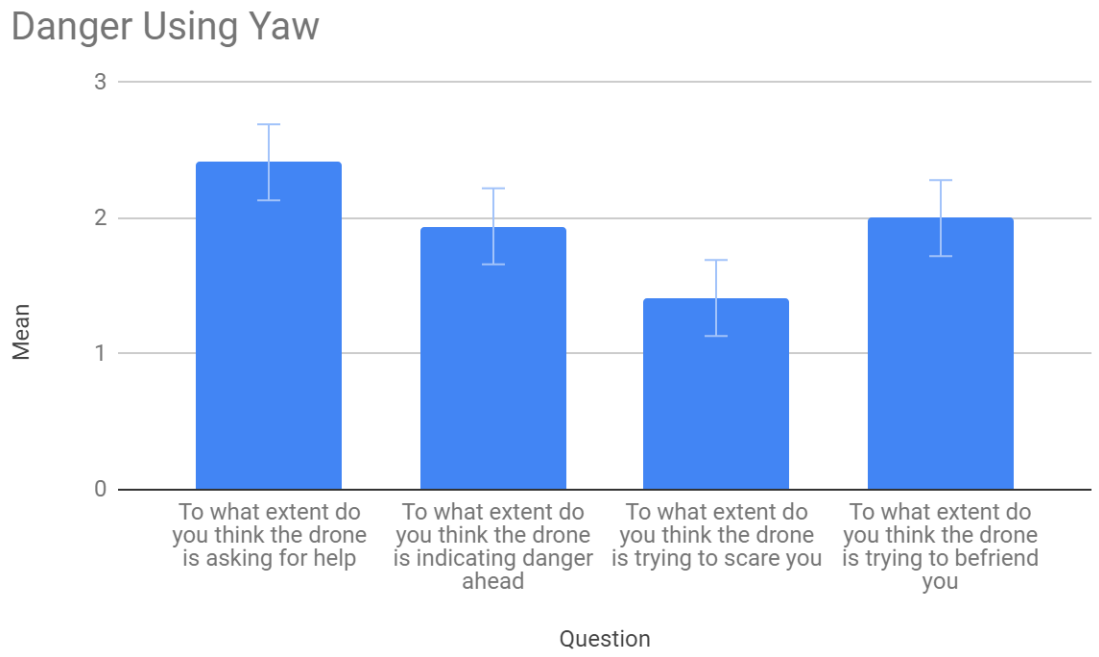


Figure 4.3: Danger Using YAW

Few responses we got from the prior interview with users before giving survey sheet:

a. “Have problems”
b. “Confused or puzzled?”

4.4 Help Using Roll:

Figure 4.4 represented below shows that Help using Roll behavior communicates well as expected. This behavior can be used by drones to ask help from people.

The demonstration Help Using Roll is shown to a total number of 14 users.

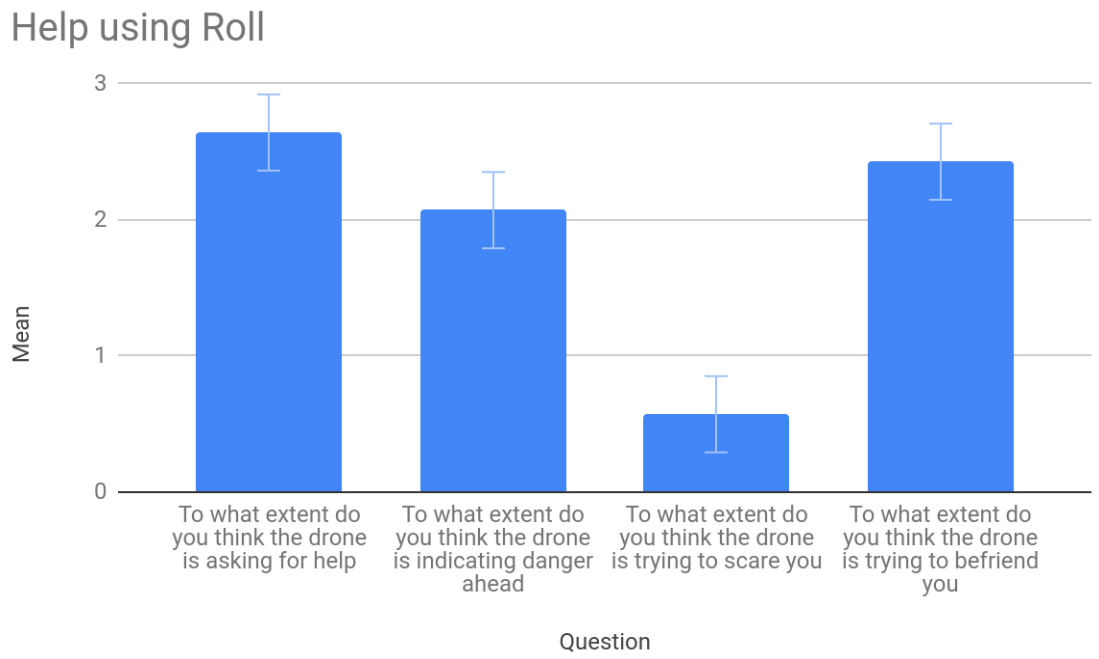


Figure 4.4: Help Using Roll

Few responses we got from the prior interview with users before giving survey sheet:

a. “asked to follow?”
b. “The drone is telling me to follow it”

4.5: Help Using Pitch:

We have designed Help using pitch behavior for drone to communicate that it needs help. But from the user study we found that this behavior does not communicate that drone needs help very well.

The demonstration Help Using Pitch is shown to a total number of 14 users.

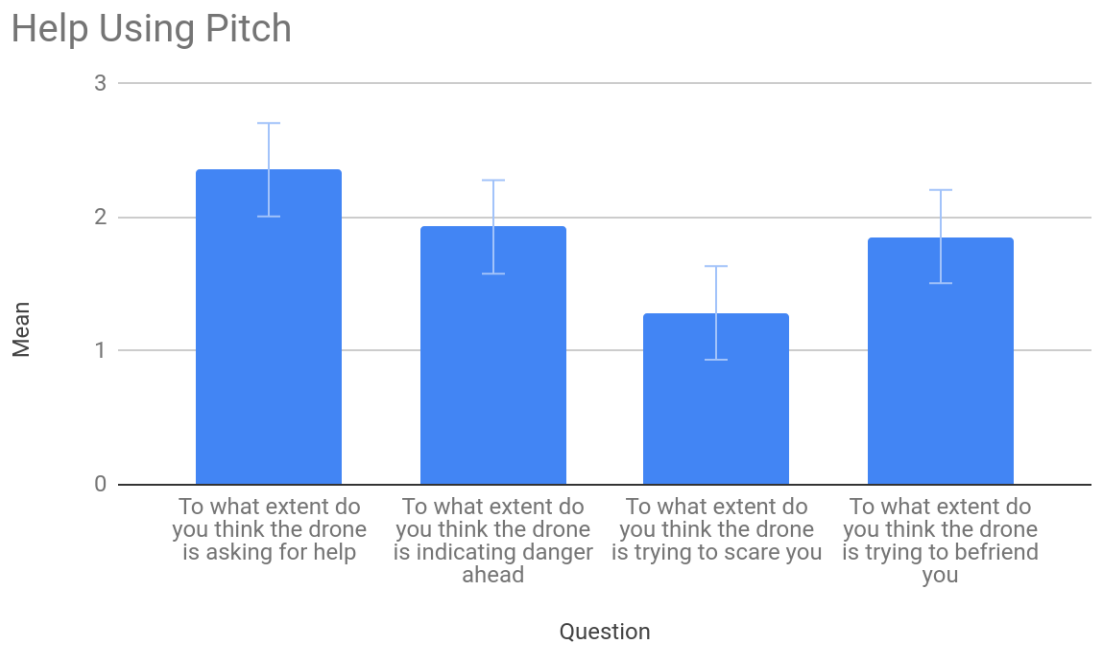


Figure 4.5: Help Using Pitch

Few responses we got from the prior interview with users before giving survey sheet:

a. "It says come after me"
b. "Is it trying to tell me to follow? Or is it avoiding me? I think it is telling me to follow it"

Figures 4.6 and 4.7 are designed as part of control group experiments.

4.6 Symbol L Control Group Experiment:

From figure 4.6 we can see that demonstration symbol L does not communicate a specific intention and is ambiguous.

The demonstration Symbol L Control group experiment is shown to a total number of 9 users.

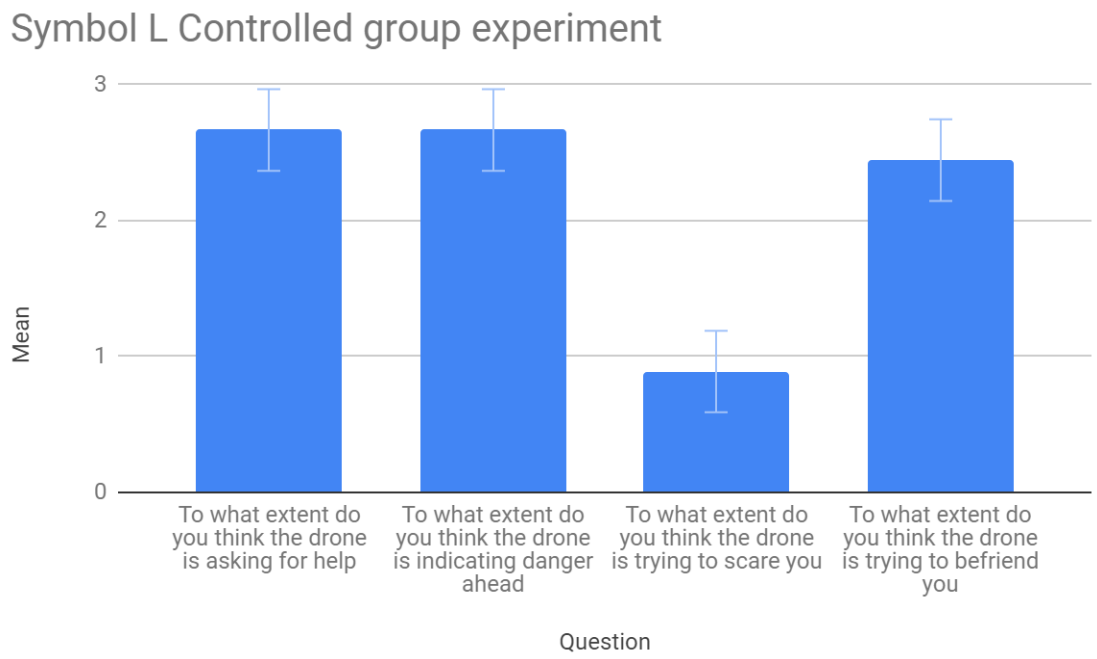


Figure 4.6: Symbol L Control group experiment

Few responses we got from the prior interview with users before giving survey sheet:

a. “Take left”
b. “Left turn”

4.7: U turn Control Group Experiment:

From figure 4.7 we can see that demonstration U turn does not communicate a specific intention and is ambiguous. From the below responses plot we can see that users understood the below demonstration both as help and danger.

The demonstration Uturn Control group Experiment is shown to a total number of 13 users.

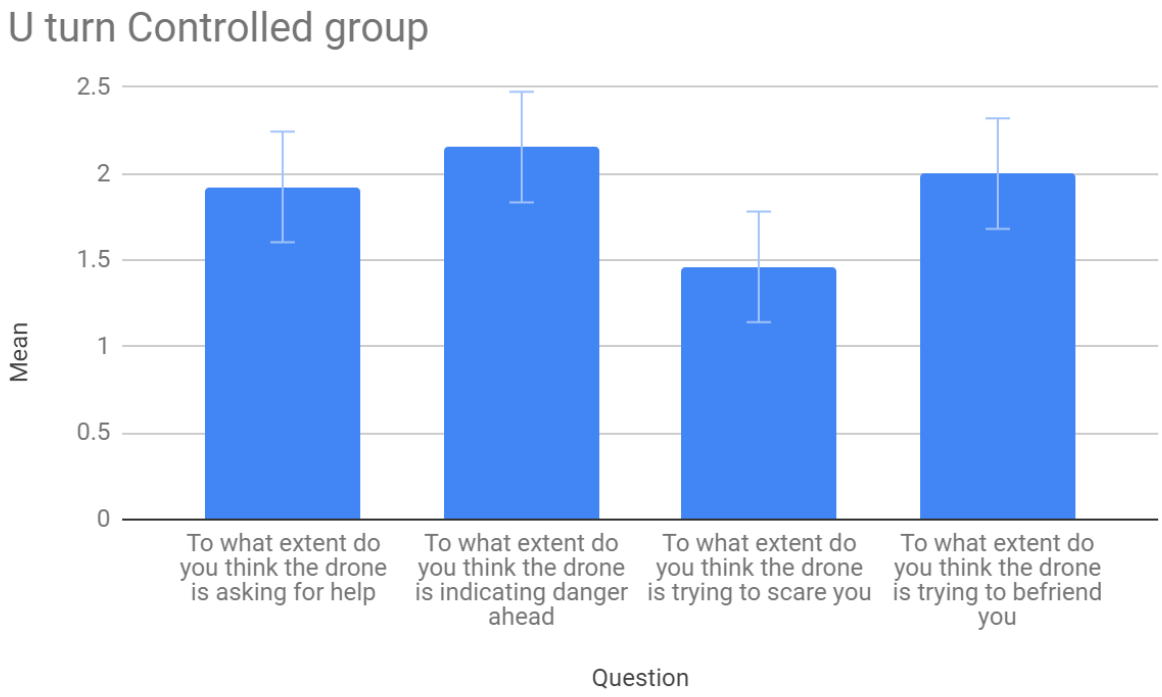


Figure 4.7: Uturn Control group Experiment

Few responses we got from the prior interview with users before giving survey sheet:

a. “semicircular motion”
b. “take U turn”

The below table 4.1 shows the keywords obtained from the feedback of the users for the demonstrations Danger and Help. We classified these words based on the prior interview sheet.

Demonstrations	Keywords
Danger	Warn, Danger, Stay away, Scare, Stop
Help	Follow, help, Come with me, follow me, asks me something.

Table 4. 1: Demonstration Keywords

The keywords we represented here are collected from the responses combined from all the demonstrations of the drone. These demonstrations include both experimental and control group experiments.

CHAPTER V

DISCUSSION

Summary:

The drone's flight capabilities are used to express its intentions to humans. Our approach shows that drone flight capabilities such as yaw, pitch and roll can be used for effective communication of drone to express danger and help to humans. Human Drone Interaction is an area of research which is increasing day by day. Even though our research is a starting point, our results show that drones can communicate with humans and help us to extend our capabilities.

Limitations:

The main limitation is asking each participant to imagine the context of the demonstration, since we are conducting the experiment in a single place for all the demonstrations users are finding difficult to immediately recognize without the survey sheet or any prior knowledge of the context. But with the survey sheet provided prior to experiment they are able to understand what drone is saying very quickly.

CHAPTER VI

CONCLUSION AND FUTURE WORK

We believe that in future drones play huge role as companions to humans and communication plays a crucial role for that to happen. Our work in this paper is one of the initial steps to bridge the gap for making drones as companions to humans. In this paper we investigated on how drones can effectively communicate with humans using its flight capabilities.

The results suggest that humans can perceive the drone's intentions and our approach is feasible. Our future work will be increasing the number of participants and to explore more areas than help and danger and explore ways like mutual reinforcement learning for drone to get feedback from the users automatically.

REFERENCES

[1] P. Abtahi, D. Y. Zhao, J. A. Landay et al., "Drone near me: Exploring touch-based human-drone interaction," Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, vol. 1, no. 3, p. 34, 2017.

[2] V. Alvarez-Santos, R. Iglesias, X. M. Pardo, C. V. Regueiro, and A. Canedo-Rodriguez, "Gesture-based interaction with voice feedback for a tour-guide robot," Journal of Visual Communication and Image Representation, vol. 25, no. 2, pp. 499–509, 2014.

[3] A. M. Brock, J. Chatain, M. Park, T. Fang, M. Hachet, J. A. Landay, and J. R. Cauchard, "Flymap: Interacting with maps projected from a drone," in Proceedings of the 7th ACM International Symposium on Pervasive Displays. ACM, 2018, p. 13

[4] J. R. Cauchard, A. Tamkin, C. Y. Wang, L. Vink, M. Park, T. Fang, and J. A. Landay, "Drone.io: A gestural and visual interface for humandrone interaction," in 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI), March 2019, pp. 153–162.

[5] J. R. Cauchard, K. Y. Zhai, J. A. Landay et al., "Drone & me: an exploration into natural human-drone interaction," in Proceedings of the 2015 ACM international joint conference on pervasive and ubiquitous computing. ACM, 2015, pp. 361–365

[6] V. Chang, P. Chundury, and M. Chetty, "Spiders in the sky: User perceptions of drones, privacy, and security," in Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. ACM, 2017, pp. 6765–6776.

[7] P. Doherty and P. Rudol, "A uav search and rescue scenario with human body detection and geolocalization," in Australasian Joint Conference on Artificial Intelligence. Springer, 2007, pp. 1–13.

[8] B. A. Duncan and R. R. Murphy, “Comfortable approach distance with small unmanned aerial vehicles,” in 2013 IEEE RO-MAN. IEEE, 2013, pp. 786–792.

[9] R. A. S. Fernandez, J. L. Sanchez-Lopez, C. Sampedro, H. Bavle, ´ M. Molina, and P. Campoy, “Natural user interfaces for human-drone multi-modal interaction,” in 2016 International Conference on Unmanned Aircraft Systems (ICUAS). IEEE, 2016, pp. 1013–1022.

[10] A. Goodchild and J. Toy, “Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing co2 emissions in the delivery service industry,” Transportation Research Part D: Transport and Environment, vol. 61, pp. 58–67, 2018

[11] B. Kim, H. Y. Kim, and J. Kim, “Getting home safely with drone,” in Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct, ser. UbiComp ’16. New York, NY, USA: ACM, 2016, pp. 117–120. [Online]. Available: http://doi.acm.org/10.1145/2968219.2971426

[12] P. Knierim, S. Maurer, K. Wolf, and M. Funk, “Quadcopter-projected in-situ navigation cues for improved location awareness,” in Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ser. CHI ’18. New York, NY, USA: ACM, 2018, pp. 433:1–433:6. [Online]. Available: http://doi.acm.org/10.1145/3173574.3174007

[13] J. A. Landay, J. R. Cauchard et al., “Drone & wo: Cultural influences on human-drone interaction techniques,” in Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. ACM, 2017, pp. 6794–6799

[14] E. Malliaraki, “Social interaction with drones using human emotion recognition,” in Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction. ACM, 2018, pp. 380–380.

[15] J. Nagi, A. Giusti, G. A. Di Caro, and L. M. Gambardella, “Human control of uavs using face pose estimates and hand gestures,” in Proceedings of the 2014 ACM/IEEE international conference on Humanrobot interaction. ACM, 2014, pp. 252–253.

[16] S. Rajappa, H. Bulthoff, and P. Stegagno, “Design and implementation ¨ of a novel architecture for physical human-uav interaction,” The International Journal of Robotics Research, vol. 36, no. 5-7, pp. 800–819, 2017.

[17] J. Scheible, M. Funk, K. C. Pucihar, M. Kljun, M. Lochrie, P. Egglestone, and P. Skrlj, “Using drones for art and exergaming,” IEEE Pervasive Computing, vol. 16, no. 1, pp. 48–56, 2017.

[18] M. Sharma, D. Hildebrandt, G. Newman, J. E. Young, and R. Eskicioglu, “Communicating affect via flight path: exploring use of the laban effort system for designing affective locomotion paths,” in Proceedings of the 8th ACM/IEEE international conference on Human-robot interaction. IEEE Press, 2013, pp. 293–300.

[19] D. Szafir, B. Mutlu, and T. Fong, “Communicating directionality in flying robots,” in Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction. ACM, 2015, pp. 19–26.

[20] ——, “Communication of intent in assistive free flyers,” in 2014 9th ACM/IEEE International Conference on Human-Robot Interaction (HRI). IEEE, 2014, pp. 358–365.

[21] J. R. Cauchard, K. Y. Zhai, M. Spadafora, and J. A. Landay, “Emotion encoding in human-drone interaction,” in Human-Robot Interaction (HRI), 2016 11th ACM/IEEE International Conference on. IEEE, 2016, pp. 263–270.

[22] F. Mueller and M. Muirhead, “Jogging with a quadcopter,” in Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. ACM, 2015, pp. 2023–20

VITA

NEELESH IDDIPILLA

Candidate for the Degree of

Master of Science

Thesis: DRONE COMMUNICATION WITH NAIVE HUMANS

Major Field: Computer Science

Biographical:

Education:

Completed the requirements for the Master of Science in Computer Science at Oklahoma State University, Stillwater, Oklahoma in August 2019.

Completed the requirements for the Bachelor of Science in Electronics and Communication Engineering at Gitam University, Vishakhapatnam, Andhra Pradesh, India in 2014.