Increasing Business Opportunities for Drone Services

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Abstract: We describe our UAV imaging research and development from a business perspective. Our main goal is to increase business opportunities for our drone services. We build on experiences from an already deployed drone service provided by our IT company. The application is using a commercial tool for processing photogrammetry. Its advantage is accuracy, but the main disadvantage is the time needed for annotation by a trained human operator. Our methodology is based on user studies and knowledge gained in communicating with potential customers at IT trade fairs and exhibitions. We analyse the duration and automation of the service as key factors. We consider two types of higher automation of the solution. First is the automation of annotation - less accurate, without human intervention. The second is automation in flight planning and implementation. The use of other drone peripherals or hybrid drones can also create new types of services. In particular, there is a demand for immediate execution of on-site flight imaging without any pre-calibration. Our considerations, expanding our services, also include various inspections or direct involvement in industrial processes. Some improvements were tested on an experimental prototype. The results indicate improvement making services cheaper and faster.

1 INTRODUCTION

We describe our UAV imaging research and development from a business perspective. Our main goal and objectives are related to increasing business opportunities for our drone services.

The author's team consists of the academia and R&D department of an IT company.

In the beginning, the company has been trying to gain a new perspective of using drones in commercial tasks and founded a flight service department.

We quickly realised that we could use drones in various cases where humans have limited access or the standard approach takes very long. Following this, we acquired the conviction that by using the equipment drones can carry, we can collect a wide variety of data in an immense amount.

After deciding to follow these ideas, we were able to finish and market our first service deployment. To address the further expansion on the market, we are looking for new opportunities for our services. Our ambition is to make them cheaper and faster for greater competitiveness. The use of other drone peripherals can create new types of services as well. Our considerations, expanding our services, also include various inspection types or direct involvement in industrial processes.

The main contributions of our paper are following:

- experiences learned from our first deployed service point to critical factor of service duration
- experiments with our experimental tool from the point of view of time complexity
- further directions of development with different level of construction and evaluation, namely
  - proof of concept of flight planning automation
  - further considerations of extensions based on experiences
    - LIDAR in unknown uncalibrated areas
    - drones extended by peripheral devices
    - image recognition inspection

The paper is organised as follows: Chapter 2 describes our starting point with a deployed tool, lessons learned from customers, and the first technical attempt to improve it. Chapter 3 describes

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ongoing work, partly, not yet fully validated in different directions regarding further development and some speculative ideas. Chapter 4 is related work. We conclude with achieved results so far, the future work is devoted to general B2B considerations about our products' future, especially in the automotive industry.

2 DEPLOYED UAV SERVICE

We build on experiences our already deployed drone service developed in our IT company. The customer requires computing volumes of wood in stock. The application is using a commercial tool for processing photogrammetry. The advantage is accuracy, but the main disadvantage is the need for a trained human intervention.

Technical description of this solution was described in (Brezani, 2021). In the following, we explain how we proceeded, especially in business considerations.

The product itself is already on the market. It is a service using a commercial photogrammetry processing tool for precise measurement and evaluation. The whole process begins by setting calibration points, placing them manually, and marking a known length on-site. Our staff workers personally create calibration points on the ground close to the measured area. It makes a base for precise calibration in the orthophoto map processing method, which comes later in the procedure.

The next step is to prepare the drone flight data manually to capture the entire area, focusing on the material supplies' location. Subsequently, the drone is ready to fly to take appropriate area pictures. The flying route is designed depending on the shape of the object being scanned itself.

Afterwards, photos are taken and collected to fit automatic processing by a commercial tool, which creates an orthophoto map. A trained user manually annotates the areas of interest (wood stock, the volume should be calculated). It takes a trained user at least half an hour, depending on the ground area and object's shape. The procedure ends by calculating the required material stockpile volume.

The first mission was to estimate the volume of current material stocks and their changes over time in the customer warehouse. It took several months for enough measurements to be made to evaluate the movement of material in the warehouse.

We focused on several factors that must be considered separately for specific flight conditions in different weather conditions when performing measurements. Each scan and measurement brought various issues. Meteorological conditions influence flights to a large extent. It is necessary to modify predefined plans for flight safety assurance and to create an optimal setting of the measurement mission in various conditions.

The main challenge was to reduce the time needed for the whole procedure and eliminate the manual interventions and expert labour needed in processing. The higher requirements on precision require more processing time in the range of hours to days. Likewise, manual interventions and professional work were an obstacle to a significant reduction in time and full automation of the process. Intelligent automation was necessary to address processing time.

3 EXPERIMENTAL TOOL

Technological description of our experimental tool is reported in (Brezani, 2021). The main idea was the ability to extract information for the customer's information system. Here we only briefly summarise the part replacing manual annotation, which is important for our business considerations. We decided to use the neural network method of automated annotation of areas of interest to address the problem. We used open-source software to create an orthophoto area map. The orthophoto area map is then automatically annotated by a neural network semantically segmenting each pixel of the input image to see if it belongs to the monitored object. The before-mentioned network is trained on manually annotating the initial machine learning examples. It is important to notice that this annotation is done only once for the domain). The type of monitoring object is decided in advance in order to prepare and train a machine learning model for this task concerning customer needs. It is time-consuming, but it is a one-time job, the result of which can be used repeatedly in services of the same type.

We are using an open-source data labelling, annotation, and exploration tool to annotate the images. The goal is to mark the woodpiles (as a pilot task) on a sample of pictures. Subsequently, we split the data images into a training dataset, a validation dataset, and a test dataset. To enlarge the size and diversity of annotated data, we pick augmentation within the training cycle to prevent overfitting in neural networks (Ronneberger, 2015). We were trying a wide range of transformations to convert both image and segmentation data. In our case, we are using affine transformations (rotation, shift, zoom), contrast adjustment, noise generation, etc.

To replace human annotation of the area of interest, we apply the segmentation models library as a ground for our work. The library implements four model architectures for binary and multi-class classification. It uses the transfer learning method and allows using one of the pre-trained networks as a backbone for the semantic segmentation architecture. The technique makes it possible to use a trained neural network, or part of it, for related categories of tasks. For more details, see (Brezani, 2021).

3.1 B2B Considerations

In this chapter, we show the results of our methodology. Our methodology is based on user studies and knowledge gained in communicating with potential customers at IT trade fairs and exhibitions. Based on this, we analyse the duration and automation of the service as key factors. We consider two types of higher automation of the solution. First is the automation of annotation - less accurate, without human intervention, and hence faster. The second type of automation will be treated in the next chapter.

In the previous chapter, we have described the construction of our experimental tool based on deep neural network annotation. Here we report on measuring improvements that were tested on an experimental prototype. The results indicate improvement making services cheaper and faster. Hence this is an indication that we can expect improvements in goals and objectives.

Nowadays, our ambitions aim to automatically collect outdoor visual data using pre-programmed UAVs and automatically process and transform them into knowledge using advanced computational tools such as machine learning based on deep neural networks. Deploying this solution to a real production facility will bring the capability of automatic data collection from different devices and their processing regularly, with possible direct integration to core information systems in the form of direct data transfers or, for example, gained knowledge in the form of alerts. This way, the outdoor reality could be manageable almost in real-time.

Let's imagine a system that can proceed automatically without intervention. In that case, we could streamline the entire process of regular daily inventory measurements and at the same time effectively evaluate and monitor the movements and volume changes of material in the warehouse. We could potentially get an overview of materials' movement over large areas of one or more warehouses of different customers. It would find justification in many industries by extending today's limited capabilities to almost unlimited use with automated drones for regular inventories. Of course, this is the hope our experimental tool is bearing. It needs much more work to ascertain and evaluate this in practical deployment.

Many machine learning tools are distributed as open-source and are suitable for commercial use. However, the use of these tools is not trivial and requires considerable know-how and data. Therefore, we must include this in the market price of the instrument. Using open software for machine learning and processing UAV data, we save on a professional license for photogrammetry and at the expense of a trained user. The time saved in terms of speeding up the procedure will improve our position in the competition.

In the following section, we describe the effect of the measured area and the time required to perform the whole procedure. We also provide further details here regarding the individual terminations that take place in the service. These data come from measurements already performed.

The measurement parameter ranged between 18-30ha(hectare) for double grid mapping range and resolution level up to 2 cm/pix. Increasing the measurement area is directly proportional to the extension of data processing time.

The diagram in Figure 1 analyses the difference in the service duration in areas of 100 ha and 30 ha. It also shows the expected time savings by introducing automatic and autonomous parts of processes in several phases. The procedure can be accelerated by automating manual processes, to which we would be able to provide results periodically, e.g., every hour. Thus, it would be possible to continuously control the increase or decrease of the amount of material. Customers thus receive a continuous overview of stockpiles (in the domain of our first deployment) inventory of materials every hour, every day, month, and year.

The preparation phase usually lasts 2-4 hours, depending on the measurement's conditions and nature.

The flight usually takes 40-70 minutes.

The computation phase usually takes 3-10 hours for maximum quality. The fastest result is within 60 minutes, with an accuracy of around 70%. More accuracy needs more processing time. The resulting accuracy can increase to 91-97% over time, but it is time-consuming. The standard accuracy is around 80%. The required time for the entire procedure with 80% accuracy is, on average, from 5 to 22 hours together. The following diagram compares each phase's average duration.

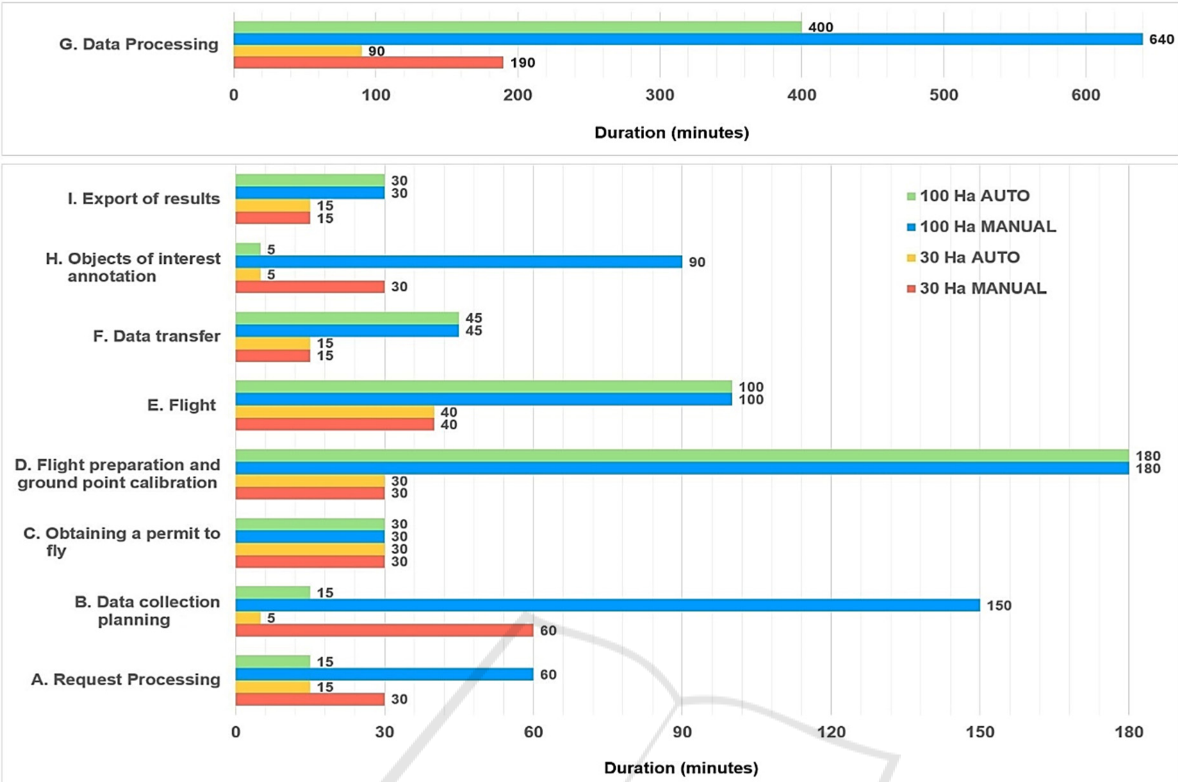

Figure 1: Dependency of processing time, the area, and auto or manual processing shows some huge discrepancies in *G. Data Processing* activity which depends on server power. But our focus is mainly on processing steps, which shows the best improvement by introducing smart technologies, which is apparent in activities *B. Data collection planning* and *H. Objects of interest annotation*. The diagram shows that automatic annotation is one of the key factors to save time and resources.

3.2 Market Situation

Here we summarise the outcomes of our informal market study. We do not discuss the formal metric evaluation. On the other hand, this is a continuous process and depends on the increase of our experiences.

Several aviation companies are operating in the market for air inspection services, collecting and processing aviation data. In our survey, we focused on providing the maximum added value. Our output against the competition differs in terms of data collection to processing and clear presentation of results. The data collection method's contribution is more precise thanks to the methodological procedures and tools used in the solution. Data collection results are processed by sorting and simple editing of photo data and then imported into a smart user-friendly application. The application is available on smart devices such as mobile phones or tablets. The outputs are more exact and linked to the location, so the customer gets accurate data based on which he can evaluate the current state from a distance. Regular data import from individual measurements gives another added value, namely the development of parameters in time.

The application also contains several tools, thanks to which it is possible to store status assessment notes in the photo data. In this way, it is possible to mark abnormal sites suitable for preventive monitoring. Regular monitoring helps eliminate power outages by early detection of the problems in the initial stages. Finally, our product's descriptive advantages are access to the databases of individual objects for assessment. The application is available for Android and iOS devices, as well as for Windows. In conclusion of our internal study, the competition does not provide such benefits in such a form.

4 FURTHER DIRECTIONS

In this chapter, we describe several further directions of development with different levels of construction. Some are in the form of proof of concept, and some are speculations (as encouraged by organisers of call for position papers).

As mentioned in the previous chapter, there is a second type of increased automation in flight planning and implementation. Proof of concept gives us hope that this can contribute to goals and objectives.

Further, we mention that using other drone peripherals or hybrid drones can also create new types of services. In particular, there is a demand for immediate execution of on-site flight imaging without any pre-calibration.

Our considerations, expanding our services, also include various inspections or direct involvement in industrial processes.

4.1 Flight Planning Automation

In order to shorten the overall duration of the services and obtain regular and up-to-date data, we proposed simplifying respective processes so that, as a result, we can provide repeating services for the recurring daily needs of the customer. It was necessary to increase the automation of processes that today take several to tens of hours and shorten them to minutes. The process of realising the request for specific data from the field begins with defining the exact requirements of the customer. The following is validated as proof of concept. For this purpose, we have created a smart application on the web interface into which the customer directly enters his request, defines, e.g., the type of data he is interested in, e.g., measurement of quantities, map creation, measurement of warehouses, etc., then enters the request for the location and the time of execution. It saves a lot of time in the consultation as the client's requirements are clearly defined. Of course, it remains to test the intuitiveness and self-explainability of our interface.

Based on the request, we are ready to schedule the autonomous flight so that during it, the drone performs the necessary data collection. We plan the flight mission so that the data collection is carried out safely and so that the necessary data is collected in the highest possible quality during the mission. According to several criteria, dependent on the shape or type of data needed, we set the plan in the flight planner and adjust the operation of the individual peripherals. So far, when the flight plan is ready, the pilot/copilot flight unit drives to the place of activity, sometimes 100s of km away from the place of the lab.

For this reason, we have designed an automatic drone box to be placed in an industrial area, from which the drone is ready to take off and execute the planned flight within a few minutes. With this process, we can save a lot of time which can be used for the implementation of the customer's requirement. The implementation and data collection will take place autonomously and under the same conditions repeatedly. There is no need to plan the flight for each request. Thus, after the data collection process, we can import the raw data directly to our remote processing PC after successful landing by the ground box. After receiving the data, the metadata check and verification of correct execution follow. If everything went well, then the raw data processing into usable data for the customer as defined in our application interface follows.

Data processing is a process that takes several hours in common practice today, depending on the application. Still, our contribution in the field of automation and machine learning has pushed the boundaries and thus shortened this process to the level of minutes. This is due to the fact that there is not so much manual work of a trained worker in the field of post-processing. The software can automatically recognise and automatically annotate the object in the scope of interest (as described in the experimental tool). This way, we can streamline the processing time by only working with the relevant data and not processing the rest.

Automating data processing is a key element for reducing process time and making services cheaper because it requires minimum manual work.

4.2 Further Extensions

Previous research was evaluated by deployment, experiments, and proof of concept. In the following chapter, we describe our further considerations.

4.2.1 LIDAR in Unvisited Uncalibrated Areas

In the meantime, we have improved our UAVs by extending our equipment. Our main idea when using LIDAR is that it will be possible to calibrate the map without the need for expert intervention.

LIDAR can be an exciting source of data for automated processing with machine learning. Such as in self-driving cars - (Sometimes, artificial intelligence can make better predictions than a human could because it can access different data, such as feeds from cameras, RADAR, and LIDAR around a car (Agrawal, 2019)

LIDAR is a 40 times heavier device than a regular camera. It is used only in the case of measurements at the level of cm, where it is necessary to shift photogrammetry accuracy to a limit of less than 5%. The LIDAR deviation level is 1-2%, and mapping a large area is several times faster. Data processing requirements increase by 20-30 times. The use of LIDAR is intricate and reduces the drone's flight time, which increases the cost. It is always necessary to consider its benefits from shooting with a full-frame camera.

Besides, this could open up the possibility of using UAVs in new, unknown areas. We hope this can attract some customers to use our on-call services, so we increase our operability. We keep in mind mountain rescue operations, which cause many fatalities in our country each year.

To increase the overall efficiency of air services, we have proposed a procedure for accelerating data collection through flight automation. In the next step, it is necessary to adapt the sensors. We know from practice that it is necessary to obtain a lot of accurate data for customers. The solution is to use a LIDAR sensor for mapping large areas over 100ha. Mapping large areas have great potential for customers, e.g., from forestry, agriculture, and automotive.

4.2.2 Inspections by Drones

In other areas of our research and development, we are working on image recognition. Using this knowledge can help us use drones in inspection tasks. So we think of classic inspection tasks, such as power lines, bridges, etc., see, e.g. (Fowler, K. R. and Dyer, S. A., 2020). Surprisingly, we do not have much competition in this area in our country.

Inspections using UAVs are based on detailed optical data collected from a safe distance using a 20 to 30 fold approximation to specifically defined locations on the object. During the mast's inspections, we focus on the insulators' damage, the temperature of the source adapters and antennas, and the condition of the construction of the handles with the search for corrosive joints or screws. Camera correction is necessary, and the manual flight method is time-consuming.

The inspection procedure depends on the type of object. The whole inspection must be pre-planned and programmed using flight simulation and simulation of the object's camera views. This way, the entire infrastructure inspections can be planed. Recognising and distinguishing objects in the current camera view is a necessary part of the data collection process.

4.2.3 Drone Peripheral Extensions

Peripherals are an integral part of drone equipment. They are selected based on dimensional limits and parameters that lead to the efficient management of drone energy. Preferred tools are elementary sensors and multiple camera types that can capture a wide range of map layers from a given area, for example, IR, NIR, RGB, or others.

By combining several data and linking the measurements of several types of data to a specific location, we can provide the basis for a detailed, in-depth analysis of the object, which is fundamental to the customer's analytical decision-making and predictive action.

5 RELATED WORK

Market analysts agree that commercial drones are revolutionising business operations. For example, our first deployment changed the inventory processes in the case of our customer. Further summarisation reads as follows: Drone industry revenue in the commercial sector is forecast to grow worldwide by a compound annual growth rate of 13.8 % from 2020 to 2025, reaching a value of 43 billion U.S. dollars, according to DRONEII. The biggest drone markets today are in China and Japan. These are not a result of research papers. These are global market observations. In this related work, we sometimes give voice also to subjective opinions of important market players.

By reading Tech Briefs magazine, it became evident that UAVs have become an integral part of the research that uncovers and makes available their use in various fields. Detection of dangerous circumstances, such as gas leakage, mapping of changes in the form and size of glaciers, monitoring forest stands with early fire detection, rescue missions, and industrial processes optimisation are just some of the magazine's reports. An interesting fact is that UAVs' use is clearly shifting from manually operated aircraft to autonomous systems controlled by computer systems involving artificial intelligence. E.g. (TechBriefs, 2016)[1] recognised the need to safely manage UAVs flying at low altitudes in airspace not currently addressed by authorities.

The American Meteorological Society states in its research that UAV technology and systems can be considered a missing piece of the puzzle between

[1] https://www.techbriefs.com/component/content/article/tb/pub/features/articles/23938?start=2

satellite observations and observations from the Earth's surface. AMS states that UAV systems' deployment will increase the accuracy and timeliness of meteorological parameters measurements, which will result in better prediction of weather developments and abnormalities (see, e.g. (AMS, 2013)[2]).

P. Murphy, in his book (Murphy, 2017), ranked drones and the UAV system among the leading technologies to move the company to the stage of an automated company. Interestingly, he identified transport and means of transport as one of the main areas for drones (see our future work).

A similar conclusion reached Automotive Logistics magazine's research, which identified considerable scope for UAV systems' involvement in B2B, B2C logistics, and logistics within production plants and integrated supply chains (see, e.g. (Williams, 2017)[3]).

Nowadays, global trends concern UAV services. The next part of related work considers cloud and SaaS, which is not part of our research but the next step for our customers. So far, the deployed solution is running on our servers. Nevertheless, in the future, we have to consider also this option when the customer decides.

Cloud-based solutions have significantly increased the availability of sophisticated and powerful software solutions for research and economic entities of all sizes. Chue Hong et al., in their work (Chue Hong, 2018)[4] , offer a guide for decision using cloud computing in research. They warn before too great optimism. One has to check several questions and dangerous scenarios before such a decision. Of course, there are also some benefits possible. (Lakshmi Devasena, 2014) is an empirical impact study that emphasises the consequences of adopting Cloud Technology in business organisations (micro, Small Medium Businesses (SMBs), and Small Medium Enterprises (SMEs)) and how it affects business development. Finally, (Konersmann, 2020)[5] recognise immense possibilities cloud computing can offer R&D in Life sciences and health care organisations in the global pandemic crisis.

We are at a stage where industrial production is beginning to open up to the use of SaaS-based software solutions. After the SaaS model's initial change, in which industrial institutions moved administrative and support information systems to the cloud, the phase of transition to the SaaS model of critical production systems begins. Based on research by Statista, the use of SaaS software in production is expected to increase by almost 100% by 2020 see (Statista, 2020)[6] for 2008 to 2020 data.

There is a more similar material, but we do not consider it to be mentioned here given the scope. Now we mention two research papers relevant to our doing.

In the paper (Fotouhi, 2019), the authors study the rapid growth of consumer unmanned aerial vehicles (UAVs), creating promising new business opportunities for cellular operators. UAVs can be connected to cellular networks as new types of user equipment, therefore generating significant revenues for the operators that can guarantee their stringent service requirements. We are also motivated by this, as 5G gives enough throughput and makes AI computations possible on ground computers.

A substantial part of our development is to create autonomous flying services. In the paper (Jahan, 2019), they consider autonomous systems integrated into our lives as home assistants, delivery drones, and driverless cars. The implementation of the level of automation in these systems from being manually controlled to fully autonomous would depend upon the autonomy approach chosen to design these systems. This is exactly our position. Motivated by the author's review of the historical evolution of autonomy, its approaches, and the current trends in related fields, we incorporate these ideas in our work.

Another option we have to consider for our goals and objectives is the decision between build and buy.

(Fowler and Dyer, 2020) propose a model for recommending build-versus-buy decisions when developing embedded systems. They compare designing a custom unit with integrating a commercial unit into the final product (exactly as we did on our first deployment with commercial photogrammetry). It accounts for the expertise of the development team, tool resources available to the team, partitioning of the tasks, and quality of commercial units, vendor support, premiums, and product life cycles. This is now a challenge for our R&D department. Especially interesting for our flight department is the paper (Martin, 2018)[7] mentioning a

[2] https://www.ametsoc.org/index.cfm/cwwce/boards/board-on-enterprise-strategic-topics/offshore-wind-energy-annual-partnership-topic-committee/apt-final-report/

[3] https://www.automotivelogistics.media/ups-tests-residential-drone-delivery/17665.article

[4] https://www.software.ac.uk/best-practice-using-cloud-research

[5] https://www2.deloitte.com/us/en/insights/topics/digital-transformation/cloud-enabled-research-and-development-innovation.html

[6] https://www.statista.com/statistics/510333/worldwide-public-cloud-software-as-a-service

[7] https://search.informit.org/doi/10.3316/informit.591123771201857

global trend of Asia-Pacific nations making strides towards supplementing foreign helicopter acquisitions with domestically built projects. Nations like South Korea, China, Japan, and India are leading the way with a number of increasingly sophisticated transport and utility helicopter designs.

6 CONCLUSIONS

This position paper's main topic is studying the impact of drones in industrial business and B2B considerations of its comprehensive application. We describe ongoing work on further development and ideas from a business perspective. Our foundation is in already developed and deployed service using UAV imaging. We dealt with a further extension of our service's competitiveness by making it cheaper and faster and extending services to other domains like inspections and direct industrial processes involvement. Some of them are in the phase of evaluated experiments, some are ascertained as proof of concept, and some are further considerations based on our previous experiences.

B2B considerations on the impact of the deployed tool on the market are well advanced. Drones extended with LIDAR equipment for unknown uncalibrated areas offer new market opportunities. Other ideas discussed and reworked relate to drones with peripheral enhancements and their use for image recognition-based control. We evaluate our market positions and competition. Future ideas include testing applications to support industrial processes in polytechnic vocational schools to gain experience in an environment as close as possible to the real industrial one. We believe that this will bring us closer to the significant extensions for drone-based services. We hope this will help us with our future research topic for drone-based services in the automotive industry.

We are trying to create synergy between UAV use to collect and extract knowledge with immediate feedback to control and manufacturing processes.

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