Final Bachelor Project

at student team Blue Jay Eindhoven

The future of indoor drones

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EXECUTIVE SUMMARY

The objective of this project was to establish indoor drone application exploration and besides development of significant communication possibilities. Blue Jay Eindhoven is a student team, which I joined, focusing on the future usage of domestic drones. This team highly focused on healthcare purposes, but lacked on proper reasoning behind their choice. Therefore extended knowledge about different user needs was valuable to acquire, however not highly prioritized according to the team goals. It was more important to develop communication software to demonstrate the social functionalities this domestic drone also could have. Proper insights in varying opportunities were still shortcoming.

In the period at team Blue Jay two seperate activities were chosen. The application analysis and the communication software. The completion of application exploration was kindly appreciated by the team and can be taken into account in further stages. Moreover this analysis could be used by multiple other indoor drone developers which cover similar domains. Apart from this analysis also speech recognition software was developed. Since it was impossible to already test this it remains unclear how valuable this recognition software really becomes. Hopefully the speech recognition test results can provide enough insights in the potential of social features on indoor drones.

TABLE OF CONTENTS

0 EXECUTIVE SUMMARY

1 INTRODUCTION 7

2 ABOUT BLUE JAY EINDHOVEN 8

2.1 Motivation

2.2 My role

3 LITERATURE REVIEW 10

4 IDEATION 13

4.1 Brainstorm at Health Innovation Campus

4.2 Communication methods

5 APPLICATION ANALYSIS 17

5.1 Healthcare

5.2 Hospital logistics

5.3 Hospital visitor guiding

5.4 Fire safety

5.5 Education

5.6 Agriculture

5.7 Evaluation

6 INTERACTION DESIGN 33

6.1 Gesture recognition

6.2 Speech recognition

6.3 Hardware

6.4 Software application

6.5 Evaluation

7 DISCUSSION 40

8 FUTURE WORK 42

9 PROCESS 45

10 REFLECTION 49

10.1 At Blue Jay Eindhoven

10.2 My process

11 ACKNOWLEDGEMENTS 52

12 REFERENCES 53

13 APPENDICES 54

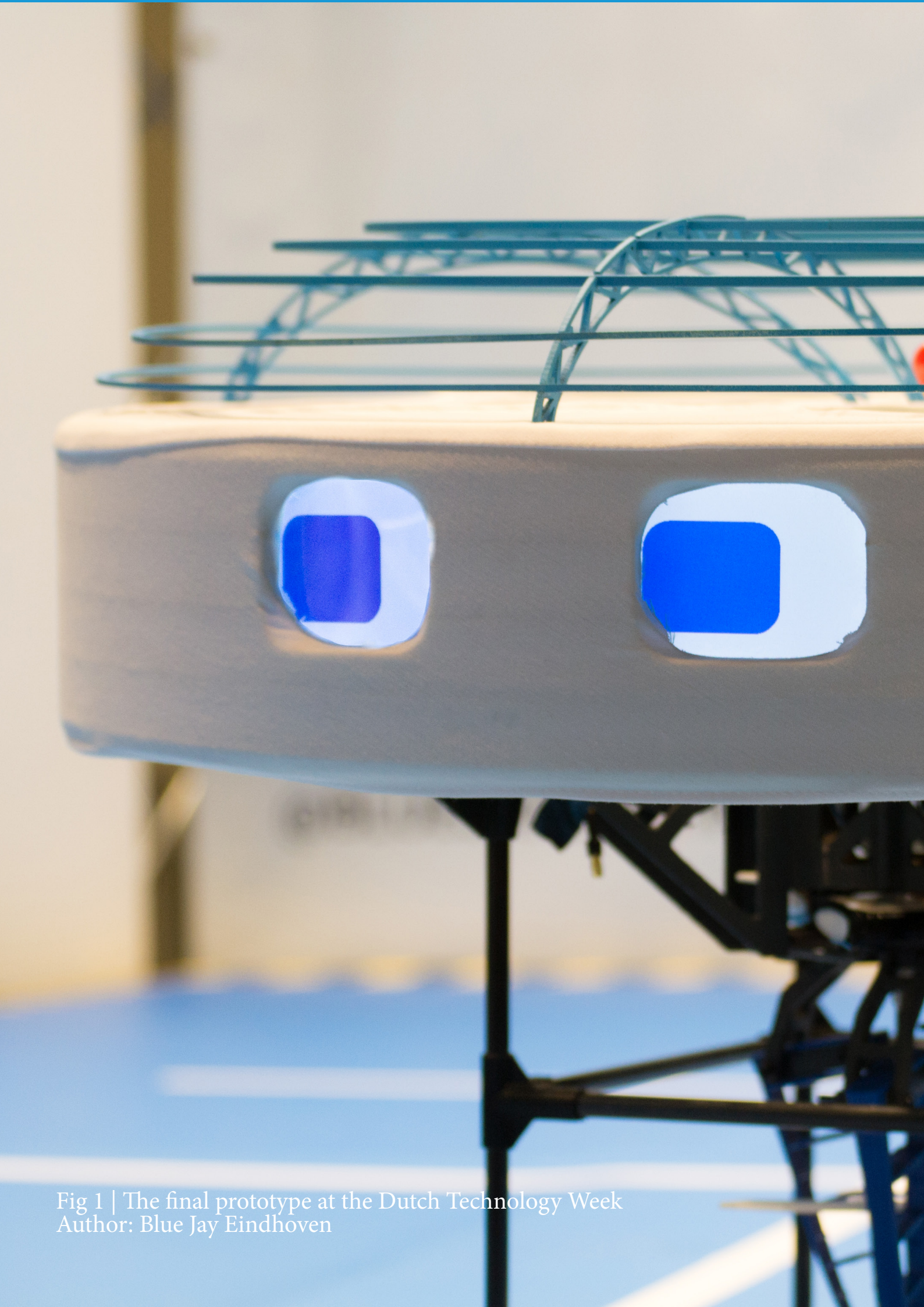

Fig 1 | The final prototype at the Dutch Technology Week
Author: Blue Jay Eindhoven

01 INTRODUCTION

I am Olivier van Duuren, a final bachelor student Industrial Design at the Eindhoven University of Technology. In the past half year I got the opportunity to join the student team Blue Jay Eindhoven. As Industrial Design student a commitment to an external project is extraordinary interesting. In this report I will guide you through different activities, ending up with my process description and reflection. What did I do and especially why I took specific decisions.

Throughout the whole report there is made a significant difference between ‘domestic’ and ‘indoor’ drones. In my consideration a domestic drone is a specification of an indoor drone due to its focus on social interactions. Blue Jay Eindhoven relies on the term ‘domestic’. I will only deviate from that in my application analysis reasoning.

First I will introduce team Blue Jay Eindhoven and my designer vision, answering the following question. Why did I join Blue Jay Eindhoven?

02 ABOUT BLUE JAY EINDHOVEN

Blue Jay Eindhoven is a team consisting of dedicated students from various faculties, who are all working together to develop the world's first domestic drone. Today, drones are deployed as instrument to observe, transport and entertain in the outdoor world. The Blue Jay drone is the first domestic drone which flies indoors. Flying indoors is quite a challenge, since GPS(Global Positioning Software) does not work inside. For now the team tends to develop these drones and desires to generate more and more insights for the world.

The first year's team (started in 2015) exposed the first prototype during the world's first Drone Café at the TU/e lustrum festival. Right now, the second team is improving the prototypes by means of hardware and software and strives to prove the application possibilities in healthcare. Will this be a better application area than serving drinks? In any case, Blue Jay is curious to discover!

Fig 2 | The drone presentation
Author: Bart van Overbeeke

2.1 MOTIVATION

I am highly interested in interactions between technology and users and therefore striving to apply acquired knowledge of human behavior into research. I wanted to perform extensive user research and with that focusing on the importance of human to product interaction.
“Team Blue Jay is developing a drone that understands you and helps you with daily tasks. It’s safe and operates completely autonomously.” [1] This team is entering a new world of opportunities. Within this wide field of exploration there is great need for user understanding. Is there any user actually interested in this domestic drone and are they even in need of such technology? I think there was agonizing need for valuable user consideration and that is why I came in. Besides, there was major interest in communication development, which also got me enthusiastic.

2.2 MY ROLE

I was asked to be part of the interaction team of Blue Jay which is dedicated to develop all different interactions between drone and user, as for instance face recognition, eye movement, sound display, all concerning drone to human communication. At first for me there was a role in human to drone communication, the other way around. Blue Jay Eindhoven requested me to develop gesture recognition. Something they found promising. Later on I switched to speech recognition. Decisions on this topic will be discussed in section ‘Speech recognition’ at page 19.

03 LITERATURE REVIEW

When developing robots to solve societal issues such as in healthcare it is important to consult previous considerations and implementations. How do people react to robots? Do they want to be helped by robots in what context? More research is needed to be able to judge on indoor drones in specific. Since this is a ground-breaking topic only considerations regarding to robots in general were taken.

There is already a big amount of existing literature in robotics focusing on the acceptance of health robots. However insights still remain explorative, there are already interesting argued suggestions found. According to Kuo et al [2] people's gender has significant effect in healthcare robot acceptance. In this study there was found that after the robot performed blood pressure measurements, males had more positive attitude towards the robot than females. This combined with a study from Broadbent et al [3] showed that next to gender also age, needs, cognitive ability education level, past experience and culture. This study (Broadbent et al, 2009) also determines robot appearance as influence on acceptance. Accordingly humanness, size, gender, ergonomics and 'personality' have significant impact. It needs to be considered that when developing indoor drones all these individual variables are needed to take into account in order to secure user acceptance.

Since indoor drones might fly among humans very closely it is necessary to incorporate proxemics behaviors. In a study by Takayama and Pantofaru in 2009 [4] it is clear that personal experience does affect, decreases, personal space.

Moreover, whenever a robot is oriented towards the user's face, the minimum comfortable distance decreases for men, however decreases with women. From this research is learned that again gender has relevant influence on the way people feel safe with robots. Developers of indoor drones should pay close attention whenever the robot faces towards people and at least consider personal spaces in general.

Fig 3 | Dutch Technology Week
Author: Blue Jay Eindhoven

Fig 4 | Brainstorm at Health Innovation Campus
Author: Blue Jay Eindhoven

04 IDEATION

4.1 BRAINSTORM AT HEALTH INNOVATION CAMPUS

On the 8th of February 2017 team Blue Jay brainstormed about the future of domestic drones together with a lot of different companies (e.g. RSZK ZorgProfessionals, Accenture, Maxima Medisch Centrum etc.) at the Health Innovation Campus in Veldhoven. The aim of this brainstorm was mainly about getting insights from many healthcare specialists about the different healthcare application possibilities varying from hospital to home care. As part of this research it was valuable to be involved and to discuss the potentials of healthcare applications.

During the brainstorm a lot of first interesting insights were found. At first there was learned that domestic drones were most promising in long term care, because increased population ageing [5] and shortage in caregivers [6] are rising societal problems. Promising target users were stated to be children who have prolonged diseases, elderly in homecare, people with dementia or handicapped patients. Eventually team Blue Jay needs to involve tje target users instead of the experts in further research.

4.2 COMMUNICATION METHODS

Domestic drones are entering human environments. In any case drones then tend to need a specific method of communication from human to drone. Wherever the drone would be most applicable, this method analysis will provide

most suitable communication method out of the ones taken into serious consideration. Users can communicate with drones via mobile devices, vision based gesture recognition, data gloves and speech recognition. Other possible techniques were not researched.

Mobile device

Communication with mobile devices probably was an obvious and easy solution. People in today's society are almost all equipped with such a device. In that case it seems to be the solution. A mobile device often allows direct control and is not distance depended. However this device is depending on battery, active connection (e.g. Bluetooth or Wi-Fi). Imagine healthcare scenario's which certainly are not allowed to have any lack of connection. Besides mobile devices have low embodied/intuitive interaction affordance. Interacting with a drone via another extra device might feel very illogical, especially in cases without 100% immediate feedback.

Vision based gesture recognition

Implementation of this communication method was initially proposed by team Blue Jay. Depending on the physical position of your hand different messages can be produced, analyzed and recognized. There was assumed that deaf people who need to analyze and recognize communication from other human beings communicate also by means of vision based gesture recognition.
When considering people with normal hearing there is no improvent whenever producing communication with gestures anyhow. Users are required to learn the 'dictionary'

of this language, which demands a lot of effort. Next to that this communication method is limited to the physical abilities of human hands and therefore has limited message variability. Furthermore it is probably distance depended and demands body movement which probably is energy consuming for especially elderly. As final remark this method on itself is not able to get the required attention from the drone in cases when drones are looking to the other side. Then patience is needed, as seen when visitors in a restaurant need to get attention from waitresses at first to communicate there relevant message.

Data glove

People can as well communicate with drones by wearing gloves which translate hand posture and instantly signals messages, also when drones are at large distance or not even paying close attention. This can be illustrated with a computer mouse (related to a computer) with which is acted subconsciously when controlling your interface. With this method you might afford better measurement accuracy compared to vision based gesture recognition and also permit direct control. However it is an extra device which you first need to wear before communicating is even possible. It is also highly depending on strong connections via Wi-Fi or Bluetooth. Besides, such communication through using gestures is still limited to the physical abilities of your hands and therefore constrains the message variability.

Speech recognition

People can nowadays also control devices through using

voice as we communicate to human beings. Speech recognition development is improving every day and affects the way we communicate with a lot of other high tech products already. It has great message variability and affords direct control, although limited to small distances (not surpassing hundreds of meters, depending on environment noise). Nevertheless as compared to human to human communication microphones can be used to solve this issue. This method of communication is obviously most promising, however still lacking of high accuracy for most developers since this is not open-sourced and especially not affordable yet.

Result

When comparing speech recognition communication with the optional alternatives, which provisionally belong in the scope of team Blue Jay, speech recognition is the number one choice to continue developing.

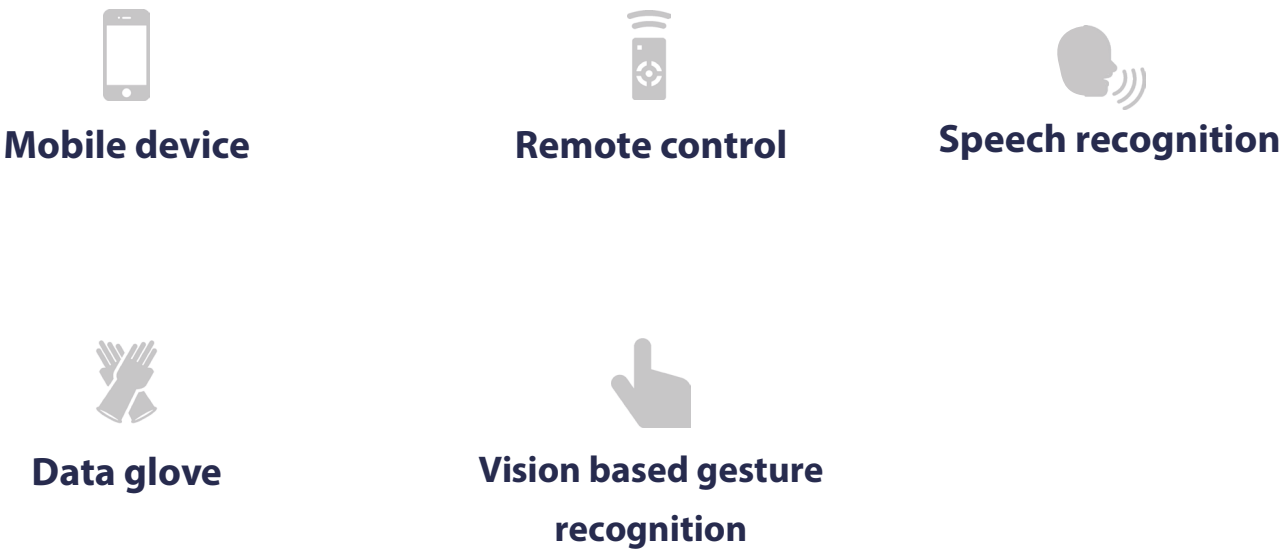

Fig 5 | Different communication methods
Author: Olivier van Duuren

05 APPLICATION ANALYSIS

New technology with lots of opportunities is not always valuable to the user, who developers might think will be most promising. The aim of this application area exploration is to provide an overview of the different approaches drone developers need to take into account. As many drone developers might just start within a particular domain, it can be valuable to search for some more detailed information which matters when developing in that specific context. In this analysis a few healthcare applications, hospital logistics, fire safety and hospital visitor guiding are seriously considered and discussed with field experts. Education and agriculture are less explored since there the associated people were not available. Nevertheless some first insights in these applications were collected to emphasize the yet existing potential for indoor drones in both domains.

5.1 HEALTHCARE

This year team Blue Jay chose to invest and explore healthcare applications and especially care for people with physical disabilities. However whether these people truly need a drone to improve their quality of life was not clear yet. Therefore it was valuable to dive into this domain again and even find additional applications associated with healthcare if present. Since this topic is very broad and has many different purposes there is no general problem definition. This needs to be determined per specific domain.

The first physically disabled person involved in this research

was paralyzed in her legs and therefore in a wheelchair. Still living at home without extra serious help needed. She was very positive about Blue Jay's health purposes. A drone is less present than a not-flying health robot and can offer much more functionalities with its flexibility. The highest value for her was as she said: 'Helping me to get drinks in the garden, over the bump, without spilling anything on my way'. Furthermore the drone could occasionally assist her in getting a cake tin located in a high closet. Then the drone should be able to get objects wherever located. However, since she is not really depending on caregivers and these examples do not frequently occur, the drone is not offering enough value by now. Most of the time she can handle things on her own and once in a while she demands assistance from her partner or neighbors. These constraints are habituated and are not worth the value of such a drone, since there is also low budget in this stage.

The second person involved in this research had more severe physical disabilities and with that she was a lot less self-reliant. This could affect the way she thought about indoor drones in comparison to the first person. This patient gets home care offered by the organization called 'Fokus'. An organization which strives to make living at home with physical abilities feel normal and easy again by the many caregivers and accomodations they offer [7]. The patient reported that in her situation a drone would have no potential. In her view drones are still not offering the help caregivers, in other words humans, can provide . Drones actually cannot offer the help she needs, such as getting in to bed, changing cloths etc. Something

which was not taken into account so far. After all, again, independent of the severity of the disability, drones are not that promising as might be imagined. Giving the fact that even with serious consideration about the willfulness of people about their disabilities and how ignorant they could be concerning the upcoming shortage of caregivers, this application remains undetermined.

Besides, these more or less depending people living at their homes, it was probably more interesting to get in contact with people moved to nursing homes. They might have more need for alternative home care. That's when the focus shifted to Vitalis Berckelhof; a nursing home providing home and care for mainly elderly [8]. During a visit over there, a lot of insights had been gathered through different talks with individual inhabitants. All of them were convinced that there was unavoidable future for drones in healthcare.

Fig 6 | Interview with healthcare patient
Author: Yvonne Potting

However they did not see it happen yet and moreover they did not think it was yet for them to experience. In their agreed opinion drones could probably assist once in a while, but not offer enough valuable assistance. Only one of them said there probably was potential in social engagement. If this was an exception or a true potential, remains unclear. According to specific research [9] this thought can be supported. This paper suggests that there is potential for social robots in improving the well-being of elderly. This certainly has to be investigated more.

5.2 HOSPITAL LOGISTICS

The 23rd of May an application exploration interview with Fons Segers took place who is employed at the Maxima Medisch Centrum hospital in Eindhoven as head logistics.

Fig 7 | Maxima Medisch Centrum
Author: Olivier van Duuren

We got in touch via the brainstorm at Health Innovation Campus co-organized with Blue Jay Eindhoven.

Logistics of Maxima Medisch Centrum is consisting of a few different activities. They coordinate the storehouse, the supply and discharge from nutrition, sheeting and waste to medicines(partly) and patient samples. Today visitors are allowed more and more at the hospital, which causes that the logistics and therewith the sound level and other complications are perceived by people more often. Next to that the tube post (still todays transport of the majority of samples) is not distributed to all the different departments. This still implicates a lot of transport risks. Furthermore the supply of samples to the lab isn't that continuous flowed as desired. Instead of delivering 100 samples each hour, the lab wants it gradually spread over the hour, which is actually almost impossible for the logistics team. Summing up these problems and taking a few more into account, it seems time to seek for new alternatives.

Would indoor drones be a solution to these problems? Fons Segers thinks there are a few opportunities, however keeping in mind that people nowadays can work very efficient in most cases and can transport a lot more. Indoor drones would be an alternative for laboratory transport. Four to six times a day the logistics team walks by the departments to pick up boxes with samples. Since the weight is approximately 300-500 grams per box it would be interesting to let a drone transport that. Keep in mind this process needs to be examined first. Testing whether it is actually more efficient and less expensive. As well it would

be an opportunity for indoor drones to autonomously deliver continuous flow of samples to the lab. It seems there is great value, however as mentioned above, it needs to be tested if this actually improves the process. As well, according to an additional talk with Lars Prinsen and Arthur Salters(both involved in hospital construction) in some hospitals there is a big distance between the Operating Room(OR) and the laboratory. As the operators often need a lot of blood products from there, during surgery, it's needed that someone/something can get it for them. This is a very inefficient walk and is definitely something where drones could become very useful.

The drone would need different functionalities. Within laboratory transport the drone must be able to fly indoors autonomously. The most important consideration of flying indoors in hospitals is the height of the corridors. Since a lot of visitors are passing by, drones need to fly safely outside of reach. This is highly prioritized according to Segers, Salters and Prinsen and is and will be quite a big focus for new constructions the upcoming years. Indoor drone also needs to communicate with doors and elevators from distance to provide good flow. Especially when providing blood products to the OR it is essential that it can pass doors. Fortunately nowadays the new constructed hospitals are already implementing doors and elevators which allow this communication. The drone also needs a gripper to displace objects from location A to location B. This needs to be strong enough to prevent it from dropping after small clashes. Moreover when transporting blood products to the OR the products are preferably stored on

top of the drone where it is better protected.

Unfortunately there already are some pitfalls envisioned. Firstly, there is time needed for staff and visitors to adapt on this innovation. People need to feel comfortable about drones flying around inside. This process will also at least take some time. Furthermore it is definitely relevant to everyone that the drone is approximately silent. The current sound level is still very loud (estimated 60 dB) and needs major attention.

A few parties are engaged in this drone integration. The technical staff needs to adapt and supply indoor navigation to the drones which can be read. They need to consider changing infrastructure indoors differently. The logistics team needs to adjust existing methods, schedules etc. Intern and extern communication is very important to decrease the adaption time of indoor drones. In this way you can let people know there is something new and currently applied in the building.

5.3 HOSPITAL VISITOR GUIDING

There was deviating potential in ‘patient’ logistics, according to Fons Segers. Daily around 10000 people enter the building. Most of those are visitors and still a large percentage is wandering around to find their final destination. The information columns, instructing volunteers and ‘golf cars’ (driving people to their destination) are not effective enough. As discussed, drones can offer help

in guiding people from entrance to their destination. Especially in large buildings, instructing people at the entrance is not good enough.

Indoor navigating mobile applications are not the desired solution, since they lack of 100% guaranty of reaching the destination. Next to that Segers explains that drones, especially Blue Jay, can be more socially connected and assist visitors more appropriately. The perfect scenario would be that visitors enter the building and can ask a drone to assist them to a specific destination. On their way the drone can communicate about which departments and facilities they pass by. However if you consider the percentage of people entering unfamiliar buildings without knowing where to go, you probably need at least five to ten of these drones to provide all the user demands.

Fig 8 | Wandering visitor at Maxima Medisch Centrum
Author: Olivier van Duuren

5.4 FIRE SAFETY

The 23rd of May I had an application exploration interview with Paul van Dooren. He works as consultant Repression and Innovation at Veiligheidsregio Brabant Zuid-Oost. He, himself, approached Blue Jay Eindhoven one year earlier. This is how I set up the meeting.

Veiligheidsregio Brabant Zuid-Oost is mainly focusing on people less self-reliant and less mobile. The specific application area which we elaborated on during the meeting is 'Fire safety' buy in general 'Living safe'. People live at home longer and longer and with this the self-reliance of these people decreases. This can cause increased dangers in health, burglary but especially fire safety which is his main expertise.

The value of this indoor drone is mainly distributed over a whole process of preventing and fighting against indoor danger. At first the drone can detect fire danger by measuring heat violation. At second it can (maybe over distance) warn the inhabitant and simultaneously try to shut down the power of the product(e.g. television or coffee machine) in danger. The step afterwards is alarming the family and/or neighbors. Depending on the severity it could also directly inform the emergency room at the fire services. In some cases it can itself extinguish the fire. However it is more important to navigate the inhabitant outside as quick as possible. According to Paul van Dooren this is most prioritized. At the time the fire keeps increasing the fire brigade is send on their way. The drone can support them

as appropriate as possible by sending its sight whenever they are on their way or at the site. This can continue as long as the brigade needs it.

Regarding the functionalities of the drone a few are necessary and a few are less important. In order to navigate inhabitants outwards it must fly autonomous and be able to fly in smoke and dark areas. Next to that it should be able to communicate to family, neighbors and the fire brigade. Then it is also important to sense heat in order to prevent fire danger. Less important would be the capability of extinguishing with a gripper and providing sights at the location of fire. There is no value in other things, such as covering unreachable heights and face recognition for instance.

Fig 9 | Office Veiligheidsregio Brabant Zuid-Oost
Author: Olivier van Duuren

advantages of indoor drones according to Paul van Dooren. However a few things should be taken into account. At first, we need to consider the low budget and the unfortunately still expensive purchase of indoor drones. It might be offered by insurances with low rates or owned by the fire brigade itself, however this is still uncertain. Another remark, as mentioned earlier, the heat, smoke and darkness in these areas are circumstances in which the drone still needs to function. Therefore this should be integrated in the prototype testing plan. It is also important to keep in mind that drones need to communicate with doors to navigate from room A to room B. This technology is, as Van Dooren said, already in the shelves.

A few parties have engagement in the process described above. As described family or neighbors but especially the emergency services are closely involved in the prevention of danger via communication with the indoor drone. Each different stakeholder should be easily connected to the drone to afford this communication with the inhabitant. The indoor drone needs to overrule any circumstances and be able to transfer the severity as quick as possible. All these different stakeholders can make use of the drone to warn the inhabitant possibly more directly. This can help to prevent any kind of danger. Besides prevention it is important for the fire brigade to understand and oversee the situation during their job appropriately. They have major benefit to a quick and supportive indoor drone, which can react on their input if necessary. When the fire brigade is close enough at the site they probably desire to take over the controls of the indoor drone. Blue Jay needs

to afford that if needful. Then the fire brigade is required to be skilled enough to take over and control the indoor drone and make it assist as seamless as possible.

5.5 EDUCATION

What about indoor drones for education purposes?
This might slightly outstand the other application area's discussed above. In an early market analysis 'education' would have never became a potential application for indoor drones as it is now. Yet people with education expertise fortunately changed this thought completely . During the Dutch Technology Week in Eindhoven there was an event called 'Night of the nerds' organized for a lot of school classes coming from different cities out of Eindhoven as well. A big event where mainly educators/staff got really interested in the drone technology which was presented on behalf of team Blue Jay Eindhoven. As from a comprehensive talk with an IT(information technology) manager Bas Becu from Ixperium and afterwards with a school director it was pointed out that both had meaningful interests. At primary school there is lots of interests in allowing children to confront with today's technology. If this drone can enable young children to explore technology appropriately it definitely can be promising, they both explicated. Apparantly these people both purchased some drones for educational purposes. However these were not safe enough and crashing a lot.

Most importantly is that the developers of the drone need to offer an additional platform (e.g. ‘Scratch’) to simplify coding for young unknowing children. In order to provide a great variability of executing tasks the children can learn more and more. Therefore the drone should allow a broad range of functionalities like the communication to people and products, the transportation of objects etc. Obviously these functions are not hardly needed and this can vary depending on the feasibility of the different developments.

Apart from this new platform, the drone obviously still needs to fly autonomous and especially very safe. In crowded environments like class rooms, if this would be the fly zone anyhow, it is necessary that despite coding failures of children it can guarantee safety in any case. Since, in education, failures are still common, the drone must be able to overcome wrong commands. Besides a class room environment might be very hectic. So flying safely is of great importance in this application.

Education is an interesting and probably slightly deviating application, however can still be promising. Nevertheless, for future developments there needs to be taken into account that this domain is not highly prioritized. There is a lot of technology which is already suitable for education purposes and indoor drones are despite their growing interests still far from application possibilities. While considering the development and functionalities of the Blue Jay drone at least.

5.6 AGRICULTURE

Would drones be the future of agriculture applications? According to several people, drones would be a promising new piece of technology enabling farmers to detect dry spots or unhealthy plants in large greenhouses earlier. These days someone often needs to walk through the greenhouse and manually randomly check some samples, which is not quite efficient and very unrepresentive. Business developer Pieter van Warmerdam, explained that farmers in Morocco already look for drones to monitor their fields as well. This apparently is, as he stated, not only promising in western countries like the Netherlands where we have many greenhouses due to the climate, but also in African countries.

In the scenario of monitoring large fields, promptly analyzing droughts and informing the farmer about the specific information, there are a few considerations need to be taken into account according to Chris Ramsay. As obvious the drone needs to fly autonomously to surpass todays inefficient monitoring. Safe flights are needed to prevent injuries to laborers in the field and to prevent damage to the field, construction and harvest. It is necessary that the perception and with that the analysis of the drone can be reviewed whenever needed by providing storage of its vision. High quality vision should be carried along, since the drone needs to be able to analyze the harvest circumstances. It is needed that the camera can be mounted to the bottom directed to the plants below it, for high accuracy reasons. In order to provide this sophisticated

vision the drone as well needs to fly nearly stable. This is probably a crucial requirement which needs to be developed with great focus. A speed of one or two meter(s) per second is fast enough and therefore probably would not have big impact on its stability.

Agricultural purposes are interesting and certainly not that quite distinquishable to what the Blue Jay drone can offer right now. Still a few functionalities need to be improved to offer more guaranty of success. As for the rest there needs to be more investigated into this specific domain, since the approach lacks of complete information. In order to get more valuable insights a manager or field worker needs to be consulted. Furthermore, contact with Chris Ramsay is recommended to maintain since he is running a project in Delft concerning indoor drones in greenhouses.

Fig 10 | Drone in greenhouse
Author: Chris Ramsay

5.7 EVALUATION

The executed research remained needless whenever the knowledge transfer was not properly done. In order to achieve this, a booklet (Appendix A) was established for the future of the Blue Jay drone development in particular. Since the team has not changed yet a few current members were asked to give feedback. This evaluation is concerning input from the team manager, the hardware/fly architect, the interaction architect and the electrical architect.

Generally, the booklet was considered as valuable and the team, in particular the team manager, saw the benefits. According to the hardware architect still somethings were not properly integrated. As in his opinion there is for instance need for smart home environments in healthcare applications just like communication with elevators and doors was stated in 'hospital logistics'. On that account there was learned that there was a significant difference in the content of each meeting. Some requirements were missing, because they had not been covered during the meetings. Minor change to the booklet was recommended.

Lastly, the interaction and electronics architects pointed out that some functionalities were not completely true. As was stated that the drone could lift 500 grams and it actually could only lift 350 grams at the end. This variable has changed frequently at this early stage and that resulted into miscommunication once in a while. Proper communication and also final checks from other developers will be in need to correctly report the list of functionalities in the future.

06 INTERACTION DESIGN

6.1 GESTURE RECOGNITION

This communication method was the first one I started to develop after supportive research. The aim of this communication implementation was to give people the opportunity to connect to the drone socially. This was approached via the use of a game. At first several vision based gesture recognition games were worked out. Eventually the well-known game rock-paper-scissors [10] was chosen based upon the familiarity of this game among the great majority of people asked. During the development of this game several intermediate games were set to prevent possible pitfalls. As well there was a game scenario established to provide structured progress. This seamlessly mingled together with other interactions (e.g. eyes and sound) of the drone. Therefore close collaboration with the team was necessary.

Due to some software restrictions, set up by team Blue Jay, there was limitation to only code with Python language. Software development in any other code language could harm the outcome while running several codes at once. Since Python was a very new language to me, there were some startup problems, mainly because there was dependence on open-sourced code on the internet [11].

Besides spending time in order to obtain basic understanding of Python, there was lots of effort put in to understand the used gesture recognition code. Multiple attempts were needed to manipulate and adapt the code in order to establish the rock-paper-scissors game on time.

The 9th of March team Blue Jay had arranged there first drone presentation for partners and friends. During this event there was possibility to individually present my work and afterwards the potenials of this communication method could be discussed. Fortunately it was a successful demonstration and many people visited the demonstration and provided me from valuable insights.

6.2 SPEECH RECOGNITION

After the communication method analysis there was quick focus on the new chosen software. This was crucial since during the Dutch Technology Week, two months later, there was appropriate implementation needed. Again the same restrictions on the software language were applicable in this case. The speech recognition must be working without Wi-Fi connection, since this was problematic due to the interference issues of many visitors' mobile devices previous year. Furthermore, environment and voice testing was required since it probably would be noisy during the crowded event, where many different voices could interact with the drone.

Firstly, there was performed an analysis of different API's(Application Program Interface). Google, CMUsphinx and Microsoft and more were compared upon the above mentioned restrictions. Eventually CMUsphinx [12] was most suitable for Blue Jay's purposes due to its feasibility and accuracy. This, according to a contact person from the software company Fourtress with which team Blue Jay

just recently established collaboration with. With some help from Fourtress the installation of the API eventually succeeded. For future development this process was documented in great detail.

Unfortunately a lot still had to be tweaked since the API was not accurate enough. Therefore the range of messages was significantly constrained in order to guarantee higher recognition accuracy. Besides, a lot of API training was performed to strengthen the filters which were set to improve message selection as well. Furthermore environment testing was executed to perfect the software even more. On that account several buildings and outside acoustics were tested. Luckily the results showed that the recognition accuracy was good enough, because of minor affections. Finally, there were some voice tests executed by several people. After testing some varying voice frequencies of women and men a last improvement could be performed on the recognition. Namely by changing the microphone. This improvement will be discussed in the section 'Hardware' at page 36.

Eventually the recognition was accurate enough for the three different messages presented during the tic-tac-toe event during the Dutch Technology Week. A 'hey'-message to get attention of the drone, a 'yes'-message to agree upon playing against the drone and a third more used message 'Your turn' after each move to let the drone know whether it is its turn (code available in Appendix B). Unfortunately the tic-tac-toe game was not the perfect demonstration for speech recognition, but this could not

be avoided due to the program of team Blue Jay. Another disappointment was that speech recognition was not able to be integrated and tested in the game during the event since team Blue Jay faced some difficult software and hardware problems with flying. This obviously is higher prioritized and therefore speech recognition was appointed less important.

6.3 HARDWARE

How do humans speak to this drone? From where and via what sort of device? Integrating a microphone in the drone would be optional. However this would limit the distance of speech. Besides, whenever the drone is actively flying around or performing tasks the produced noise can seriously interfere the speech control.

Therefore it was possibility to let the user wear the microphone. Wearable microphones are already seen in human to human communication and human-product communication a lot (e.g. headsets for game entertainment, calling and lecturing). Nevertheless it is definitely important that the user accepts this wearable in order to communicate with a drone. Why should the drone's user wear microphones to communicate with it? In order to answer this question the benefits of drones were needed to be found. Whenever this becomes clear, users would sooner wear such a wearable device.
After assuming that users would accept wearing a microphone based upon answers of different target users,

there was major investment put into the manner of wearing. At first, a simple earplug Bluetooth microphone was used. However because of hygienic reasons this idea eventually got cancelled. As alternative there was designed a holder for the microphone which could be attached to clothing After a few iterations the 3D-printed model finally reached perfect shape and strength.

This holder was brought along to several interviews with healthcare patients suffering of physical disabilities. Whenever they would think this drone could offer them the support they needed, which they truly denied (see section ‘Healthcare’ on page 17), they believed it would not bother them a lot. One of them even mentioned that in severe cases the microphone possibly could be sophisticatedly integrated in electronic wheelchairs. In this way it can lower the level of acceptance if needed.

Fig 11 | Microphone attached to 3D-printed holder
Author: Olivier van Duuren

6.4 SOFTWARE APPLICATION

When considering speech recognition as the most promising communication method for indoor drone applications, there is still a remaining question. Is speech recognition actually required in each application domain? As found in the application analysis ,not in every domain speech recognition and generally communication is required. First application is hospital logistics. In the conversation with Fons Segers (see section 'Hospital logistics' on page 20) there was no user need found for sophisticated communication via speech. Simple commands, when perhaps needed, could be communicated via a simple screen. In this case speech recognition would not be necessarily a requirement for valuable functionality. An equal reasoning can be used to the application domain 'Agriculture'. In any case direct communication with people is nearly ever essential for valuable performance.
As for fire safety counts it is highly important that the drone can offer speech recognition to let inhabitants in fire danger zones communicate with outsides brigade in case of emergencies.
It is uncertain whether when applying drones in these scenarios there are already better alternatives.
In remaining applications also discussed in the section 'Application analysis' there is obvious need for communication, because people when needed, wanted to instruct the drone in order to execute certain tasks. This counts for healthcare purposes, education and hospital visitor guiding. Whenever this will be certainly crucial, it needs to be validated during user testing.

6.5 EVALUATION

Is there still potential concerning speech recognition in Blue Jay's drones next year? Team Blue Jay recently set up a knowledge transfer meeting with the follow-up team. The aim of this meeting is to prevent all the work and effort from diluting. Instead there is intended to let every single part of software, hardware, research and even more be useful for the next team as well. With that, speech recognition and other work concerning interaction design will be transferred properly. In this way there is higher guaranty to take over previous work.

There is an additional document established for correct installation of the speech recognition software. This very extended document was especially set up for the upcoming knowledge transfer day. It kindly guides you to every single step which has to be carried out in order to correctly use speech recognition from nothing till eventual speech recognition.

Considering the deliverables many Blue Jay members stated that they see the hard work and the result with it independent from the event. For the next year's team they think it will be easy to continue with. As well they evaluated the established installation document and were quite enthusiastic about the extensiveness and were truly convinced that they could reproduce it according to these summarized steps.

07 DISCUSSION

The work presented in this report needs to be considered as first exploration. The drone development of Blue Jay Eindhoven is still in a beginning phase. Therefore the application analysis cannot be fully applied and used yet. Although a lot of findings were already worked out in great detail, still a lot of additional research is required. When specifying to a single application more meetings could be arranged. Interpreting the results can definitely steer other researches involved in indoor drone practices. However at this point of the research there is difficulty to pick out one most promising potential. On the scale of budget there is most potential in hospital logistics. Yet if drones are applied on the scale of distinctiveness they tend to score very low in comparison to fire safety. However in this application there are a lot of requirements which the indoor drone needs to meet. Since every application has its disadvantages and advantages in comparison to others, this research suggests to interpret the results per individual domain, separately.

In order to improve and surpass this research, other techniques are desired which allow the possibility to compare potentials properly. Improvement on usage of tools which can make obtained knowledge easily comparable is recommended. Furthermore it is suggested to put more effort in the specific product markets. How did target groups behave in regard to similar products on the market? This might emphasize the highest potential as well.

Regarding the discussed studies in the section ‘Literature’ on page 10 it is especially important to keep statements about proxemics behaviors in mind. Some findings are

supporting the addressed literature, however it remained unclear how different users in a specific application domain would react to indoor drones during test flights.

Fig 12 | Dutch Technology Week
Author: Unknown

08 FUTURE WORK

Evidently indoor drones and especially domestic drones are at a beginning stage of development and certainly application. In order to perfectly integrate this technology into society, definitely depending on the application, several and for some even more years will pass. During these years a lot of more research and testing can be performed. This application exploration is only a first step into the future of indoor drones. Eventually also software will be better and better and can be implemented more seamlessly.

At first it is recommended to discuss indoor drones with a lot more people to obtain more detailed insights. On agriculture, education and hospital visitor guiding there is still limited insight and therefore arrangements with respectively farmers, educators and/or young children and hospitality employees have to be arranged. As well for other domains like healthcare, fire safety and logistics it is still valuable to collect different perspectives. At least when developing a drone for one single purpose more insights are needed to take proper decisions. Furthermore there are still applications left which regrettably did not get enough attention in this research. Catering is one example worth mentioning. Business developer Pieter van Warmerdam explained that there occasionally are events organized for elderly and/or physically disabled people, who all need to be provided with drinks for instance. Indoor drones could be promising in this application as well.

In addition, it is necessary to notice that sometimes skepticism can be needed while evaluating user research. ‘Potential’ users do not always see or feel their need.

Whenever new products enter the market, users will not always be convinced of its purposes and functionalities. However after purchase and usage often this feeling suddenly changes. In other words, other techniques need to be practiced to get probably more valuable insights.

Fig 13 | Upcaling of the Blue Jay drone
Author: Blue Jay Eindhoven

Fig 14 | The drone presentation
Author: Bart van Overbeeke

09 PROCESS

During the past months I fanatically participated in the journey of Blue Jay Eindhoven. Due to the strict deadlines of this external party and the requirements of the faculty of Industrial Design there had been some adaptions in the habituated design process I apprehended in previous projects. This new approach highly conflicted with my habits, however was very well illustrating the possible genuine outcome of ground-breaking high-tech projects.

Firstly, I was busy settling in the team by understanding their process of development, their hierarchy, their management and so on. Almost simultaneously I started executing field research in order to gather valuable insights concerning the context of existing literature about robotics. Several scientific papers are considered to get understanding of interactions, acceptation and opportunities of drones and indoor robots in particular. Next to diving into that literature I quickly started to shift my focus to more literature about gesture recognition, since afterwards I needed to start developing the software to demonstrate during the drone presentation the 9th of March. This was a hurried continuation of the process, however was necessary for smooth delivery of interactions to the Blue Jay drone. After this research shift I started building the software mainly focusing on playful interaction to afford social engagement. The idea was to play a rock-paper-scissors game against the drone for prolonged sick children as entertainment.

After the development of gesture recognition software there was some time to for reflections which implied

that this communication method turned out to be an obvious misconception. This is enlightened in section ‘Communication methods’ (page 13). That is why an alternative communication method was needed. In order to prevent any second misconception a communication analysis was performed. As result of this analysis, speech recognition was chosen as new drone communication.

Speech recognition development implicated several big tasks like environment testing, voice training, software integration and more. After an intensive period of time eventually the software was correctly integrated in the drone, however could not be tested appropriately. This was unfortunate and therefore Blue Jay never actually got a moment to appreciate the effort. I did properly hit the deadline of this speech recognition which was the Dutch Technology Week (15 – 20 May). This work eventually diluted because of other priorities for team Blue Jay and myself as well.

Since up till now there was only minor exploration of domestic drone application area. It became quite important to still discover that part as well, which definitely should have been performed earlier on. Nevertheless I started to interview a lot of people with different expertise in all different domains. I involved people from Maxima Medisch Centrum about logistics, visitor guiding, accommodation constructions,from Veiligheidsregio Brabant Zuid-Oost about fire safety and even a few more. This can be found in section ‘Application analysis’ on page 17. After this extensive research it became quite clear that the drone

should be developed differently per specific application. The drone's functionalities (unneeded and needed) and the requirements and wishes of the domain are both relevant. With this research indoor drones can be developed more appropriate. This applies to the team of Blue Jay and also to others developing drones with similar purposes.

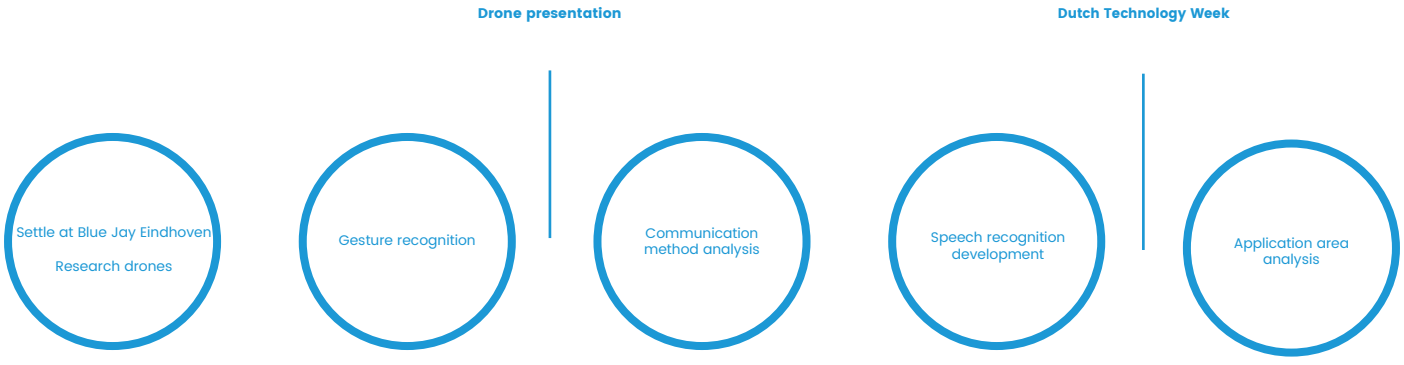

Fig 15 | The process
Author: Olivier van Duuren

Fig 16 | The brainstorm at Health Innovation Campus
Author: Blue Jay Eindhoven

10 REFLECTION

10.1 AT TEAM BLUE JAY EINDHOVEN

From the start to the end I found working in a large multi-disciplinary team incredibly interesting as well as its ground-breaking intentions and technology. Working in such a team was definitely worth it and implied several valuable and, despite everything, also a few confronting experiences. Cooperating with many students from varying disciplines with all different kind of commitments demanded great effort and was completely new to me. Communication and planning therefore became very crucial. Next to students I also connected with multiple partners from Blue Jay during the development of the drone but especially also during the several events the team organized. This had major impact on my professional attitude. Besides, strictly structured communication also concept understanding and meeting skills were strengthened. Meetings with Philips, Accenture and NXP and different talks with people at events significantly improved my professionality.

Furthermore, there were a lot of intermediate and end deadlines which needed to be reached. A missed individual deadline could impact the team's deadline and in also other person's goals as well. Therefore commitment to your work was put on the first place. For me this pressure has never been so high. Through these multiple experiences I learned a lot about working pressure and how to handle it next times. With this pressure unfortunately people got frustrated very quick, which sometimes affected me personally as well. I find it quite difficult to encounter this

personal pressure sometimes. Luckily I am used to work hard and deliver high quality so this rarely affected my process. I am almost sure that this individual pressure can be mostly blamed on the expectations people caught from me. Therefore I really learned to understood how creating high expectations can also have negative impact.

I think my role as interaction designer was good and I do not anyhow regret declining the offer to become interaction architect. This could have been interesting and definitely educational, however this had cost lots of extra time which I did not have. Furthermore I believe that although focusing on some deviating tasks I stayed in my role as good as possible. My application area exploration was not totally in line with the imagined role according to team Blue Jay. The reason for this was that I incorrectly communicated it in the beginning due to uncertainty. Eventually I guess I learned a lot from this role and it got me even more eager to proceed with it in upcoming projects.

10.2 MY PROCESS

At first I was convinced that my approach was definitely feasible and worth investing in. I started to think of different research questions and design goals which I also shortly followed. However after a while I noticed that the process was proceeded differently than I was used to experience. This particularly came to my mind when preparing for the drone presentation. Which made me kind of put extra effort

in matters I normally would not do that early. I realized that also upcoming software deadlines would interfere other more relevant parts of the project. Of course, I had major interest in developing the software communication, due to my preference for human-technology interaction. Although in this case it unfortunately conflicted with the normal design process I was used to execute. In my belief, this moment was really crucial, since in this way I realized how processes can be proceeded otherwise in real hectic situations. The way my process in fact deviated this much was actually educational. I learned that it also can go differently due to desires of second parties and maybe even third ones. This awareness was still missing on beforehand and therefore I am convinced this external project was also a great success.

Fig 17 | Dutch Technology Week
Author: Blue Jay Eindhoven

11 ACKNOWLEDGEMENTS

Firstly, I want to thank team Blue Jay Eindhoven for all their hard work and support. Due to their patience and dedication I have contributed to the future of indoor drones. With help of Blue Jay Eindhoven I also got in contact with several experts. I appreciate the time and effort Paul van Dooren, Fons Segers, Lars Prinsen, Arthur Salter, Bas Becu, Chris Ramsay, Pieter van Warmerdam took out for me to discuss application areas of indoor drones. Without their help there could not be explored as good as I did now. The time and effort a few healthcare patients took out for me is also highly appreciated. This external project was covered by the 'Design for social and physical rehabilitation ' project at the University of Technology in Eindhoven. The study was supported and coached by prof. dr. M. Rauterberg. I appreciate him for providing insights regarding specific methods and thoughts and the whole project leading for their assistance. Finally, I want to thank all the people in general who have had and have crucial impact on this ground-breaking technology.

12 REFERENCES

[1] Blue Jay Eindhoven. (2017, Feb. & march). Joining our team? Retrieved June 14, 2017, from https://www.bluejayeindhoven.nl/

[2] Kuo, I. H., Rabindran, J. M., Broadbent, E., Lee, Y. I., Kerse, N., Stafford, R. M. Q., & MacDonald, B. A. (2009, September). Age and gender factors in user acceptance of healthcare robots. In Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on (pp. 214-219). IEEE.

[3] Broadbent, E., Stafford, R., & MacDonald, B. (2009). Acceptance of healthcare robots for the older population: review and future directions. International Journal of Social Robotics, 1(4), 319.

[4] Takayama, L., & Pantofaru, C. (2009, October). Influences on proxemic behaviors in human-robot interaction. In Intelligent robots and systems, 2009. IROS 2009. IEEE/RSJ international conference on (pp. 5495-5502). IEEE.

[5] Lutz, W., Sanderson, W., & Scherbov, S. (2008). The coming acceleration of global population ageing. Nature, 451(7179), 716-719.

[6] Graham, J. U. D. I. T. H. (2014). A shortage of caregivers. The New York Times (February 26, 2014).

[7] Fokus. (n.d.). Gewoon wonen met een lichamelijk handicap | Fokus. Retrieved May 10, 2017, from http://www.fokuswonen.nl/Home

[8] Vitalis WoonZorg Groep. (n.d.). Onze diensten. Retrieved May 11, 2017, from https://www.vitalisgroep.nl/

[9] Hutson, S., Lim, S., Bentley, P., Bianchi-Berthouze, N., & Bowling, A. (2011). Investigating the suitability of social robots for the wellbeing of the elderly. Affective computing and intelligent interaction, 578-587.

[10] Sinervo, B., & Lively, C. M. (1996). The rock-paper-scissors game and the evolution of alternative male strategies. Nature, 380(6571), 240.

[11] M. (2016, July 02). Mahaveerverma/hand-gesture-recognition-opencv. Retrieved February 15, 2017, from https://github.com/mahaveerverma/hand-gesture-recognition-opencv

[12] Shmyrev, N. (n.d.). CMUSphinx Open Source Speech Recognition. Retrieved March & april, 2017, from https://cmusphinx.github.io/

13 APPENDIX

A APPLICATION ANALYSIS BOOKLET

The nine application tables can be consulted in this section. Take into account that less relevant pages of the booklet are attached. Thus this is not the complete booklet.

Healthcare

vitalis woonzorg groep

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely
Transport objects	Can transport weights of 500gram max.
Communicate with people	Sound output Emotion output
Social engagement	Speech recognition Face recognition Emotion recognition

Still needed to:
- fly approximately silent
- offer the care people need

Health patient 1

disabled but self-reliant

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely Avoid obstacles frequently
Transport objects	Can transport weights of 500gram max.
Communicate with people	Sound output Emotion output
Social engagement	Speech recognition Face recognition Emotion recognition
Provide vision to device	Can provide vision

Still needed to:
- get objects wherever located
- fly approximately silent
- be low priced

Health patient 2

disabled and not self-reliant

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely Avoid obstacles frequently
Transport objects	Can transport weights of 500gram max.
Communicate with people	Sound output Emotion output
Social engagement	Speech recognition Face recognition Emotion recognition

Still needed to:
- offer the care people need
- fly approximately silent
- be low priced
- Grab objects on the ground

Hospital logistics

máxima
medisch centrum

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely among a lot of people	It flies safely Avoid obstacles frequently
Transport samples to lab	Can transport weights of 500gram max.
Transport with track and trace	Carry along sensors
Listen for execution of tasks	Speech recognition

Still needed to:
- fly approximately silent
- save time
- communicate with doors and elevators

Hospital visitor guiding

máxima
medisch centrum

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely
	Avoid obstacles frequently
Communicate with people	Sound output
	Emotion output
Comfort people	Speech recognition
	Face recognition

Still needed to:
- fly approximately silent
- fly for more than an hour at least
- guarantee 100% accuracy

Fire safety

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely Avoid obstacles frequently
Detect heat violation	Carry along sensors
Provide vision for brigade	Can provide vision
Communicate with people	Sound output Emotion output

Still needed to:
- navigate inhabitants outwards
- fly in smoke zone
- fly in dark zone
- communicate with doors
- shut down power supplies
- be high temperature resistant
- detect people

Agriculture

Agriculture

inspecting harvest in greenhouses

Requirements	Specsheet
Autonomous flights	Autonomous
Fly safely	It flies safely Avoid obstacles frequently
Communicate vision to other people or systems	Can provide vision
High quality vision	Can transport weights of 500gram max.

Still needed to:
- fly stable

Education

CENTRE OF EXPERTISE | LEREN MET ICT

Requirements	Specsheet
Automous flights	Autonomous
Fly safely	It flies safely Avoid obstacles frequently
Transport objects	Can transport weights of 500gram max.
Communicate with people	Sound output Emotion output

Still needed to:
- fly approximately silent
- communicate with products
- offer easy coding(e.g. Scratch)

B SOFTWARE CODE

This software code is part of a greater collection of different scripts all needed for the speech recognition API to work and for the event which Blue Jay was going to present. Please contact me whenever questions arise!

Please consult the following link:
https://drive.google.com/file/d/0Bxbamf_wRoBUX0c3ZnI2enBZSjA/view?usp=sharing