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**Search and recombination of innovative technologies: the case
of drones and Artificial Intelligence**

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ABSTRACT

Search and recombination, when it comes to the innovation process, are concepts largely studied by many scholars since the 30s of the last century. Many aspects of the innovation strategy of a firm are studied and insights are provided to the practitioners in order to succeed in the market.

A case of technologies recombination is found on the inclusion of Artificial Intelligence software in the drones companies' business proposal. Drones have become, during the last years, a rich source of data collection for the companies in many sectors. The segment growing trend enables to foresee further enhancements in term of number applications, thanks also to algorithms which enable to autonomously perform decision making and real time processing of data collected.

The objective of this Thesis, developed together with Drone Observatory of Politecnico di Milano, is to analyze the market offer and demand of drones' solutions combined with Artificial Intelligence and to introduce some characteristics of the firms which are related to this kind of recombination.

Keywords: search and recombination, drone, Artificial Intelligence, industry 4.0.

ABSTRACT (ITALIAN VERSION)

Ricerca e ricombinazione, quando si parla di processo di innovazione, sono concetti largamente studiati da molti studiosi sin dagli anni '30 del secolo scorso. Molti aspetti della strategia di innovazione di un'azienda vengono studiati e vengono fornite informazioni ai professionisti per avere successo nel mercato.

Un caso di ricombinazione di tecnologie si riscontra nell'inclusione di software di Intelligenza Artificiale nella proposta commerciale delle società di droni. I droni sono diventati, negli ultimi anni, una ricca fonte di raccolta dati per le aziende di molti settori. Il trend di crescita del segmento consente di prevedere ulteriori miglioramenti in termini di numero di applicazioni, grazie anche ad algoritmi che consentono di svolgere autonomamente processi decisionali ed elaborazioni in tempo reale dei dati raccolti.

L'obiettivo di questa tesi, sviluppata insieme all'Osservatorio Droni del Politecnico di Milano, è di analizzare l'offerta e la domanda di soluzioni del mercato dei droni combinate con algoritmi di Intelligenza Artificiale e presentare alcune caratteristiche delle aziende correlate con questo tipo di ricombinazione.

Parole chiave: ricerca e ricombinazione, drone, Intelligenza Artificiale, industria 4.0.

EXECUTIVE SUMMARY

During the last years, in the industrial world, it has become of common use the term “Industry 4.0” as a definition for the occurring industrial revolution that follows the other three which took place during the past decades and centuries. The revolution is addressed to impact the way the companies produce and perform their operations: thanks to an extension on the capabilities attached to their plants and assets, provided by dedicated technologies, the goal is an increase in terms of efficiency, and a decrease in cost and time to market.

The new technologies involved in this process enhancement are, among the others, Internet of Things, cloud computing and Artificial Intelligence: their involvement triggers a process of factories and processes “smartification”, where the decision making is quicker and more effective. The “raw material” for these enhancements are the data: “Big Data” is one of the terms related to “Industry 4.0”, and it describes the foundation on which the revolution is occurring. Together with cutting edge sensors, these technologies perform tasks of autonomous data collection and data processing which make available a large quantity of aggregated and high quality data that are aimed to have a crucial role within the companies’ operations and organizations.

Within this changing market environment, it is finding increasing space and employment the drone technology: the flying platform has become a powerful data collector from the sky and from danger spots. Thanks to the involvement of dedicated technologies, the data collected can be stepped into a real time data management process which allows the operators and decision makers to effectively act.

This thesis, developed together with the Drone Observatory of Politecnico di Milano, proposes to approach the process of integration of the Artificial Intelligence software within the operations of the drones’ companies, in order to understand, under a managerial point

of view, which are the characteristics of such technologies combination and their impact on the technologies recombination, as well as the innovating model adopted by the firms. The methodology applied starts from an analysis and categorization of the drones' solutions provided by companies operating in the Italian and international market, with a specific focus on Artificial Intelligence integration and goal for which it is integrated. The categorization is then applied to the use cases present in the Drone Observatory database where AI is mentioned. At the end a quantitative analysis, through an econometric model building, is used to analyze the recombination between drones and Artificial Intelligence.

The thesis is developed in 4 sections: the first one is dedicated to building up the theoretical background for the study, introducing the study field of “search and recombination of innovative technologies” employed for analyzing the drones and Artificial Intelligence cases, and a technical and business introduction on the technologies themselves. The second chapter deep dives the drones' software and payload solutions with a categorization proposal, applied then to the market demand and offer in the third chapter. The fourth section addresses the survey section building for the purpose of obtaining an explanatory econometric model, which is analyzed in the fifth chapter. The sixth one represents the conclusion of the study, aggregating the results obtained by the different sections and proposing possible future developments of the studies within the field.

LITERATURE REVIEW

The literature review and research is performed joining two different threads: on one hand the scholars academic papers on “search and recombination” are analyzed for defining the theoretical perimeter through which addressing the case of drones and Artificial Intelligence, on the other it is provided an indication through a combined analysis of academic papers

dedicated to the technologies introduction and a web search for defining the publicly available knowledge on the business.

“Search and recombination” field is a concept introduced in 1939 by Schumpeter, who proposed the innovative model for the firms of leveraging on recombination of existing knowledge for obtaining new outcomes. On this view, many scholars have then approached many different topics related to the areas of innovation.

The process of technology recombination entails a whole series of organizational needs that have to support the change in order to succeed. In the case of Artificial Intelligence attachment to support drones’ operations, the recombination leads to what is defined by the scholars as a “smartification”: a process of digitization which includes the reinforcement of existing knowledge structures and entails the complement of existing competencies.

Some characteristics proposed by the scholars’ studies are considered to be relevant for approaching the technologies of interest.

The starting point for the analysis regards the “search” process undertaken for finding the useful knowledge to be integrated within the proposed business model of a firm, for reaching the goal of producing innovative outcomes. The search can be either performed within the firm perimeter and leveraging on the expertise available, or can be retrieved from external sources. A topic studied by the scholars analyzes the relationships between different players operating in the same market, involved within what it is defined as “knowledge network”. Within this network, that involves players as other companies, startups, universities and research centers, consulting partners and other possible external experts, the companies performing the recombination needs to have the sufficient “absorptive capacity” for being able to integrate the retrieved knowledge within the existing companies’ business.

The information retrieved by the studies on academic literature are then immersed in the drones and Artificial Intelligence environment. The scholars make them part of the Industry 4.0 revolution, and provide a description on both technical and business sides.

Drones are the flying platform employed as “eyes in the sky” of humans, features that allow them to be employed for several applications. The flying platforms are integrated with payloads, tools that enable the operations performed by drones, and together with the help of sensors enable the collection of data. The data processing is then allowed thanks to the inclusion of dedicated software: the data collected are analyzed and provide an outcome for the decision making.

Here comes one of the purposes for which Artificial Intelligence algorithms are employed: Machine Learning and Deep Learning are between the intelligent logics applied by the platforms in order to provide both efficiency in data processing and autonomy and independence in operations performing.

According to the studies performed by DRONEII in 2019, states that 100% of software developers for drones data analysis rely on AI algorithms, either solely (37%) or in combination with traditional computer vision software (63%).

In light of what obtained by the literature review the target for the thesis is resumed through the following the research questions:

- 1- Which is the state of art of the drones' environment with respect to the provision of solutions attached with Artificial Intelligence?*
- 2- Which characteristics of the firms are correlated with the recombination between drones and Artificial Intelligence?*

DRONES MARKET: OFFER AND DEMAND CATEGORIZATION

In order to approach the first research question, together with the Drone Observatory, it is analyzed the offer present both in the national and international market and it is proposed a categorization able to include the solutions.

Starting from the software side, the providers' offer is categorized according to 4 different possible needs for the companies operating with drones:

- Mission planning, flight and operations management: software employed from the preparation process until the performance of a specific mission;
- Data analysis: software addressed to process data collected and to provide output to the decision makers;
- Navigation: software enabling the control of the platform in the flying activities;
- UTM (Unmanned Traffic Management): software that deals with the integration of UAS systems in the airspace and all the activities of supervision and safety of the latter.

Passing to the payload categorization, it is provided a first distinction among the solution sensor based and the solution "sensor-less": the goal of the first section of payload is the data collection thanks to the inclusion of the dedicated sensors, while the second section are the tools attached to the drones which act event driven.

Most common sensor based payloads are represented by cameras, able to process various wavelength ranges (from the Red, Green and Blue to the multispectral and hyperspectral range), laser scanners, radar and gas, radiation and other substance detectors.

Other types of tools, not attached with sensors, are categorized as distributor and other cargo systems, dispenser (of liquids, dust or other substances) and another category of which other solutions retrieved not belonging to the previously mentioned categories are part. The categorization is validated by technical experts and afterwards it is applied to the offer and demand database of Drone Observatory. The offer side categorization provides a quantitative view on the national and international players: on the national side the main focus is on the

solutions including Artificial Intelligence while on the global market the focus is on the geographical distribution of the providers. In this regard, around half of the offer is provided by American and Canadian companies.

The categorization is finally integrated to the use cases of the Drone Observatory's database: the solutions involved are analyzed considering the presence of Artificial intelligence and the main purpose of its involvement. Just a small part of the cases involves Artificial Intelligence software, but during the analyzed period (2019-2021) it is noticed a clear growing trend.

MARKET SURVEY & ECONOMETRIC MODEL

In order to answer the second research question, it is leveraged on the annual survey proposed by the Drone Observatory to the active players in the drone market: thanks to the processing of information collected from the “search and recombination” current, it is included a dedicated section in the survey on the innovation model of the companies. Together with questions dedicated to scout the Artificial Intelligence state of art within the business proposal of the firms, the “Innovation strategy” answers concur to propose an econometric model for exploring whether some of the dimensions introduced by scholars following the “search and recombination” study, have been analyzed along the years. The question proposed in this section covers both qualitative and quantitative aspects of the firms' innovation strategy and positioning: it starts from understanding whether a firm perceives itself as developing, aiming to disrupt the market, with a technology push strategy, rather than acting according to the rising market needs, with a market pull strategy.

Some questions are then dedicated to the “network” topic: it is asked to the companies whether they entertain relationships with external actors and eventually from which sources they finance their business. Moreover, it is asked to the companies whether relationships with external actors are limited to the national perimeter or they extend it to the global dimension.

Under a quantitative point of view, it is asked to the companies the amount of R&D expenditures addressed to the drone area development.

The companies' answers to the questionnaire are then aggregated and transformed on binomial variables following defined logics. For the answers showing continuous distribution, there is a strategy of division between the half with higher values and the one with lower values, as in the case of R&D distribution or number of employees.

The transformation process is applied on a dependent variable, identified as the answers to the question related to the presence of Artificial Intelligence among the software employed for business purposes. As predictors, on which the correlation is investigated, 5 variables are identified: the first one is related to the innovation approach, which distinguishes market pull from technology push models. Two variables assessing the network theme are included: one related to the network presence and one related to external actors involved, with a specific focus on universities and other startups. One variable on the number of employees, included as a proxy for the companies' size and one on the R&D investment undertaken on drones' activities, identified by the scholars as a proxy for firms' absorptive capacity, finalize the model. The aggregated dataset is used for Stata software feeding.

The model computed shows statistical significance and correlation with the presence of Artificial Intelligence for three variables:

- Network presence: model shows positive correlation between the firms replying to involve AI within their business and the ones stating the inclusion of external actors in their development process;
- Number of employees: according to the model outcome, negative correlation is highlighted between the increasing on employees number and AI reconfiguration;
- R&D expenditure on drones' activities: negative correlation results on the increasing value of R&D expenditures and AI involvement.

CONCLUSION

According to literature review evidences, no studies have addressed the specific process of drones and Artificial Intelligence recombination, therefore this thesis reaches the goal of opening the discussion on this side and on providing new use case to the literature on “search and recombination on technologies”. The outcomes collected from the model provides some possible hints for future studies, deepening for example the analysis of the drones’ networks. This thesis focus has put on the recombination occurrence, not on the business results obtained: therefore possible future studies may investigate the variables impact on the companies’ performances.

The activities performed together with the Drone Observatory of Politecnico di Milano show a growing market: articles from reliable newspapers document an increase in terms of use cases which involve the action of Artificial Intelligence for enhancing the drones’ operations. This is found covering the different purposes of analyzing collected data, controlling the platform, managing the operation or keeping safety in the aerial space.

CHAPTER 1: LITERATURE REVIEW

The first chapter introduces the academic current state of art on search and recombination of innovative technologies, that in this thesis is applied on the study field of drones and Artificial Intelligence solutions.

The chapter is divided into three parts, in order to reach a solid basic background for developing the thesis:

- First part is addressed to explain the methodology applied in the literature review: it is joined a systematic review method choosing papers which can explain the current on ‘search and recombination’ innovative model that fit the drones and AI case and academic studies on ‘drones, AI and data analytics’ for providing reliable definitions and state of art;*
- Second part on ‘search and recombination’ state of art, providing definitions found in the academic literature of the main concepts and highlighting some sub-categories of interest for developing a study on drones and AI recombination;*
- Third part on ‘drones and AI’, in order to provide acknowledgments to the reader on the main subject of study, performed through a combination of academic literature review for defining the technologies under scholars’ point of view and web search for finding interesting applications and knowledge publicly available.*

The thesis goal is explained by two research questions which are proposed after the theoretical background introduction, in order to develop the study current on ‘search and recombination’, applying it to the Drones and AI case, and to provide a further categorization on AI solutions employed by drone’s industry.

1.1 Introduction and methodology

‘Search and recombination’ innovating process is a concept which finds its birth in the 30s of the last century: since then many scholars have started to deepen different shapes of this field, highlighting many aspects of interests for innovative companies. The aim of this thesis is to extend this academic thread to the field of drones combined with artificial intelligence solutions. First of all the focus is on the key words to be employed for outlining the topics of interests. Their combination results in four different queries which are used for finding academic papers on SCOPUS¹ database:

- After having analyzed 4 papers (Gruber et al 2013; Lanzolla et al 2021; Albino et al 2017; Messeni Petruzzelli and Savino 2014) provided by ‘Drone Observatory Politecnico di Milano’² it is first built a complex query containing key words as “search”, “recombination”, “integration”, “digitalization”, “digital transformation”, “creation”, “generation” and “innovation”. The query obtained resulted in 90 papers which have been selected through abstract and title analysis after a selection of most reliable sources by SCIMAGO³: 8 papers have been considered reliable but of very low interest about the drones and AI’s study field, with just the introduction of some technological developments study cases in completely different business areas. It is assessed that many of the key words employed find very wide applications, therefore a more specific query is needed for presenting the state of art of the topic.

¹ <https://www.scopus.com/home.uri>

² <https://www.osservatori.net/it/ricerche/osservatori-attivi/droni>

³ <https://www.scimagojr.com>

- It is then chosen to build a simpler query containing three key words: “search”, “recombination” and “knowledge”. These are obtained by query performed by Messeni Petruzzelli and Savino (2014) which outlines the concept of “knowledge recombination” as the current of study of this innovation method. Behind the technology there is the knowledge on how to manage it, therefore this simple query is more specific and suits the goal for providing theoretical knowledge employed by scholars. 41 papers are retrieved, 28 are considered of interest after title and abstract analysis and after the sources’ validation through SCIMAGO all are considered reliable (27 papers belong to Q1 and 1 to Q2⁴, meaning high level of reliability of sources). Just 19 are finally analyzed because 9 are found not available for Politecnico di Milano⁵ institution. Some integrations for specific concepts are then added referring to sources cited in the papers retrieved.
- In order to provide the knowledge about “drones, AI and data analytics” a query combining the key words “drones”, “UAV”, “AI”, “Artificial Intelligence”, “data analytics” and “business analytics” is employed. 60 articles are obtained, among which 42 considered of interest after title and abstract’s analysis but just 17 belonging to the first 2 quartiles on SCIMAGO source’s valuation. These papers are employed for providing reliable definition of topics of interests and for enriching public knowledge on applications retrieved on web search.
- A fourth query is thought to combine “search and recombination” with “drones and AI”, resulting on 0 query obtained by SCOPUS. This fact leaves space for this research

⁴ *Scientific Journal Rankings indicator*

⁵ <https://www.polimi.it>

to enrich the academic literature since no scholar has studied the case of drones' industry under this innovating point of view so far.

The papers' list found in SCOPUS are selected and categorized in an Excel work sheet and afterwards papers of interest are downloaded through Google Scholar⁶.

In addition to SCOPUS searches, it is performed a querying directly on Google Scholar with specific terms in order to enrich the chapter with academic and reliable definitions.

1.2 Literature content on 'search and recombination'

Academic studies on search and recombination of technologies are addressed to provide solutions and results to practitioners around the study fields of organizational learning, technological innovation, organizational adaptation, strategic management, innovation management, and organizational design (Lanzolla et al, 2021). The scholars have studied both innovation and digitalization as processes (Lanzolla et al 2021; Albino et al 2014; Gruber et al, 2013) and the micro-structural aspects which are included in the process, focusing on soft skills required for implementing the innovation process and firm's characteristics (Grigoriou and Rothaermel, 2014; Ardito et al, 2018; Gruber et al, 2013).

In this thesis for the analysis of drone's industry it is employed a mixed analysis between process and micro-structural features useful for understanding the integration and providing insights for practitioners. The starting point is a trial to provide a definition of the main concepts retrieved from the theoretical background of the papers analyzed, including the time of the definitions expressed and their development. Afterwards, the relevant studies

⁶ <https://scholar.google.com>

which are considered to be of interest for the drones and AI field are exploited and analyzed as sub categories, trying to find relevant aspects for deepening the knowledge about the object of analysis. Due to the wide literature on this topic, some aspects of the background of “search and recombination” are either just named in the chapter or not even considered due to the fact that are hardly linkable to the process of recombination of drones and artificial intelligence.

1.2.1 Definition of ‘search and recombination’

The aim of this paragraph is to provide a theoretical assessment of the process of search and recombination, starting from the definition of the single concepts, arriving to a development of studies and specific areas which integrate the main topic.

Search

Winter (1984) defines the concept of search as the “manipulation and recombination of the actual technological and organizational ideas and skills associated with a particular economic context”. It is already clear how within the process of innovation are involved both technological knowledge but also organizational skills which are essential for succeeding. Two ways are recognized for approaching the search activity: the first one implies to retrieve knowledge by other firms operating in the same area or directly in the internal environment of the firm itself, process defined as exploitation (Winter 1984); the second implies a search in the external environment in order to find elements which may trigger a breakthrough innovation, the exploration (Winter 1984). This is the starting point for the differentiation between search depth (Lanzolla et al 2021; Savino et al 2013; Kim 1998; Alnuaimi et al 2021) and search breadth (Lanzolla et al 2021; Savino et al 2013; Agard et al 2015; Almeida

and Rosenkopf 2003; Alnuaimi et al 2021; Berchicchi et al 2017) which further distinguish inward looking firms from outward looking firms (Alnuaimi et al 2021).

Search depth

The process of search performed looking within the current knowledge: the existing structures and areas of expertise are exploited in order to deepen the basic internal knowledge. The result of this process may be either positive or negative. Search depth allows to exploit the “experience effect” (Lanzolla et al, 2020). The reuse of internal knowledge facilitates the development of team specific domain's absorptive capacity (Kim 1998) and generally results in higher quality and fewer mistakes (Fleming 2001). To this kind of process are associated lower costs for integrating components (Lanzolla et al, 2020) and firms already have soft skills which let to innovate applying this method (Savino et al 2013). On the other hand routines and reuse of old components may lead to a lock in existing solution and rigidity towards new ones (Lanzolla et al, 2020) and risk to develop peripheral novelties (Savino et al 2013). Too much reuse may decrease the innovating impulse due to the low search of novelty (Alnuaimi 2020). Savino (2013) introduces the need of coordination, knowledge, management and communication within the firm in order to succeed in this process, with a focus on the centrality on an effective team creation.

Search breadth

Search breadth consists in looking for knowledge outside the current knowledge (Lanzolla et al 2021): the knowledge of the firm is therefore broadened with respect to its basic expertise. The external sources of knowledge are identified in customers, suppliers, competitors and universities (Savino et al 2013). According to the evolutionary theories of organization, the broadening of knowledge has positive impact on firm's activity because it stimulates the

impulse for novelty and adaptation (Lanzolla et al 2021, Savino et al 2015). External search is considered more effective in industries with high degree of complexity (Savino et al 2013) and where managers assess operational problems (Berchicci et al 2017). The concept of distance is included in the search breadth context: the distance between existing and new knowledge may have negative impact due to integrating costs, reliability of integration and need of developing new expertise (Lanzolla et al 2021). The distance of knowledge may be geographical or technological (Almeida and Rosenkopf 2003) and it is proposed to be overcome thanks to the mobility of inventors, at the individual level, and formation of strategic alliances, at firm level. Alliances encourage cooperation between partners which stand in time (Almeida and Rosenkopf 2003). With respect to the case of search depth, in search breadth the knowledge is unlimited, rising in possibly unlimited outcomes (Lanzolla et al 2021).

Recombination

For the recombination concept it is performed a disclosure on the evolution of the term starting from Schumpeter (1934) and the definition of different shades which integrate it with successive scholars' elements. "New combinations" can lead and open the door to new markets proposing new models, products, services or processes (Schumpeter 1934).

The recombination has an impact on the creative process itself, providing different nature of the output depending to the fact it happens between old or new component in old or new methods (Weick 1979). The way a firm is able to recombine and reuse different technologies is referred as "transformative capacity" (Garud and Nayyar 1994) which is aimed to integrate the absorptive capacity concept expressed by Cohen and Levinthal (1990). Depending on these factors and some degree of casualty, the market sometimes open opportunity to enter with new degree of novelties (Lanzolla et al 2021) arising from the recombination of given

technologies which propose as vectors for the final innovation purpose and methods. Behind the recombination study field there is the study of linkage between the components recombined. The knowledge built upon a group proposing ideas which try to link them, may create a better outcome than a group proposing ideas in silos (Harvey 2014), underling the importance of highlighting the common thread which link them.

As well as in an innovation process formation this stands also for organizational aspects: finding the links between different parts of a firm may lead to a better knowledge management with better results in term of outcomes (Hargadon 2002). Hargadon (2002) intimates how the linking of existing knowledges application in new situations for creating new combinations must occur across people, groups and over time. The recombination is embedded in the search concept itself: when a firm goes deepen its knowledge, it better understands the linkages occurring between components and situations (Katila 2002) and in the case of broader search the recombination enables to create new outcomes (Fleming and Sorenson 2004).

Search and recombination development

Among the different scholars that have analyzed the current of this study field, there is unanimity in citing Schumpeter as the first one approaching the innovation as the result of recombination of existing components (Schumpeter 1939).

The concept is then exploited and deepened by many others: after having defined the process on how the recombination makes it possible to innovate, the focus switches to the different components and the way they are linked. This makes possible to extend studies and analysis on effectiveness of the recombination process and features needed by the different components and actors involved in order to succeed. The different technological components can be seen as different building blocks, assemblies and methods which have to be combined

for developing new technologies (Fleming 2001; Arthur 2007). The view concerning the recombination as the antecedent for innovation is integrated by the “foundational view” which claims that recombination process may also be detrimental to final result because breakthroughs can born only by a completely disruption from the past (Taylor and Greeve 2006). Recombination of technologies require recombination of knowledge, and once the knowledge is too deep in a certain field it may limit the openness to other. Kaplan and Vakili (2014) consider the “double-edged sword” nature of the recombination process: on one hand in fact distant recombination may help to overcome the lock in caused by narrow knowledge of a specific domain; on the other hand sometimes specific knowledge may be required for opening space for breakthrough innovation.

Digitalization

The process of search and recombination is embedded in the digitalization development of firms (Lanzolla et al 2021): it is agreed that the digitalization has a deep impact on search and recombination of knowledge but yet is underdeveloped the linkage between digitalization and organizational capabilities of the firms, involving what they need for

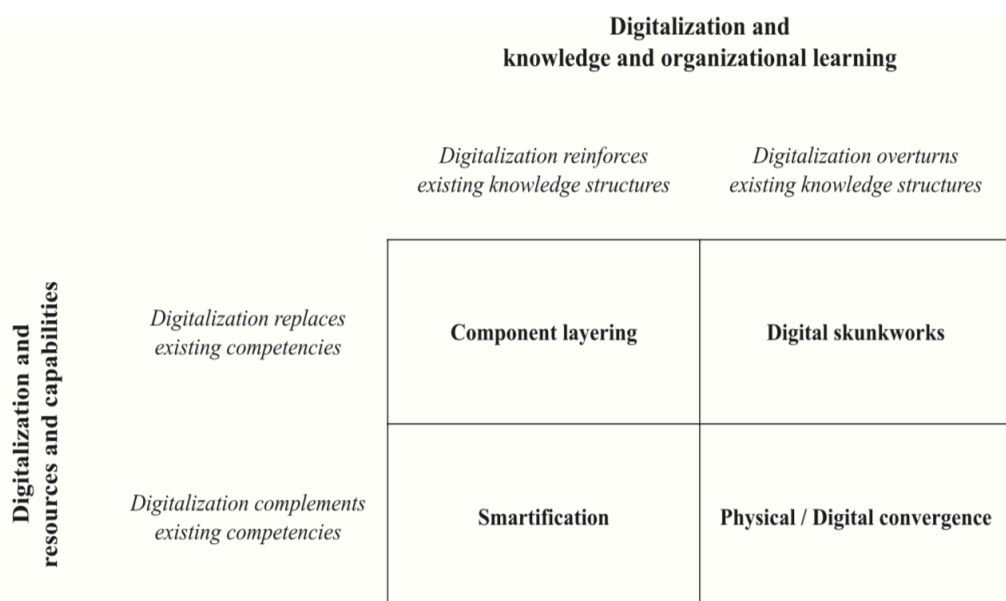


Figure 1 - categorization framework of digitalization process (Lanzolla et al 2021)

achieving in the process. Lanzolla et al (2021) exploit the concept that digitalization causes new tensions in organizational layers within the process of innovation, affecting the firm on different dimensions. It is here proposed a framework (*Figure 1*) for product innovation in the digital age, combining the digitalization impact on organizational learning with resources and capabilities (Lanzolla et al 2021). The framework proposed helps in categorising the process of recombination in case of inclusion of digitalizing elements.

For the purpose of this thesis the most relevant quadrant is related to smartification, in which the digitalization reinforces the existing knowledge and complements existing components. As a matter of fact Artificial Intelligence is aimed to integrate processes in the drone industry, not replacing the existing habits.

This is a case in which integration costs are lower than the case in which it is required the replacement of the components or the existing knowledge structure is completely overturned (Lanzolla et al 2021).

The main factors impacting on the nature of innovation are exploited in the next paragraphs in order to find an academic method for approaching the process of recombination in the case of drone industry's integration of the artificial intelligence.

1.2.2 Characteristics of 'search and recombination'

Some of the elements which affect the nature of innovation employed by firms and the impact they have on their business (Fleming 2001; Kaplan and Vakili 2014) are retrieved on some different dimensions of analysis exploited by scholars within the study of this topic: in the literature are found studies on knowledge and components age (Messeni Petruzzelli and Savino 2012; Levinthal and March 1993; Katila 2002; Ardito et al 2018), organizational

learning of the firm (Messeni Petruzzelli and Savino 2012; Alnuaimi et al 2020; George and Zahra 2002; Levinthal and Cohen 1990), proximity under technological, geographical and organizational point of view (Liu et al, 2018); inventors background (Gruber et al 2013), presence and positioning on a network of knowledge (Alnuaimi et al 2020; Pedraza-Farina et al 2020; Karamanos 2016; Lin et al 2021; Balachandran and Hernandez 2017; Grigoriou and Rothaermel 2014; Schilling and Fang 2014) firm size, resources and capabilities (Ardito et al 2018, Lanzolla et al 2021) and cognitive and emotional costs (Lanzolla et al, 2021).

Knowledge network

Heidl et al (2012) provide a definition for the concept of knowledge network, assessing that “it is a system of actors, individuals or collectives with heterogeneous knowledge and agents that operate along the system searching, transmitting and creating knowledge”. It can be represented as a series of nodes, in which both the nodes and the arrows linking them have certain characteristics and value for the effectiveness of the knowledge management (Heidl et al 2012). Each element has its own positioning on the system.

Role of networks finds large space in academic literature with regard to search and recombination branch (Alnuaimi et al 2020; Pedraza-Farina et al 2020; Karamanos 2016; Balachandran and Hernandez 2017; Grigoriou and Rothaermel 2014). Balachandran and Hernandez (2017) propose a three ways configuration on networks, dividing them in foreign, domestic and mixed: to each configuration is associated a different model of recombination with foreign inclusion providing access to new knowledge, domestic higher integrative facilitation and the mixed balancing the two dimensions. The inclusion of external actors is proposed by Savino et al (2013) and expects them to be found among universities, suppliers, customers and competitors.

There is a further distinction on networks which imply different level of analysis: interpersonal, intra organizational and inter organizational (Heidl 2012).

The other two categories are useful for distinguishing inward looking firms and outward looking firms (Alnuaimi et al 2020): inward looking firms are more susceptible to internal embeddedness and sensitive to the intra organizational network mechanisms, with subsequent optimal internal knowledge reuse; outward looking firms are more embedded in inter organizational networks and prefer a knowledge broadening process. (Alnuaimi et al 2020). Embeddedness is the quality of being ingrained in a network (Alnuaimi et al 2020): since the multi dimension of networks, the firms themselves are triple embedded. The first embeddedness dimension is on the inventors network (*Figure 2*) : this implies the relationships which run within teams boundaries. The second level is on the team

Figure 2 - example of inventor network with nodes and arrows (Alnuaimi 2020)

embeddedness within the firm's boundaries and the third level is on the firm embeddedness within the intra organizational network.

Inventors

Inventors are the actors directly involved in processing the information retrieved about new knowledge combination. The analysis on inventors is included in the micro structural analysis: understanding the composition of a team is considered crucial by scholars in order to achieve effective results for the firm. Beyond the composition of different level networks' study, scholars focus on the background of inventors (Gruber et al 2013, Melero and Palomeras 2015). Gruber et al (2013) assesses the impact which have the education on the inventors, differentiating the output of inventions between scientists and engineers. Results of the study show that scientists provide inventions with significantly higher technological breadth than engineers. Some other dimension positively impact on the technological breadth such as the doctoral training and the closeness in term of time distance from the degree. Melero and Palomeras (2015) extend the concept of "generalists" inventors, which are individual with a broad knowledge set help their team in outperforming on the teams without these individuals. The idea started from a study on management decision making simulations in which the teams with elements with broad knowledge usually won on other teams: the scholars tried to transfer this idea on the team level analysis on the branch of innovation activity, finding that these figures help in achieving better results.

Absorptive capacity

Cohen and Levinthal (1990) define the absorptive capacity both as the ability to find appropriate knowledge from different sources and the way it is integrated in the firm's organisation. It relies both on the individual level and to the organizational level (Cohen and

Levinthal 1990), because the firm's absorptive capacity is considered dependent on the absorptive capacity of the single individuals involved. The studies on this branch are aimed to assess the preparation of the firms to the innovation process.

Cohen and Levinthal (1990) propose a model which implies the assessment of R&D investments of the firms as antecedents for creating stronger absorptive capacity. The idea behind it is that firms invest in R&D not only for achieving business goals, but also for broadening and deepening its basic knowledge: the higher the basic knowledge on a field the higher is the critical thought that results in better understand of technologies' integration mechanisms. As a matter of fact there are found R&D investments also in fields which are publicly available (Cohen and Levinthal 1990): with respect to previous studies which proposed that the competitive advantage for a firm can be found on diversification process (Nelson 1959), Cohen and Levinthal (1990) show that the more a firm becomes technologically advanced in a field the more it increases the basic research in that field. This is done for every field of interest, increasing the overall absorptive capacity.

George and Zahra (2002) define the absorptive capacity as a dynamic capability of the firm to transform and keep a competitive advantage along the time. In this model the absorptive capacity is split in two dimensions: potential and realised. The potential includes the

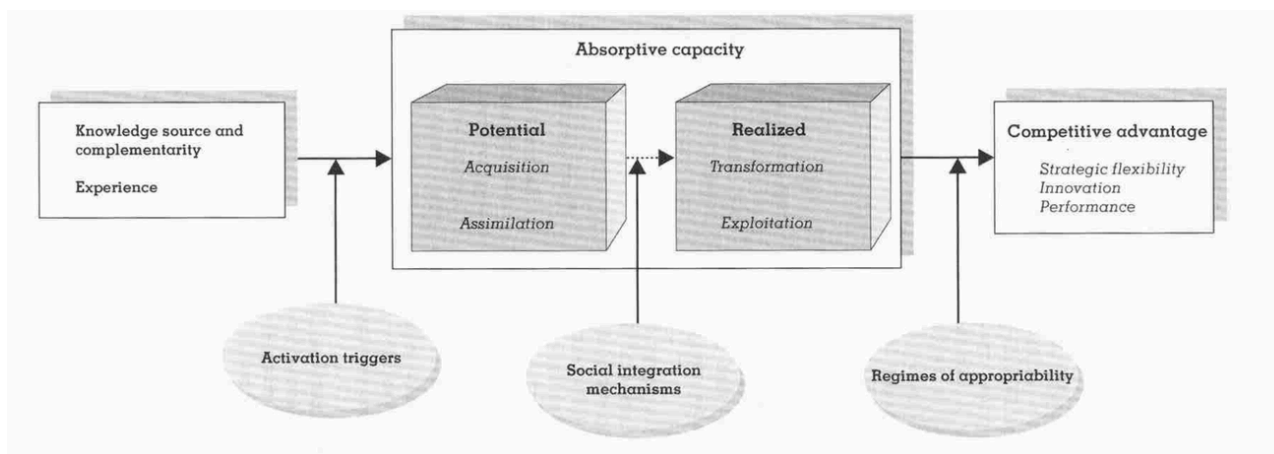


Figure 3 - absorptive capacity framework (George and Zahra 2002)

knowledge and assimilation capabilities, while the realized regards the transformation and exploitation (*figure 3*).

Assessing the knowledge source (George and Zahra 2002) there is an extension with respect to previous studies (Cohen and Levinthal 1990): it is still confirmed the dependence of R&D investments on learning capabilities, but it is added the dimension of knowledge retrieval from external sources including acquisitions, purchasing and contractual agreements (Granstrand and Sjolander 1990).

The division between potential and realised capacity (George and Zahra 2002) implies that there is distance between the two dimensions: social integration mechanisms are recognized as the trigger for reducing the distance and making the realized capacity as close as possible to the potential. Presence of coordinators and social networking are proposed as mechanisms for contributing to knowledge assimilation (George and Zahra 2002).

Knowledge age

The effectiveness of a recombination process is linked to the age of the components, with different thought currents to bring argumentations on this regard. On one hand aged components are considered to be the cause of obsolete outputs (Sorensen and Stuart 2000), assuming the high validity of nascent technology; on the other it is considered a “recency bias” (Ardito et al 2018) with respect to the idea of nascent technologies to be more valuable than old ones.

Old knowledge characteristics are found in being more reliable and to cause less uncertainty and costs for utilization (Messeni Petruzzelli and Savino 2014). New knowledge, instead, is considered to trigger novelty and technological development, opening space for new markets, products, methods and processes (Schumpeter 1934). The effect of new knowledge implies an unlock from old habits and reduces the risk of stagnation for firms.

Ardito et al (2018) exploits the concept of knowledge maturity relating it to the age of firms: the usage's effectiveness of new and old components depends on the nature of the firm itself. Young firms are valued to be more effective in employing new knowledge, while old firms

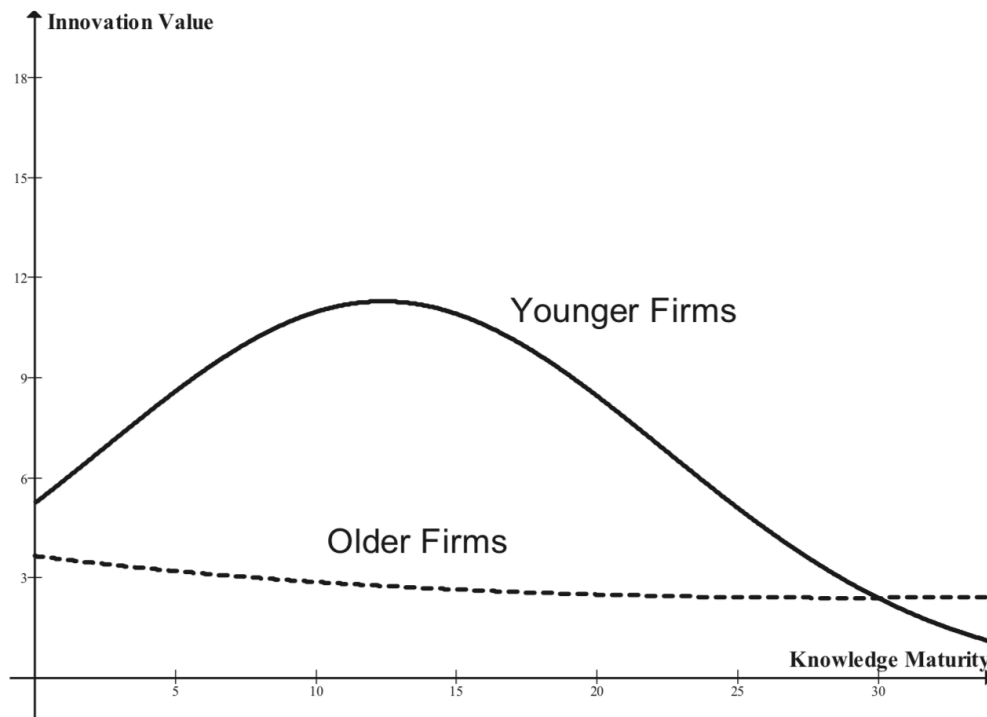


Figure 4 - knowledge maturity - innovation value (firm's age) (Ardito et al 2018)

can better exploit their knowledge maturity approaching to old components. As shown in the (figure 4) (Ardito et al 2018), innovation value is high for younger firms when approaching young components, while it is overcome by older firms once the components age gets older. Expertise of older firms allow to retrieve knowledge by larger time span (Ardito et al 2018). The second firm's feature linked to the knowledge's age is the firm size (Ardito et al 2018): with respect to this dimension it is obtained that large firms are able to both exploit old and nascent knowledge. This results from their capital availability which lets them to approach both new knowledge reducing risk and uncertainty and broadening the usage of old components. On the other hand small firms optimize the exploitation of middle age knowledge, minimizing the risk of employing nascent components and the costs related to integration of old ones (Figure 5) (Ardito et al 2018).

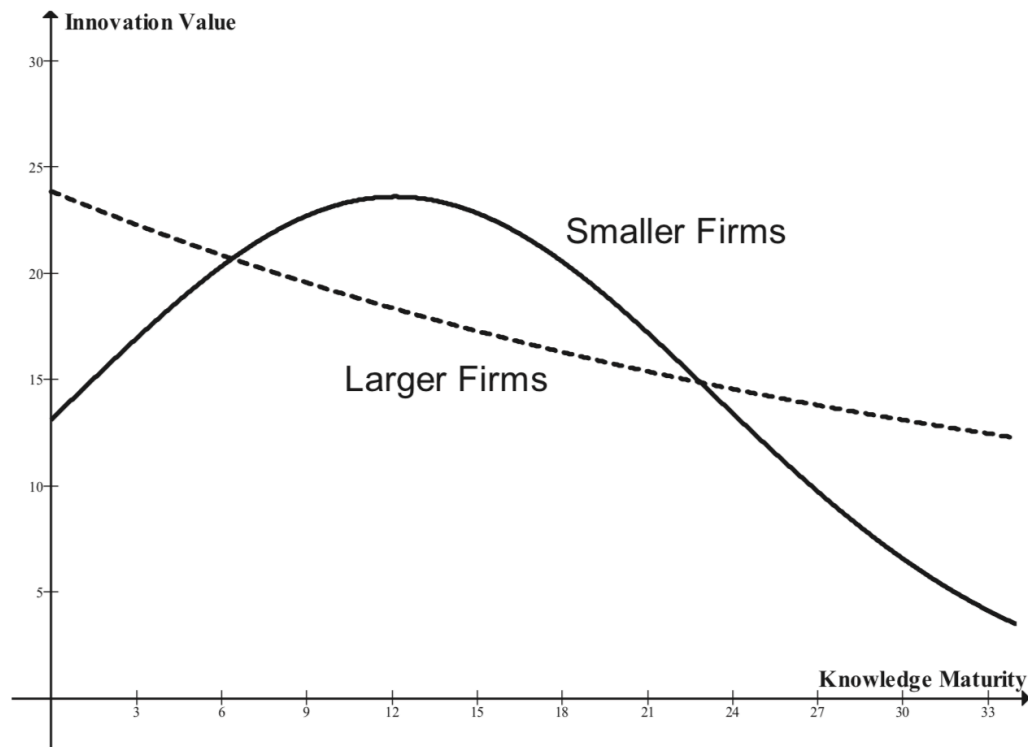


Figure 5 - knowledge maturity - innovation value (firm's size) (Ardito et al 2018)

1.2.3 Gaps on search and recombination

Researches on search and recombination of technologies are wide and cover many sub categories of the main field, which is the process of innovation. Combining key words of drone and AI environment with the ones from search and recombination branch results in zero papers, therefore there is space for approaching the analysis of recombination in this business field. Previous studies have been exploited by scholars largely relying on 'patent method', which implies to relate number of patents, used as a proxy of the innovation process outcome, to their employment by external actors or number of citations in academic papers. This way is considered not applicable to the case of the drone's industry, therefore it is here proposed an alternative method for approaching this field.

In this case there is a smartification (Lanzolla et al 2021) of the processes thanks to the integration of Artificial Intelligence, which lets the machine to operate and process data autonomously and more quickly, rather than the development of completely new products. Some hot topics of search and recombination current are exposed in the previous paragraph, with the provision of some results from analysis, and the aim of this thesis is to include them approaching the firms operating in drones' industry.

Studies have built some models of innovation implemented by firms, the trial of this thesis is to understand the model joined by firms operating in UAV environment with respect to the inclusion of Artificial Intelligence. This will lead to a comparison between new findings and precedent results and assessments.

It is of interest the presence of networks of knowledge, either including the presence of external actors or internal activities in case of in-ward looking firms and eventually their positioning in the networks; the background of the individual level of the firm, including an assessment of inventors' education, the presence of coordinators in the process of innovation and the role of management; evaluation of the absorptive capacity of the firms, thanks to the inclusion of some proxies such as R&D investments and team building activities and finally the inclusion of some specific features of the firms' sample, such as their age and their size.

1.3 Technology of drones and Artificial Intelligence

Thanks to a mixed research between academic literature and public information, the aim of this paragraph is to provide an overview on the rising market of drone with a specific focus on solutions which include the usage of AI. The starting point is the definition of the technologies involved and a brief introduction to their history, so that there can be made assessments with regard to their age and some further hypothesis under a 'search and

recombination' point of view. Definitions are mainly retrieved by academic papers in order to provide reliable indications. Once it is clear the technical environment, the business environment is deepened: applications and goals of the drone and AI employment are shown, thanks both to the academic literature and to the public information retrieved, highlighting the most relevant benefits and challenges brought by Artificial Intelligence with respect to traditional operations. To conclude it is assessed the state of art of these technologies thanks to the analysis of reports drawn up by industry experts.

1.3.1 Drones

The aim of this paragraph is to provide a general overview of the drone technology, presenting different solutions available on the market and main features related. The drone system is composed by the flying platform and the equipment attached, commonly known as payload (Bondt et al 2016). The system can be employed for different reasons and having different goals. Depending on this the equipment is arranged following different layouts.

Types of drone

Drones, known also as Unmanned Aerial Vehicle (UAV), are categorized on different dimensions depending on its flying platform nature, considering the aspects which physically define the system and its ability to fly. The first differentiation is made accounting the system which lets the drone flies (Bondt et al 2016): drones can be divided in fixed wings system, multirotor and other hybrid solutions.

The difference between fixed wings and multirotor system is the nature of wings, that in the first case are fixed and in the second are rotary, both with the aim to generate lift (Bondt et

al 2016). The hybrid types are the solutions that can be categorized neither as fixed wings or multirotor, to that have some characteristics from both the classes.

The second dimension of categorization regards the capability of the machine to act on its own: there are remotely piloted UAV (Cohen and Jones 2020), automatic UAV and autonomous UAV (Bondt et al 2016). Automatic and autonomous drones differ of one degree of freedom: automatic perform a pre-determined assignment while autonomous can react to unexpected events. The autonomy can be the result of preprogrammed software of rules which makes it able to choose when it's required.

The third categorization made on drones is on their size and weight: according to this there are distinction between small and big UAVs (Clarke 2014) and heavy and light UAVs (ILT 2013).

The last categorization is made on the source of energy employed, which is differentiated in fuel, battery cells, solar cells and fuel cells (Custers et al 2015).

Types of payload

The flying system is equipped with tools which enable the drone to perform specific operations and that can be arranged in different combination depending on the purpose (Bondt et al 2016). These instruments are known as payload, and in this paragraph there is a brief introduction and characterization of the most employed ones found in the academic literature.

Among the most common payloads attached to drones there are cameras: they can be regular cameras or infrared (Bondt et al 2016). According to their nature they can retrieve visual or heat data, which have widespread applications.

In order to provide stabilization to the system, the drone is attached with a gimbal, which represents the pivoting point around which the machine rotates (Cohen and Jones 2020).

Another relevant payload is the megaphone (Bondt et al 2016), useful for example in dangerous situations.

Other specific sensors are able to retrieve data from the environment such as chemical composition. (Bondt et al 2016).

In order to provide positioning information about the machine it is provided with a GPS module (Cohen and Jones 2020): these data can be transmitted by antennas.

The other typology of payload is referred to all of that loads which are not targeted to retrieve data, not being sensors. It is the case of everything that can be delivered, including for example parcels, medicals, meals and supplies (Bondt et al 2016).

History

Aggarwal and Kumar (2019) provide an interesting section on UAV development since its beginning: this technology was born at the end of 18th century, as a bomb filled unmanned balloon (Aggarwal and Kumar 2019). A big step forward in this technology is done in the following century, when during the 1860s the UAV has been provided with a camera for the first purposes of surveillance, an application which still finds widespread application today. The first remotely control based UAV was developed in 1940s in the context of World War II, and since then many different models have been designed.

It is clear how the first applications of drones were intended for military usage. A development for commercial purpose was proposed in 2003 by Jeff Bezos, ex Amazon CEO (Aggarwal and Kumar 2019). Since then the hype for this technology has exponentially increased, resulting in drones' employment in many different business solutions, which are listed and explained in next paragraphs.

1.3.2 Artificial Intelligence

Artificial Intelligence is a deep and broad field of study, the aim of this paragraph is to provide some basic concepts on the technology and its development which can both acknowledge about the topic and that can make clear concepts which are included in the drones' environment.

Artificial Intelligence

Artificial Intelligence is a branch of computer science which target is to make the machines intelligent (McCarthy 2004). Intelligence is referred as the computational part of the ability to achieve goals (McCarthy 2004). Therefore a machine provided with Artificial Intelligence can be perceived as a system capable of autonomously process information in order to succeed in certain tasks.

First studies on this topic started right after the WWII, when Alan Turing (1950) proposed some conditions that a machine should respect for being considered intelligent: he opened the debate between scholars on the intelligence and abilities of machines to replicate humans' mind. There are opposite ideas and currents on this regard, with some scholars convinced that AI will never reach human level and others proposing that could also overcome it (McCarthy 2004).

For the purpose of this thesis only few key points of the Artificial Intelligence are exploited, in order to reach the main goals for which drones' companies have chosen to integrate it in their operations.

The literature on Artificial Intelligence is yet very fragmented due to the different scholars' approaches: these visions depend both on the scientific analysis and involve philosophic

studies. The most relevant AI themes for drones' environment are retrieved on DRONEII.COM⁷, relevant source of drone environment.

The first theme approached is the Machine Perception, which is the ability of the machine to perceive and absorb the surrounding reality through the usage of specific sensors. This is mainly referred to the activity of data collection.

Moving to the data analysis, it starts from the concept of Computer Vision or Machine Vision (Jain et al 1995): it groups all the methodologies and algorithms which proceed in analyzing and processing autonomously the raw data obtained for obtaining meaningful information. The goal of Machine Vision is to replicate the real world on a model through information retrieved by the reality projection (Jain et al 1995). A step forward for Artificial Intelligence techniques is the machine provision of the ability to learn from experience: on this regard two different learning levels can be introduced, Machine Learning (ML) and Deep Learning (DL).

Machine Learning is related to the “automated detection of meaningful patterns of data” (Shai and Shai 2014). It groups algorithms which enable the machine to learn from previous experience and due to the higher data availability: machines are allowed to improve their performances thanks to their past experience.

The other group of algorithms addressed to the autonomous learning is the so called Deep Learning (DL): it is still part of the ML category, but Artificial Neural Networks are employed for the information processing in decision making. These algorithms let the machine to see the world as a series of hierarchy of concepts which are interrelated between them, with each concept being determined by relationships which has with other simpler concepts (Bengio et al 2016). All the relationships created build the reality, and in this context the machine is

⁷ <https://droneii.com>

able to act and decide autonomously. Moreover internal parameters are step by step changed and updated relying on new data available.

Artificial Neural Networks are moved by parallel computation in the brain which enable to successfully perform complex tasks (Hassoun 1995). This system can be enabled by GPU (Graphic Processing Units), which are both a powerful graphic engine and parallel programmable processor which enables the layers to interact (Houston et al 2008). They are attached to the machine, where the DL algorithms can be finally exploited.

1.3.3 Drones and Artificial Intelligence

After an introduction to the technologies of interest, the aim of this paragraph is addressed to provide the state of art of their combined employment.

AI is applied by drones' companies mainly with two purposes: path planning and data analytics (Figure 6). This thesis is focused mainly on data analytics branch, but there are here provided also some basic insights on path planning functioning.

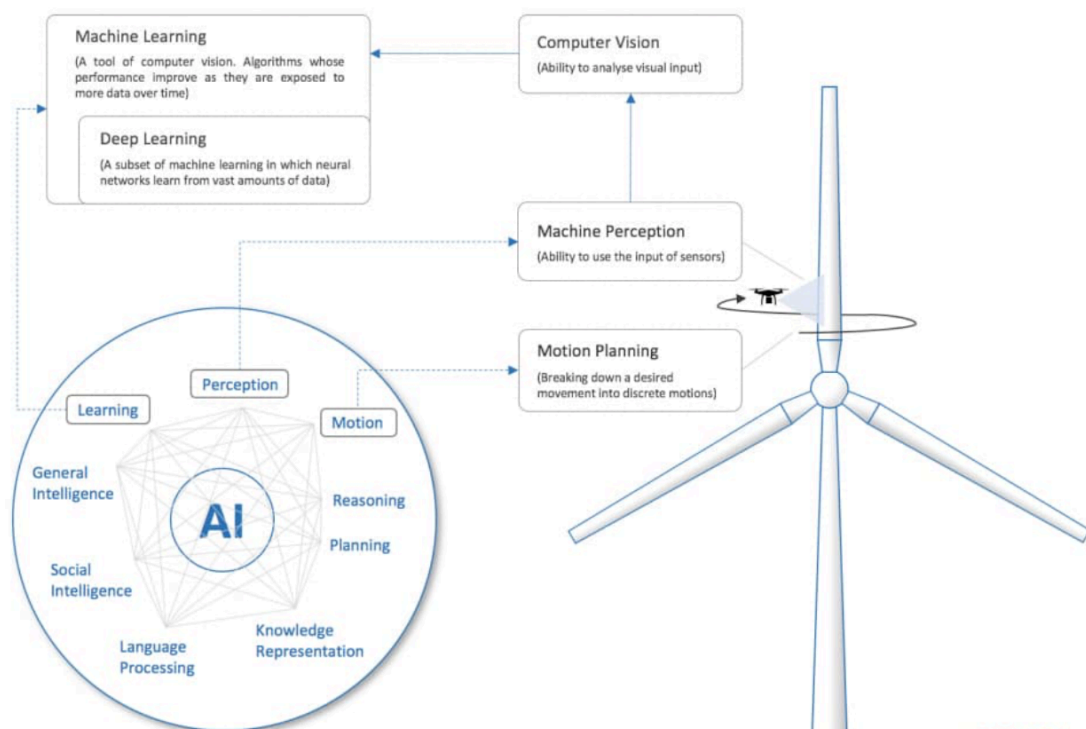


Figure 6 - Drones and Artificial Intelligence (DRONEII 2018)

Path planning

Path planning represents the challenging ability of the machine to perform a movement between two places in optimal way. It consist in recognizing the surrounding environment, localizing, avoiding obstacles and controlling speed, all features which allow to perform a successful navigation. (Aggarwal and Kumar 2019).

Some components related to path planning are essential to make it effective (Aggarwal and Kumar 2019): motion planning, robotics feature, which implies the ability of finding a reliable path from a starting point configuration to a specified goal configuration, including the avoidance of collision of eventual obstacles; trajectory planning, which includes the kinematics properties of the machine during the navigation (Aggarwal and Kumar 2019); navigation, related to the control of the machine (Aggarwal and Kumar 2019).

In a dynamic environment it is asked to the machine to perform specific tasks autonomously due to the fact that the human presence may be somehow detrimental, ineffective or also hindered by external conditions.

Therefore the goal is to make the machine as much intelligent and autonomous as possible, so that it can be effective and quick in the decision making process.

In path planning area the Machine Perception enables the machine to perceive surrounding areas, while Deep Learning enables to recognise obstacles, whether they are humans or unmanned obstacles, and to create a route for the flight.

Data analysis

Drones are a very powerful tool for the data collection: with the help of sensors introduced in the precedent paragraphs, they can instantly collect huge amount of data. The first help provided by the drone is to scan places which are inaccessible or dangerous for humans, that

can be a deep mine, the surrounding area of a fire, a brake or high electric trusses. Once the data are collected there are two alternatives: on one hand humans can process them and use for decision making, otherwise specific software can autonomously and quickly process them. For this purpose it is employed the Artificial Intelligence.

The relevant impact of AI is to effectively process huge amount of data without the human presence (DRONEII 2019), resulting in reliable and actionable information. As shown in the graph (Figure 7), the data output can be both employed real time, in case the situation requires sudden intervention, or ex post in case it is targeted to subsequent evaluations. AI algorithms previously explained are exploited and combined for operational purposes, providing reliable data in more effective and quicker way than humans, thanks to the parallel approach included in Artificial Neural Networks. For understanding and categorizing data retrieved by drones it is interesting to introduce the main business sector cases which include the combined employment of drones and AI.

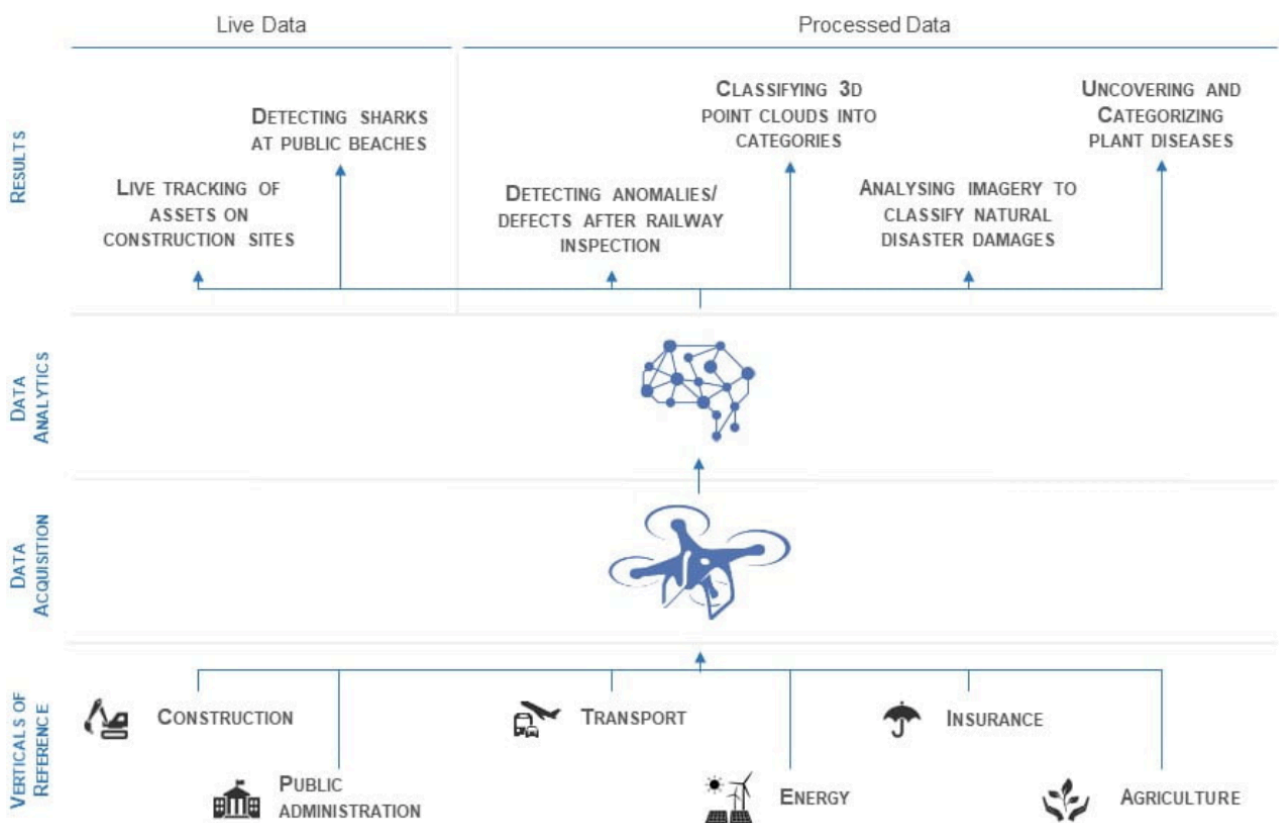


Figure 7 - Drones, Artificial Intelligence and data analytics (DRONEII 2018)

1.3.4 Business Applications

This paragraph is aimed to provide the state of art of the focused technologies: some cases are retrieved from public sources, others are selected from academic papers. The applications presented involve drones and AI, highlighting its the role in operations and which are the benefits introduced.

Military and Defense

Military and defense sector is where drones' development is found: they are born mainly for surveillance or sites' inspections purposes, but governments are step by step equipping their armies with unmanned vehicles with the aim of combatting enemies. They started as pioneers and searchers, and as the time has gone by they've become increasingly more intelligent and autonomous, improving communication abilities and capacity of approaching different tasks. Military sector can be considered a trigger for technology: as well as other technological developments in the past, drones employed in warfare may represent the antecedent towards further developments in industrial and civil contexts. Scholars have drafted a possible outcome for what concerns future dimension of war and battle space: governments are providing their armies with drone and robot fleets, which are going to fight a remote war based on data and technological development (Allenby 2015). But it's argued that if in the past technological innovation have impacted in circumscribed parts, nowadays we're living in a world completely shaped by humans, in which the innovation goes straight in all the directions. The impact concerns the whole innovation frontier, and the human being itself is considered part of this frontier (Allenby 2015). An interesting application retrieved by military sector which is finding space in civil world is the drone's swarm: it implies both the physical layout of drones and their ability to self organise and adapt to the surrounding

autonomously (Kumar et al 2021). Swarming for drones relies on the concept of Artificial Swarming Intelligence (ASI) that describes the collective behaviour of the self organised system.

Future outlook for wars concerns the inclusion of swarm attacks: their power can be challenged only by another swarm, implying the switch to a robotic battlefield dimension (Shaw 2017).

Agriculture

Drones are finding increasingly space in agriculture: they are considered part of the “Agriculture 4.0” (Tang and Veelenturf 2019) as a tool for making processes more effective and raising productivity level. The UAV collect data which are processed by AI in order to obtain aggregated and precise information for decision making.

They are ingrained on the IoT ecosystem (Cohen and Jones 2019): innovative solutions include the use of drones with sensors which allow the farmers to monitor crops looking for diseases, assessing yields and finding spots to be fertilised. Spectral technology makes possible to analyse the ground and plants condition, localising hot points where the water is needed with the aim to reduce water waste. Neural networks employed in Artificial Intelligence enable to solve non linear problems for estimating the crops yield. (Badin et al 2020).

Disaster management

2020 has been a record year for number of natural disaster⁸. In this context drones have found large employment due to the fact that they can offer a reliable and quick sudden

⁸ <https://www.rainews.it/dl/rainews/media/2020-un-anno-di-disastri-naturali-senza-precedenti-Il-racconto-per-immagini-517bdeef-3c72-4795-b083-321ebaba0c5b.html#foto-1>

intervention in sites which may endanger rescuers' lives. Artificial intelligence represents a further extension of this power because it allows the machine to adapt to the external environment and to be more effective analysing and processing data obtained with respect to the case of human processing (Gupta et al 2020). An use case example in this context refers to the case of forest fire which highlights the main benefits of drones' operations with respect to the past in which for the same purposes were employed satellites images, with much lower resolution, and helicopters, much more expensive (Gupta et al 2020). Technologies employed are dedicated to both monitor and predict events in a danger situation, warning people with the final result of saving human lives and reducing economic damages. Addin and Ozell (2021) propose drones' swarm as as support for firefighters in a critical situation: thanks to augmented reality the swarms are able to provide real time information to firefighters, who are able to better and quickly plan a successful operation. Results of the study show that technology improves the success of critical missions (Addin and Ozell 2021).

Construction

The ability of data collection and analysis finds large employment in construction sites inspections for real estate or insurance. Drones are able to scan buildings, providing reliable and precise visual models in a very quick way. They avoid time wasting inspections made by humans, and provide data from danger spots which would have required structure's climbing, endangering inspectors. The result of the construction sites analysis is referred as Building Information Modeling (BIM), which includes both physical and functional characteristics of the site. AI is able to provide autonomously a complete information on the building inspected, making human operations more efficient.

Transportation

Jeff Bezos, Amazon's ex CEO, introduced the idea of drone deliveries in 2003 'Self driving' drones are linked to the theme of air mobility, including both parcel deliveries and human freight: the biggest challenge is the provision of an effective 'sense and avoid' system for obstacles detection (Cohen and Jones 2020). On one hand freights may be distributed in crowded areas through the employment of light aircraft; on the other there are open discussions about people transportation in order to reduce city congestions.

Development in this area is still in an embryonic stage, with the presence of more simulations than real cases, mostly in the human freight. Many different challenges have to be faced in order to introduce 'self driving' UAVs: on the technological side the implementation of 'sense and avoid system', the need of cybersecurity against hackers' attacks and the theme on battery's autonomy; under the regulation point of view it is required a UTM (Unmanned Traffic Management) for air routes which both don't endanger people and don't annoy them (McKinsey 2019). From an ethical point of view some moral aspects are involved: Ronchi (2018) stresses the need of security standards combined with harmonised behaviours of the autonomous vehicles in order to make them ready to face risky scenarios (Ronchi 2018). During COVID-19 pandemic drones have been employed for transporting medicals, both directly to the patients' home and within the hospitals. Therefore the healthcare sector is touched by the influence of drones' employment.

Security and surveillance

Drones' Artificial Intelligence software features include human tracking and face recognition: AI model train the machine to identify people according to their facial traits. This ability is already largely exploited for security and surveillance purposes: drones are able to detect

irregular events and crimes, enabling the police to intervene more effectively and more quickly.

Other applications

Further applications are related to security and surveillance: police exploit AI features of human tracking and face recognition for inspections for more effectively operating in case of intervention against crimes; in the entertainment sector, with cases of aerial shows of drones' swarm and their employment in cinematography; for tourism and hospitality, in a period where social distancing has become so relevant drones are able to watch over tourist's points of interests and to recall for order through a megaphone (Chen et al 2020); for warehousing management: some companies use intelligent and autonomous UAVs for planning the warehouse and stock present materials; utility companies employ drones' and AI for quick inspections to electrical pipes.

The key word employed in the drones use cases' description is inspection: the UAV is a very powerful tool dedicated to this activity and the Artificial Intelligence extends this power improving efficiency and making data processing faster.

In the next chapters there is a deepening on the nature of data retrieved by drones according to the software present on the market.

1.3.5 Drones and AI state of art

The list above of drones' applications is addressed to provide an idea on the widespread usage that can be made by the technologies of interest. There are plenty of other possible employments which can be developed thanks to a progressive integration between technologies and companies' capabilities.

In order to provide a quantitative dimension of the phenomenon some data collected by DRONEII⁹ surveys to sectors' companies with the focus on data analytics are introduced and explained.

Starting from the sectors' ranking of drones' and AI software solutions for data analytics it is found that the energy sector is the one with higher employment, including most of the companies surveyed. At the second place there is the construction sector and another widely named solution is for mining sector.

As shown in *figure 8*, from the survey results that 37% of companies fully rely on Artificial Intelligence solutions while the left 63% of companies combine AI solutions with traditional method. An interesting 100% of the companies surveyed results somehow relying on AI, meaning that all the actors in drones' sector have already faced the integration process of the two technologies. Deepening the AI algorithms employed by the companies which solely rely on AI solutions it is found that half of them combine ML and DL software, 30% of them rely on ML and the left 20% on DL.

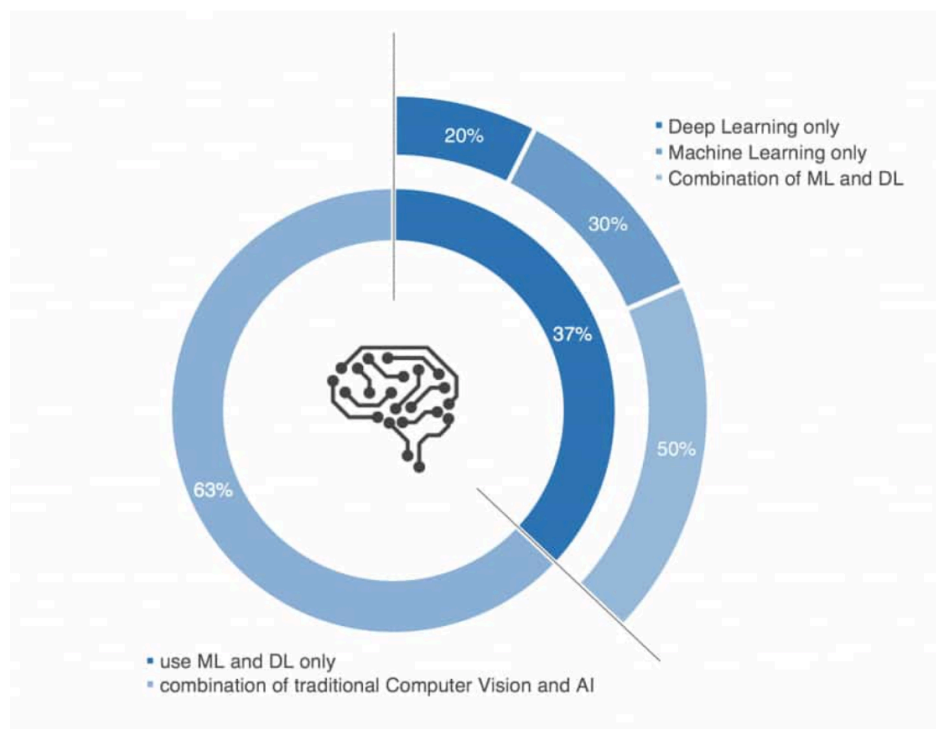


Figure 8 - Result of the survey on drones and AI (DRONEII 2019)

⁹ www.droneii.com

The survey analyzed in this paragraph is from 2019, the last events (COVID19) are supposed to have triggered the process: lower human presence due to the social distancing needs together with latest technology's developments represent an impulse for this business field.

1.4 Research questions

The previous paragraphs have introduced theoretical background on the study fields of 'search and recombination' and the focused technologies of drones and Artificial Intelligence both with the aim of presenting the state of art and to find gaps from which developing the research questions.

The first thread of study of this thesis is addressed to analyze the drones' market both on solution side, under software and payloads point of view and on demand side, offering a categorization for both sides.

RQ1: which is the state of art of the drone solutions' providers market?

As stated in the paragraph about gaps on search and recombination, the second research question is addressed to enrich the academic literature on the study field, providing the specific case of the integration between drones and AI technologies:

RQ2: which characteristics of the drones' companies are related to the inclusion of Artificial Intelligence within their business proposal?

CHAPTER 2: SOFTWARE AND PAYLOAD CATEGORIZATION

The following chapter is addressed to provide a categorization of the drones' market in order to provide a view with regard to Artificial Intelligence employment and answering to the first research question. For the categorization are considered insights retrieved by the literature review, in order to provide continuity in the study field. It is developed as follows:

- the first part is addressed to provide a classification of the software solutions retrieved on the drones' market, both national and international, in order to categorise software providers according to their impact on the drone environment;*
- the second part is addressed to provide a classification of the hardware solutions retrieved on the drones' market, both national and international, in order to design a full layout of the drone ecosystem.*

The final goal of the categorization proposal is to have a way for addressing the different solutions proposed from the market under offer and demand point of view.

2.1 Introduction and methodology

This chapter is aimed to deepen the analysis with respect to the main tasks related to the drone employment, in order to understand which are the parts that build up the drone system.

The purpose of this paragraph is to exploit the drone system starting from a mapping of the drone functioning which includes the main roles of the UAV, and thanks to a deep analysis of the market, to understand which are the enabling solutions for the tasks performed. Finally it is included the explanation of the main features retrieved from the market analysis.

The starting point is the definition of the main tasks related to the drone employment. Two main macro categories can be highlighted on this regard: on one hand it can be recognized the whole area of mission management with all the features connected, to which are related certain specific tools and systems that enables and optimises it; on the other there is the whole area of data management, starting from the data collection through specific tools attached to the flying platform to the data analytics performed with the help of algorithms.

After an introduction of the macro categories, every category is deepened and further analyzed highlighting the main features related to that specific area retrieved from the analysis of the market.

This analysis is performed starting from the Database provided by “Drone Observatory Politecnico di Milano” in which there is a scouting of the drone market. On this regard it is developed a specific categorization for both the software solutions and for the payload and sensors solutions.

For the categorization it is considered as a starting point the introduction made on the drones in the first chapter. To the concepts exploited it is here integrated a further proposal of

categorization of the drones' features, which can better fits the actual state of art of this market.

After having defined the drones' functioning, this chapters ends highlighting the state of art of the drones' applications retrieved from a market analysis. It is again referred to the DB provided by "Drone Observatory Politecnico di Milano", and the categorization proposed takes into account the main focuses developed among this thesis, which are the integrated uses of the UAV with Artificial Intelligence. Thanks to this analysis it can be enriched the introduction chapter on drones and Artificial Intelligence which theoretically exposes the employments of these technologies, with some practical examples, developing a clearer and more complete idea on the applicative state of art of the technologies.

The chapter develops as follows: firstly there is an introduction of the methodologies through which the categorizations are performed; finally there is a presentation of the results and further analysis of specific cases of interest.

2.1.1 The drone system

This paragraph represents the starting point for the categorization performed: every solution retrieved from the drone market, both hardware and software, can be considered as a part of an integrated system in which the components, acting in a combined way, enable to perform a large variety of different tasks.

On one hand there are the "operative" actions, which can be distinguished in the drone functioning during the mission, including control and navigation of the vehicle and the operative tasks; on the other there is the area of data management, which starts from the data collection for arriving to the data analytics, one of the main reasons for which the drones are considered a so powerful tools for many sectors.

This first distinction allows to include in the drone ecosystem the different hardware and software solutions proposed by the companies operating in the sector, categorising them according to their role in the “drone chain”.

The software solutions enable to understand the usage of data retrieved by the flying platform and how they can be employed by the different market segments, on the other hand the hardware solutions are defined by the data they enable to collect and the operative tasks they can perform in case not attached with processing sensors.

2.2 Software

First section to be analyzed includes the software, which represent the “hidden” systems fundamental for the drone’s functioning. They effectively represents all the software solution attached to the system, and are employed for different purposes.

The categorization starts from the analysis of the DB provided by Drone Observatory Politecnico di Milano on the Professional Drones market, 2020-2021 edition.

From the DB it is selected the section of software producers: these are the players in the market which include in their business proposition the provision of software solutions. These players can either solely provide software solutions in the case they are real software developers, or they can be recognized as operators, integrators or platform producers in case their core business is different but they still provide some software solutions.

The categorization on the nature of the companies of the DB is assumed to be the one provided by Politecnico di Milano, therefore it is used as strong assumption for starting the categorization of the solutions provided.

As software developers were included also distributors, which are the players in the market which offer solutions developed by external actors: for the purpose of the thesis it is chosen to exclude this category since it doesn't enrich the analysis on recombination of the technologies since they sell finished products.

According to the solutions analyzed, the categorization proposed is developed according to the software typology and their value proposition: in this section it is included the nature of the software provided through a categorization which is exploited aggregating and analysing the different solutions proposed by firms. It is useful for further analysis to understand the distribution of the software according to their nature. Moreover, for immediately selecting the most relevant cases of interest, it is added a section for distinguish solutions which imply the usage of Artificial Intelligence from the once which doesn't. It is made for deepening the analysis with respect to the cases of AI presence.

2.2.1 Categorization proposal

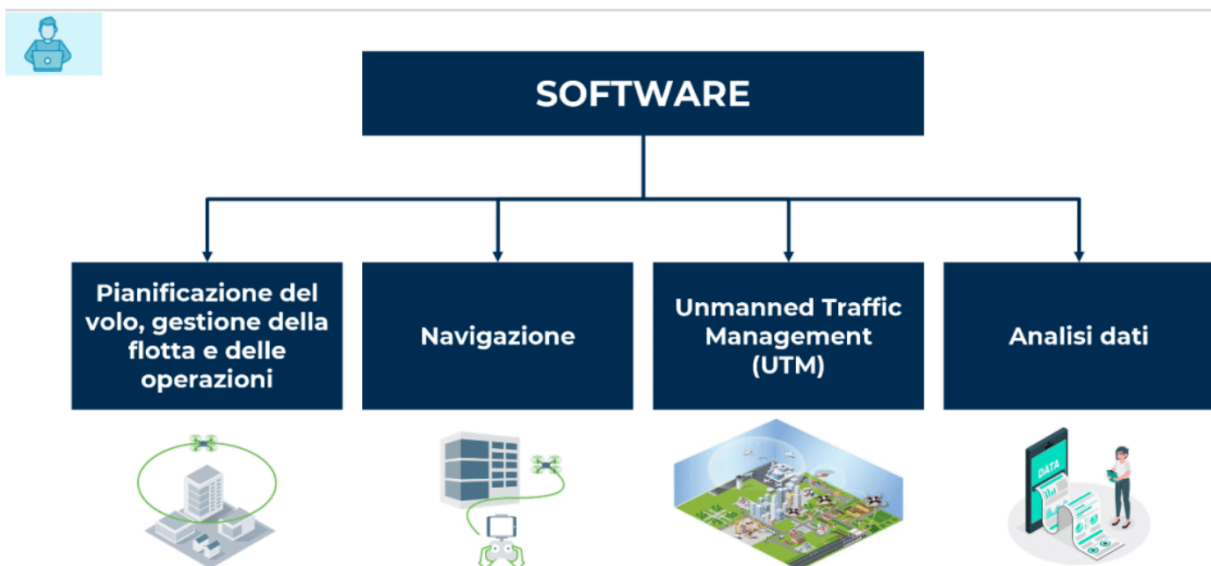


Figure 9 - software categorization

Software typology

Once analyzed the companies' websites and considering their propositions, 4 main categories are defined together with the Drone Observatory as represented in the figure, for aggregating the solutions found. In this section it is presented every category with the main features related, and the role for which Artificial Intelligence is integrated.

- **Data analysis:** the first big role of the software producers in the drones' industry is to provide solutions for processing data collected in order to build a digital model of the reality inspected. The data analysis category include all those solutions found which final goal is the creation of a model which replicates the reality with some specific features: the information are stored and provided to the final client through dashboards and other reporting layouts. It includes photogrammetry software, which provide reliable information on physical objects and environments thanks to imagery and thermographic software, which lets visualising temperature differences of the objects. The final model can be both visualised as 2D model or 3D model, with this second category more commonly provided thanks to the range of analysis which enables. In particular it is relevant to go more in deep in some specific and common features offered by digital model software providers, which characterise the photogrammetric process:
 - **Ortophotomosaic:** the images collected by drones are commonly geometrically corrected such that every object in the photo results uniform in scale. Despite in reality it can be seen a projection of the object, thanks to ortophoto it appears a map. In such a photo there can be measured distances. Ortophotomosaic is a merging of many ortophotos.
 - **Point cloud:** the concept of point cloud is expressed as the registration of a data set in space, with each point position being provided by Cartesian coordinates. It consists in defining the data collected with coordinates that can be processed and arranged together.

- 3D Mesh: it consists in building a 3D model transforming the reality in geometric shapes, for simplifying the replication for the machine. It implies information on the coordinates of the points in the space such as their height, width and depth.
- Level curves: useful for visualising peaks and valleys in a map, it consists in an equation of the nature $f(x,y) = k$, with k as constant, which tells all the points in the domain f at which they take the value of k .
- GIS: known as Geographic Information System, it provides the geographic information about the visual data retrieved. This typology of systems relates the positioning of the objects with their shape.
- DSM: it stands for Digital Surface Model and it includes the representation of both environment and artificial features.

According to the goal of the data collection the features can be employed all together or just some of them. At the end the result is a digital model available for further analysis, which can be both performed by the machine itself, with the help of Artificial Intelligence, or by humans.

The role of Artificial Intelligence is in this case to speed up the processes of model creation and to perform decision making according to requirements.

- **Mission planning, flight and operations management:** software employed from the preparation process until during the specific missions. This category includes a different range of solutions, among which request elaborations, flight approval on the flight area, fleet preparation, management and control. A relevant task is addressed to the communication role of this software, crucial in the drone functioning. Two different types of communication can be distinguished: the first one is the on board communication. In

fact the flying platform is attached with a complex system of sensors and software which need to communicate among them to perform tasks. Communication software serve as the enabling algorithms which makes possible to perform it in the most efficient way. The second type of communication is the one occurring between the flying system with the central system, which can be a ground station, corporate systems or smartphone applications. It is essential in particular for the data collection: the drone collect data and share them with the decision making base. Once data are processed, the machine needs to be instructed for going on with the mission, and once again communication software are the enabling solution. They integrate the different areas of the drone ecosystem: the enabling solutions for end to end processes, starting from the navigation of the UAV, passing to data collection and arriving to data processing and decision making for some specific tasks which can be operated directly from the vehicle in some cases. Their characteristics include the presence of a central system, which can be a ground station or a corporate application; platforms which allow to establish a system of plug ins for all the different needs that the machine needs to satisfy; flexible algorithms which are part of the DSS (Decision Support System): the presence of Artificial Intelligence enables here the machine to act autonomously and the eventual integration of Artificial Neural Networks to improve the whole process through the learning by experience.

- **Navigation:** the last category of solutions found groups the solutions with a specific focus on the drone piloting, as such as conducting specific manoeuvres in airspace, trajectories, orientation and communication systems, obstacle detection and overcoming systems, situational awareness and autonomous decision making, self-piloting systems for conducting operations in autonomous flight.. These software are addressed to control the machine and the payloads attached, with some specific features such as detection and

collision avoidance or path planning, technique explained in the introduction chapter. The machine can be integrated by a mission computer which automatically manages all the remote sensing activities. Some solutions belonging to this category include the presence of Artificial Intelligence, which in this case allows the machine to operate autonomously.

- **UTM:** Software that deal with the integration of UAS systems in the airspace and all the activities of supervision and safety of the latter. This includes automatic identification, approval and access systems in the airspace (e.g. LAANC - Low Altitude Authorization and Notification Capability), as well as a whole series of systems that offer services such as the creation and sharing of overflight maps. These are solutions which ensure a safe environment in which performing the mission due to the fact that these operations may affect people and buildings on the ground, therefore safety solutions need to be in scope.

2.3 Payload

Categorization of payload solutions is performed joining the same steps of the software categorization: starting from the DB provided by Drone Observatory, only companies which include in their business proposal “payload production” are selected. All the retrieved companies which offer external solutions are considered out of scope. Among them it is performed a scouting in their websites for disclosing the solutions proposed and then it is exploited a categorization based on two levels: first one is related to the payload themselves, categorising of the physical tool attached to the flying platform; the second one is related to the business field in which the payload is employed. As well as in the case of software categorization the business field is attached to the payload solutions in order to understand the state of art of the market with respect to the specific solutions proposed to the single

sectors. The categorization starts again with a distinction between mono-sectorial solutions and multi-sectorial. The fields considered are the same as in the software categorization, therefore they are not listed again during this one.

2.3.1 Categorization proposal

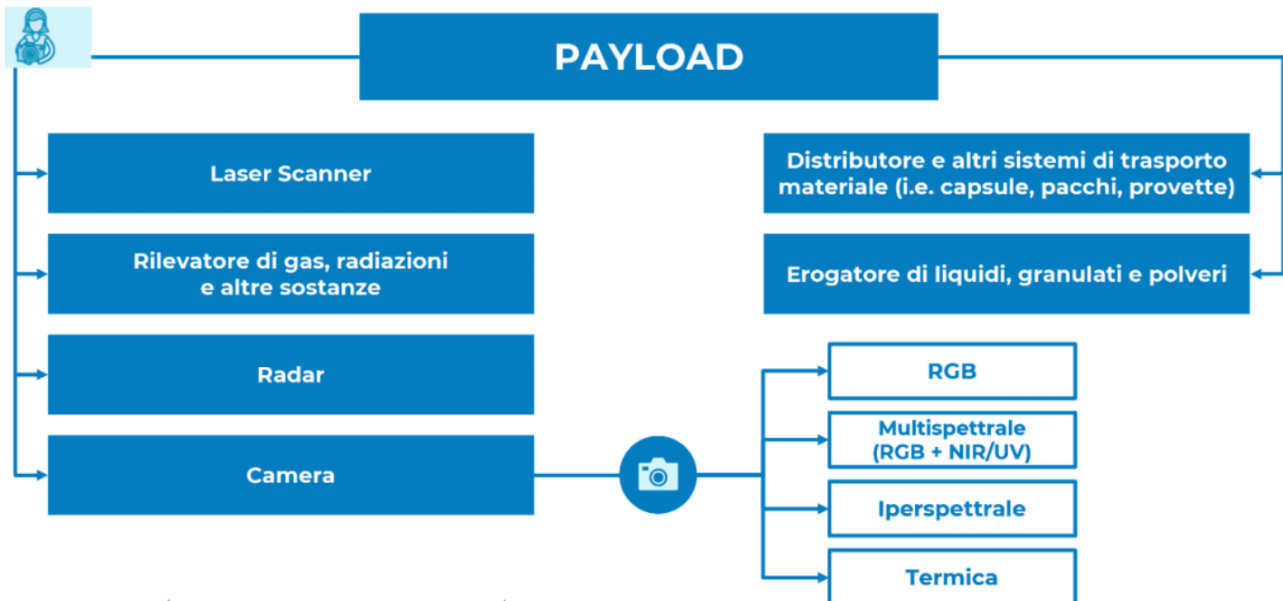


Figure 10 - payload categorization

Once analyzed the companies' websites and considering their payload propositions, together with the Drone Observatory Politecnico it is defined a categorization addressed to include, as represented in the figure.

Payload categorization regards the physical object differentiation of the tools attached to the drone. It includes 2 different macro categories of payload: the first one includes the payload with attached specific sensors which enable to retrieve data, among which cameras, laser scanners, radars and gas, radiation and other substances detector; the second includes operative tool which are addressed to operative purposes, among them are found cargo distributors and dispensers. This provides a differentiation of the solutions retrieved according to their physical nature and a distinction to the role they have in the drone environment. The payloads are the instruments which enable the machine to perform data

collection and analysis previously stated, therefore it is important to understand which role every tool cover in the system, for this reason it is included also an analysis of the sensors which enable them to process specific kinds of data.

Sensor based payload

- **Laser scanner:** high definition system which finds and is employed for a large number of different purposes thanks to its high definition scanning ability. Thanks to magnetic impulse on a surface and the reply coming back from it, it digitally acquires a massive quantity of data, recognized as the point cloud described above. LiDAR technology is a widespread laser scanning activity performed by drones: standing for Light Detection and Ranging, it is a remote sensing method used for Earth surface examinations. It is used the light in form of a pulsed laser for measuring distances. It helps both natural and artificial inspections for mapping and studying points of interest.
- **Gas, radiation and other substances detector:** category which includes either tools employed for detecting gas emission in the atmosphere for analysing the quality air, radiation measurement or other substances. The air platform is attached to a sensor which is used as the reference point for information retrieval. It produces as a reaction an electric current when it comes in contact with a defined gas which provides a trigger. The main goal of the sensor is monitoring the air quality and providing an alert in case of danger.
- **Radar:** category which includes all the tools attached with sensors able to emit radar impulse, as for example the Georadar (GPR), which processes impulse detection for building up an underground image. GPR can be employed for many applications, such for example the rock, land, ice, water, sidewalks and generic buildings analysis. Changes in

the analyzed objects can be detected and for example it can be assessed whether it is required a repair intervention.

- **Cameras:** they represent the main category of the payloads present in the drone environment. Addressed to the most widespread role for which drones are recognized and employed, the collection of visual aerial data, cameras represent the “eyes in the sky” of the operators and of the machine once it is autonomous and they enable to perform almost every task for which drones are employed. In this category are included all the attached tools which enable to inspect the environment, which are enabled thanks to specific sensors to represent reality under different points of view. The categories of cameras are identified according to the typology of data collected for the system:

- **RGB (Red, Green and Blue):** RGB is used for decomposing the images in the three basic colours which recombined between themselves are able to provide almost all the colours available for the human eye. The camera process the pixels of the picture taken assigning a combination of the three main colours. It is the basic functioning of the digital cameras, which are able to represent the visible camera. Images processed are recognized also as spectral. RGB cameras include CMOS or CCD image sensor. It includes both photo cameras and video cameras.

- **Thermal camera:** it is the tool employed for transforming the thermal energy of bodies into light in order to retrieve information useful for analysis of an object or an area. They enable to perform a deeper analysis of the areas and to detect specific points of interest: if through photocamera just the visible light is provided, with thermocamera the electromagnetic spectrum is enlarged, arriving to Infrared

dimension. Thermal scanner: it represents a device able to read an objects' temperature, therefore it provides a temperature data to the central system. Commonly they operate in the infrared (IR) dimension: in surveying is widespread employed the infrared technology, through the help of thermal camera. This technology enables to obtain thermal information on the objects of interest detecting infrared waves, showing an extension with respect to the electromagnetic spectrum of visible light which is available to the human eye.

- **Multispectral camera:** the cameras can be attached with a specific sensors which enables to represent surrounding things beyond the visible light. It is able to acquire energy from every kind of surface. As for infrared case they are based on the detection of waves, the multispectral technique attached to multispectral camera enables it to capture data within a given wavelength range, including frequencies beyond the visible range: multispectral cameras acquire pictures which a number of electromagnetic bands between 3 and 10. Beyond the most common acquisition of 3 bands of RGB cameras, these cameras can add the near infrared band (NIR), ultraviolet (UV) and the complete band of the visible as monochromatic image.
- **Hyperspectral camera:** joining the same approach of multispectral camera, in this case the cameras are attached with sensors which again enable the human eyes vision extension beyond the visible light. Hyperspectral cameras are able to detect for example the differences between different objects due to the fact that depending on their chemical composition they differently absorb the light. This technology is not constrained by the wave length interval, therefore it might be detected different

radiations from different internal sensors. A very high amount of information can be retrieved thanks to the continuous detection from the visible light spectre.

Sensors

Sensors include the tools attached to the flying platform able to collect data and transform them in information of a different nature. The sensors can be categorized according to the nature of the data they are able to collect and to the final information which they provide to the companies. Different sensors are found in the business proposition of the companies present in the DB.

- FC (Flight controller): is made up by a system of sensors able to receive indications from the pilot. Therefore it is fundamental for the drone functioning. There are many processors attached to the FC, such as accelerometer, responsible for horizontal piloting or GPS and barometer, geographic and height data providers. Moreover it integrates the connection between the battery and the drone functioning and also the video output.
- ESC (Electronic Speed Controller): are devices attached to the drones which are linked with the flight controllers and communicate with them. They are able to read signals which make them raise or lower the motor voltage, modifying the speed of the vehicle
- SAA (sense and avoid) or DAA (detect and avoid): they are systems which enable the machine to perform the mission detecting and avoiding eventual obstacles. These systems include the presence of a large number of sensors and the algorithms which stand behind them, which enable the information flow. Artificial Intelligence is of large help on this regard, because allows the drone to correct drone's path adapting it to the external environment in the best way possible.

- Flight terminator: it is a solution which enable the drone to terminate the flight in case of extreme condition or in case it is sensed a cyber-attack.

This list of sensors are employed for the control of the flying platform, another list of sensor can be defined according to the nature of data which the drones are able to provide, such as:

- Visual: visual data define the visual dimension of the reality inspected, they are exploited through the usage of visual payloads and sensors, and the result obtained is a representation of the reality. 3D modelling for example is part of this category, providing a graphical representation of data and information.
- Distance: close to the visual representation some software provide information regarding the distances between the different objects detected or information with regard to the depth of a water basin or the height of a mountain.
- Thermal: thermal data are the second relevant data retrieved and provided by drones. There are plenty of different payloads which are addressed to perform this survey, with LiDAR technology obtained by laser scanner usage as one of the most widespread. The thermal data is addressed to provide the differences between the objects detected and it is very relevant in case of rescuing or surveillance, when it is needed to find human presence in an environment or for retrieve data concerning some specific materials.
- Geographic: drones are able to provide through a combined system of payload (mainly antennas) and software, the geographical information about the mission, which can be included and integrated with other types of information collected and processed.
- Chemical: these data are detected thanks to specific sensors aimed to analyse the composition of environment under a chemical point of view. It's for example the case of drones which inspect some sites that might be dangerous for humans due to radiation.

For every typology of data processed and collected by the payload there is a sensor enabling the system to do it.

Other payload

This macro category of payload include all those solutions retrieved from the drone environment that enable the flying platform to perform actions not based on data management. Among them two sub categories are identified and employed for analysing the market:

- **Distributor and other cargo systems:** this category of payload is related to the logistics role for which the drone is step by step becoming more employed for different purposes. All those solutions which are addressed to the transportation of material, such as packages, capsules or test tubes.
- **Dispenser (of liquids, dust or other substances):** in this case are categorized all of those solutions employed mainly in the agricultural world for the spreading purpose of different substances useful for feeding or protecting the crops.
- **Other tools:** the last category aggregates some tools which are dedicated to more operative roles and not included in the previous categories, focusing on the mission management:
 - Beacon: drones are provided by beacons useful for locating the drone in a dark environment and for lighting it in case of an inspection
 - Megaphone: some drones are provided by megaphones in case they are employed for transmitting useful vocal warnings to the people on the ground, for example in a danger situation

- Gimbal: it is a pivoting system that enables the rotation of an object around an axis. It provides the stabilisation to the cameras attached to the drone, which are free to rotate to perform video footage.

CHAPTER 3: SOFTWARE AND PAYLOAD - MARKET ANALYSIS

The following chapter is addressed to analyze the drone market employing the categorization previously proposed. This is aimed to answer to the first research question which is addressed to understand the current state of art of drone and AI combined employment.

It is developed as follows:

- the first part is addressed to deepen the analysis on the offer side both of the national and international market about the software and payload solutions;*
- the second part is addressed to analyze the use applications of these technologies through the categorization of journal articles both of the national and international market, providing a view retrieved from the categorization proposed in the previous chapter.*

The final goal of the categorization proposal is therefore to have a clear state of art of technologies integration and to highlight some specific and interesting use cases to be deepened in order to approach also the second research question.

3.1 Introduction and methodology

Together with the Drone Observatory Politecnico di Milano it is performed a developing work on two databases, one related to the offer side related to the national market and one the demand side. Regarding the international market for the offer it is performed a scouting starting from the documentation provided by DRONEII in 2021 survey.

The offer side database is built up considering all the companies currently operating in the drone market, which are categorized according to their role: there are companies which act as distributor, operator, integrator, payload producer, platform producer and software producer (categorization retrieved from previous Observatory studies). The focus of this thesis and in particular of this chapter for answering the research question is on the payload and software producers.

Therefore the database is filtered considering just two categories proposals, from which it is retrieved the list of companies which business proposal include the provision of software solutions for drones and related payload dimension.

The demand side database is instead a list of use cases retrieved from newspaper, websites and other relevant sources, which is continuously renewed with the latest information. Close to the articles list there is the Observatory's categorization which deepens the analysis adding relevant dimensions for managerial approach to the market, including both technical aspects but also strategical.

On this regard it is added the payload categorization according to the new proposal previously exposed, and concerning the software view the focus is put on the use cases including the employment of Artificial Intelligence.

The chapter is developed starting from the offer side analysis, for both national and international market, for then passing to the demand side. A presentation of the quantitative

results is presented, and among them some cases of interest are chosen for further analysis with respect to the drone and Artificial Intelligence integration.

3.2 Offer side: Italian market

Offer side accounts all the solutions present in the Italian market retrieved from the Observatory database. First of all it is here explained the dimensions of the analysis considered for the software producer companies and for the payload producer companies, and then relating to the categorization proposed there is the exposition of the quantitative results in term of solution proposal in the market.

3.2.1 Software proposal

For the software proposal three dimensions of analysis are considered:

- **Software typology:** in this section it is included the nature of the software provided through a categorization which is exploited aggregating and analysing the different solutions proposed by firms. It is useful for further analysis to understand the distribution of the software according to their nature. Moreover, for immediately selecting the most relevant cases of interest, it is added a section for distinguish solutions which imply the usage of Artificial Intelligence from the once which doesn't. It is made for deepening the analysis with respect to the cases of AI presence.
- **Timing:** This category is specifically developed by the results obtained by data analysis, and distinguish software in two parts: the ones which are collected and the results of the process are suddenly employed for a real time intervention or operation, and the ones that are stored and are lately employed. This categorization is based on when the data

processed are employed, therefore also some software which could be able to provide real time results, in case they are used for successive analysis are categorized as “ex post:

- **Real time:** the real time data are those which are instantaneously processed for providing an output which can be used for sudden intervention. They are largely employed for example in rescuing: thanks to the drone in fact the rescue team is able to intervene with specific instructions provided by the inspections’ results. Some software solutions are provided by such a strong Computational Intelligence that are able to process data in a few seconds and provide a quick and reliable results. Artificial Intelligence combined with a strong processing capability replaces the need of human analysis of the data.
- **Ex post:** these kind of data collected are stored, processed and then employed for later usage or evaluations. The processing of data requires high computational ability, therefore some data could be too heavy to be processed on board: in this case they are stored and the processing happens at the central system level during or after the mission.
- **Business field:** The section *business field* is addressed to achieve two different results: for every software analyzed it is assigned the business field in which it is employed and if it is specifically addressed to that business field or it is a generic solution. In doing so it is obtained a distinction between software which are developed for a single sector, such as for example agriculture solutions or security solutions, which are very specific but not extendable to the whole environment, and software which leave space for integration depending on the sector they are employed. The business fields attributed to the solutions are retrieved directly from companies’ websites: whenever it is clearly stated which are the fields covered by solutions, they are attached, otherwise the software is categorized as generic solution. For defining the business fields it is relied on both the literature review chapter, when applications fields are defined, and eventual additions from the websites. Main sectors are retrieved from the literature review analysis, but integrated eventually

with further ones. Solutions considered are employed in the following sectors: agriculture, transportation, public administration, military and defense, utility, construction, disaster management and entertainment. Generic solutions are extendable to further sectors such as insurance and industrial segments.

02701150902	3D AEROSPAZIO S.R.L.S.	02446300390	ITALDRON S.R.L.
04045030238	3DFLOW S.R.L.	02407120993	JP DRONI S.R.L
02465610901	ABINSULA S.R.L.	01623490511	MENCI SOFTWARE S.R.L.
02375580749	AERIALCLICK (MASSARI)	03023630126	MSHELI S.R.L.
03630610131	AERMATICA3D S.R.L.	10401481006	NEAT S.R.L.
02665480345	AERODRON S.R.L.	09434470010	NIMBUS - SOCIETA' A RESPONSABILITA' LIMITATA
14149011000	AIR DRONE SERVICE	03678610365	RGESSE.IT S.R.L.
11922751000	AIVIEWGROUP S.R.L.	01453910745	SOCIETA' DI TOPOGRAFIA S.R.L.
05204171002	CODIN - SOCIETA' PER AZIONI	02644060218	SOLEON SRL
03874700168	DEV SOFTWARE S.R.L.	04812701003	TELESPAZIO S.P.A.
09535510011	DIGISKY S.R.L.	07719191004	TOPNETWORK S.P.A.
01395740457	DRONE ONE APS	02639070412	TTP-TECHNOLOGY S.R.L. SEMPLIFICATA
03366240798	DRON-E SOCIETA' A RESPONSABILITA' LIMITATA SEMPLIFICATA	04424091009	VITROCISSET - SOCIETA' PER AZIONI
02968140737	DRONEDESIGN S.R.L.	02396340990	WE SHI S.R.L.
05659960727	DYRECTA LAB SOCIETA' A RESPONSABILITA' LIMITATA	04234820407	@DRONES S.R.L.S.
03489760540	EAGLEPROJECTS SRL	11208950961	ANT-X
11020351000	EDEALAB S.R.L.	09729170960	DRB SRL
13146011005	ELITE CONSULTING S.R.L.	03874700168	DRONEXTREME
05374591005	EUROLINK SYSTEMS S.R.L.	01424300893	INTELLISYSTEM TECHNOLOGIES S.R.L.
01368800494	FLYBY S.R.L.	01998770992	LIDAR ITALIA
02611220647	GEC SOFTWARE S.R.L.	02500100991	LUMINOUSBEES
04475230878	GLOBSIT S.R.L.	01941520890	MCX SOLUTIONS S.R.L.S.
14765811006	H4RESEARCH S.R.L.	01913520894	RES INTEGRA S.R.L.
00672210507	I.D.S. - INGEGNERIA DEI SISTEMI - S.P.A.	09042941006	SENTECH S.R.L.
07085050727	ICT CUBE S.R.L.	11146450967	X - ENDER S.R.L.

Figure 11 - observatory database

Crossing the information retrieved from the categorization it can be assessed a first analysis on the state of art and the possibilities of development that the drone employment has in the different business segments according to the goal that is aimed to reach.

The database presenting the offer of software is referred to the companies' scouting for the period of time between 2019 and 2021.

As shown in the figure, there is a detail the company with some registry information such as the website or VAT number.

Filtering the database for considering just the software producers the companies in the figure are retrieved and considered for the categorization in scope.

Starting from the initial list a sample of 55 companies is resulted and for each of them it is performed an analysis of the business proposal from the attached website in the area of software provided presentation.

Deepening the initial categorization among them 20 companies have been previously categorized as “SOFTWARE PRODUCER”, meaning that the software development and offer is their core business. Beyond software producers, software provision is included in the business offer also of 3 “DISTRIBUTORS”, 5 “INTEGRATORS”, 14 “OPERATORS” and 7 “PLATFORM PRODUCERS”.

A first exclusion is performed on “DISTRIBUTORS”, due to the fact that despite in their business is present the offer of software, they simply offer software developed by third parties. Among the others, other 11 companies are excluded due to both the lack of information of their websites with respect to the software proposal. The lack of information is either related to the closure of the website, due to company’s default or acquisition by other entities, or to poor details retrieved from its technology section.

The analysis is therefore performed basing on 36 companies, for which according to the categorization proposed are highlighted some points of interest which embrace the purpose of this thesis.

The first step is to categorise the software solution found in the website among the four categories proposed: software dedicated to data analysis, navigation, UTM or mission planning, flight and operation management. Some software are recognized to be ascribable to more than one category: in those cases a “core category” is selected considering in which of the sections the solution is more adapt.

Considering the core categories the Italian market presents the following situation: 18 players offer software addressed to data analytics purpose. Among them it is widespread the creation of a digital model of the reality captured, therefore they can be commonly applied to inspection purpose for example, or for studying the ground situation. 4 of these players present also a solution which goes beyond the data analytics purpose: in some cases the data are suddenly employed for an operative goal, therefore a second category is included.

Focus of the analysis is put on the solutions which integrate the Artificial Intelligence in the data analysis area: 6 players offer an integration of the Artificial Intelligence within their software proposal.

Concerning the timing of the data usage just 4 players provide solutions which elaborate data for sudden purpose, the other 14 are still addressed to provide quick processing but the report issued is employed for further human elaboration before arriving to a final decision making. 3 on 4 “real time” software are indeed categorized also as “Mission planning software”, because in this case the software is aimed to perform a real time evaluation based on the data collected and suddenly transferred the result to a decision maker which use it for making decisions with respect to an on going mission.

Concerning the business field of the solutions, 16 on 18 propose a very flexible solutions that is employed in more than one sector, therefore categorized as “Multisectorial”. Starting from the 2 highly customised for specific business field it is found a solution addressed to agriculture, one of the most widespread usage of the drone solutions, and one related to the utilities inspection, other very common solution. The “Multisectorial” solutions are categorized basing on the purposes which are exposed in the website, in which are explained the goals for each field and the usage that the software can be employed for in that specific field. Agriculture and utility are the sectors in which there is higher offer level of software for data analysis, respectively with 13 players offering agricultural solutions and 13 players offering solutions addressed to inspect utilities. This result is in line with the technology state of art, in which the drone employment is considered in development with respect these two business sectors, in particular the agricultural one. The second most common “core category” software found within the Italian offer side is related to “Mission planning, fleet and operations management”: 12 companies offer software dedicated to the activities which occur during an operation. The drones, as stated before, can be considered as the human

"eyes in the sky", so they are likely to be attached with smart solutions which enable the human to interact with them and to make them as independent and smooth as possible during the operations. On this regard all those software in which the solution proposal implies a decision making activity (e.g. when it is described their DSS role or when the it is introduced the autonomy goal of the drone mission planning) are included in this categorization. The category "Mission planning" can be considered the most integrating one because during a mission many aspects are related: from the data analytics to the drone navigation. As a matter of fact the solutions to which is attributed "Mission Planning" as the core category have almost all a second or third software purpose attached, due to the fluidity of this label. Among them 7 solutions have data analysis attached as further purpose, 3 navigation and 4 Unmanned Traffic Management. As can be noticed by the results obtained this software category cross all the goals of software proposed by players within this market.

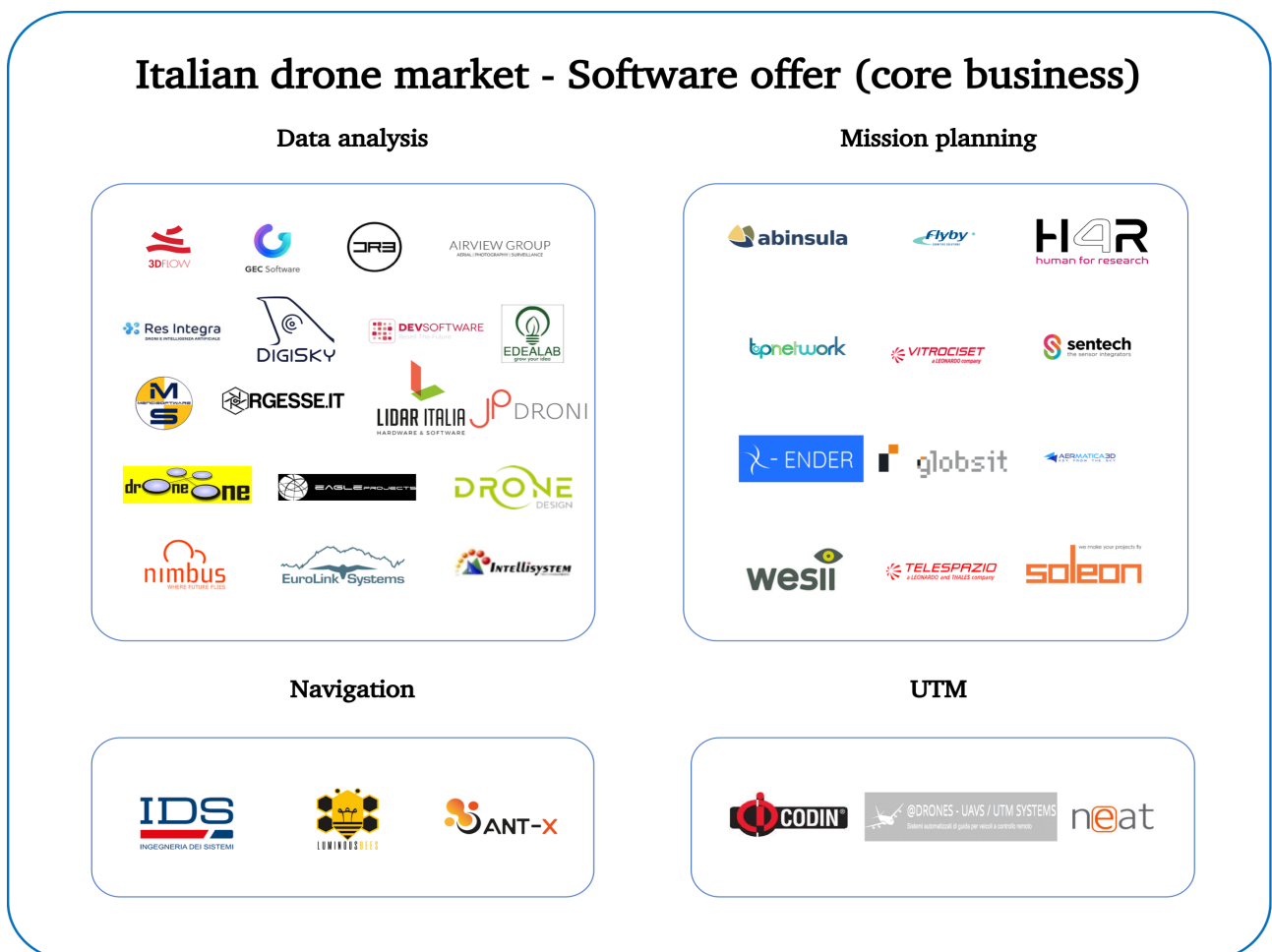


Figure 12 - Italian drone market - Software offer

Comparing with the data analysis category, in this case there is higher involvement of Artificial Intelligence software within the business proposal: 9 companies present an integration of the AI within their software, and just 3 act in more traditional way.

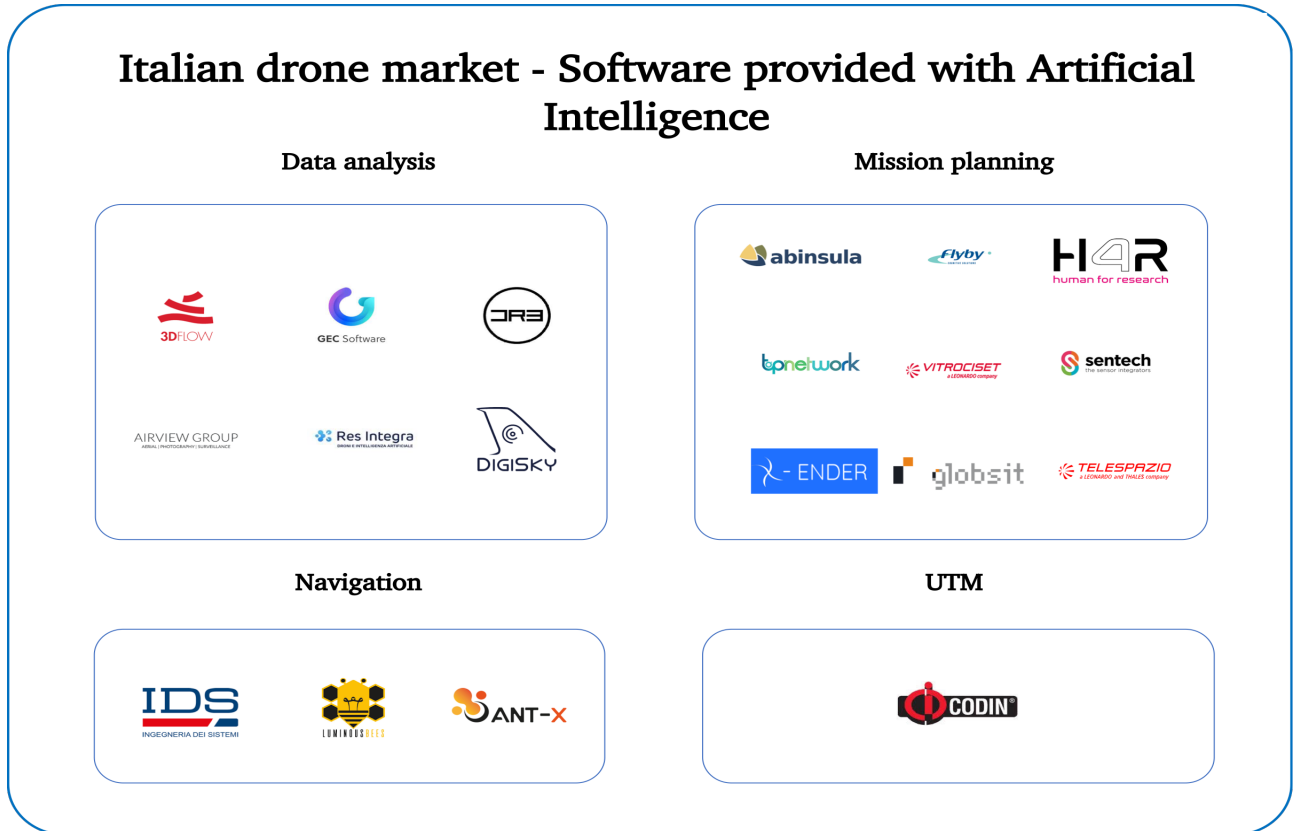


Figure 13 - Italian drone market - Software provided with Artificial Intelligence

For including some specific examples Artificial Intelligence is in the operative tasks used by the drone for improving by experience in order to act more effectively and independently from humans with respect to the past. They are employed in iterative actions such as an inspection of a plant, and they can step by step learning from the experience providing their own feedback on the status thanks to algorithms of Artificial Intelligence. In other cases the computer vision is employed in search and rescue activities. In general when there is a specific purpose of the utilisation of the drone and a direct involvement of its activities within a mission the solution is categorized in this section.

Not for all solutions in this case is relevant the timing of the software result, for example in case of UTM in which the action should be extended during the time. For the cases in which there is involvement of data analysis or navigation, 5 solutions offer are categorized as real time and 2 ex post. The ex post solutions are related to mission performed for specific purposes in order to collect data for future decision making, while in the real time solutions the mission performed and the data processing and decision making go real time alongside. Regarding the business segments in scope of this category's solutions 3 of them are specifically addressed to a single sector: as in the case of data analysis 1 company is targeted to agricultural purpose and one to utility. In this case there is a company which is in scope for a targeted solution to military and defense segment.

For what concerns the distribution of the business employment of the solutions once again the most impacted sector is the agriculture, with 9 companies offering solutions dedicated. It is joined by utility, military and defense and disaster management sectors. It is interesting the involvement of disaster management, sector which is largely and increasingly impacted by the involvement of drone technologies due to the fact they provide the possibility of operating without further endanger humans. In this case the drones are allowed both to operate autonomously, acting for example as cargo of helpful tools, or just inspect the affected zone for providing help to the rescue team with punctual and precise information.

Stepping into the "Navigation" category, 3 companies offer software which core business is dedicated to the control and navigation of the flying platform and the payload attached. These solutions are addressed to running on board the drone, thanks to involvement of ground controls and communication hardware attached to the flying platform.

One of the company categorized here offer a dedicated ground control platform which directly control the platform: the first focus is on the navigation of the drone, but are involved also the mission planning purpose due to the operative inputs which the ground control is

able to transfer and the control of the surrounding space for assuring its safety, prerogative of Unmanned Traffic Management software.

All of the 3 companies offer solutions including the impact of Artificial Intelligence: one of the purpose of operating with a system as the drone one is, is to make it as autonomous and capable of performing decision making as possible. Therefore high impact on the navigation was foreseen, thanks to the involvement for example of Detect and Avoid systems or smart algorithms which calculate the path planning of the drones. Another crucial aspect is the positioning of the UAV and one of the companies offer solutions for the indoor positioning of swarms of drones, topic already exposed also in the first chapter of this thesis.

With respect to the "Navigation" category there is no analysis on the business field because it is exploited the assumption that the drone navigation can be for definition considered cross all the sectors in which the drones can be employed.

Coming to the last category in scope, "UTM" which includes the solutions addressed to the creation and control of a safe aerial space in which the operations can be performed with control, 3 companies are categorized in this section.

The offer includes multi processing real time systems addressed to flight data management in air traffic control area and systems addressed to keep the security in the surrounding area. Another point of focus of these kind of software is the provision of a flight area of the systems with respect to the other flying objects in order to maintain under control the flight zone. The security dimension of these software is important also in the mission planning area, in fact two companies are assigned also to this second category. As well as in the case of navigation software the business dimension is not considered for this kind of software due to the fact that the safe need of the airspace can be extended to the many different purpose the drone employment is called to achieve.

Aggregating and finalising the result obtained by this categorization it is found that 25 companies offer solutions to the drone environment concerning the data analysis, 19 for the mission management, 6 for the navigation and 8 for controlling the unmanned traffic.

Overall 19 companies include Artificial Intelligence techniques in their business.

3.2.2 Payload proposal

For the payload classification two dimensions of analysis are considered:

- **Payload typology:** as well as for the software classification this section provides information with respect to the nature of the payload offered in the business of the single companies. At the end of the analysis of the companies' proposal it is built up a list of all the payloads which can be retrieved in the Italian market. This list is already posted in the previous chapter, and that is the reference point for this evaluation.
- **Business field:** following the same logic as software categorization case, the section *business field* is addressed to achieve two different results: for every payload analyzed it is assigned the business field in which it is employed and if it is specifically addressed to that business field or it is a generic solution. In doing so it is obtained a distinction between payloads which are developed for a single sector, such as for example agriculture solutions or security solutions, which are very specific but not extendable to the whole environment, and payloads which leave space for integration depending on the sector they are employed in. The business fields attributed to the solutions are retrieved directly from companies' websites: whenever it is clearly stated which are the fields covered by solutions, they are attached, otherwise the tool is categorized as generic solution. For defining the business fields it is relied on both the literature review chapter, when

applications fields are defined, and eventual additions from the websites. Main sectors are retrieved from the literature review analysis, but integrated eventually with further ones. Solutions considered are employed in the following sectors: agriculture, transportation, public administration, military and defense, utility, construction, disaster management and entertainment. Generic solutions are extendable to further sectors such as insurance and industrial segments.

The database presenting the offer of software is referred to the companies' scouting for the period of time between 2019 and 2021.

02375580749	AERIALCLICK (MASSARI)
03630610131	AERMATICA3D S.R.L.
14149011000	AIR DRONE SERVICE
09535510011	DIGISKY S.R.L.
04456990409	DRONEBASE S.R.L.
02968140737	DRONEDESIGN S.R.L.
03489760540	EAGLEPROJECTS SRL
13146011005	ELITE CONSULTING S.R.L.
06744450484	LITE SYSTEMS ENGINEERING - SOCIETA' A RESPONSABILITA' LIMITATA
05374591005	EUROLINK SYSTEMS S.R.L.
04475230878	GLOBSIT S.R.L.
03514100365	SAL ENGINEERING S.R.L.
09990270010	SALT & LEMON SRL
02644060218	SOLEON SRL
00865310247	STS ITALIA S.R.L.
05625111215	DESA S.R.L.
09729170960	DRB SRL
01512490911	DRONELAB SRLS
02422080719	DRONES BENCH
01424300893	INTELLISYSTEM TECHNOLOGIES S.R.L.
01941520890	MCX SOLUTIONS S.R.L.S.
09042941006	SENTECH S.R.L.
02165150224	UP CAELI VIA
11146450967	X - ENDER S.R.L.

Figure 14 - Observatory database

Filtering the database for considering just the payload producers the companies in the figure are retrieved and considered for the categorization in scope.

Starting from the initial list of companies mapped by the drone Observatory for the year 2019-2020, and to which is afterwards integrated the updated version, a sample of 22 companies triggers the mapping of the payload offer within the Italian market. These companies are considered for the assessment of Italian offer, analyzed through a surfing of the companies' websites. Deepening the initial categorization among them just 3 companies have been previously categorized as "PAYLOAD PRODUCERS", meaning that the payload development and offer is their core business. Beyond payload producers, tools provision is included in the business offer also of 3 "DISTRIBUTORS", 4 "INTEGRATORS", 4 "OPERATORS", 6 "PLATFORM PRODUCERS" and 1 "SOFTWARE PRODUCER".

Once again as in the case of software categorization, exclusion is performed on "DISTRIBUTORS", due to the fact that despite in their business is present the offer of payload, they simply offer third parties products. Among the others, other 9 companies are excluded due either to the lack of information of their websites with respect to the payload proposal or to recognition of absence of in house developed tools. In fact in some cases the companies simply offer externally produced products and according to the categorization performed resellers are not in scope.

The analysis is therefore performed basing on 10 companies, for which according to the categorization proposed are highlighted some points of interest which embrace the purpose of this thesis. These 10 companies are considered to be a reliable source for what concerns the study of the offer of payload in the Italian perimeter.

Firstly are approached the sensor based tools, the ones which enable the user to collect data from the drone employment.

The analysis starts from the analysis of the most widespread tool attached to the drones and that enable the vehicle to perform the majority of the tasks it is employed for, the cameras. As described in the previous chapter dedicated to categorization 4 different macro categories of cameras are retrieved within the offer side: cameras able to process RGB spectral range, multispectral cameras, hyperspectral cameras and thermal cameras able to detect infrared light. Many other differentiation can be performed according for example to the definition of the image (e.g. HD, 4K), but this categorization clearly allows to assign and distinguish the solutions retrieved from this analysis.

The most widespread offer of cameras in the Italian market is dedicated to thermal cameras, the cameras attached to a specific sensor which enables them to detect the energy rising from the surfaces. In fact many of the activities performed by the drones are related to the collection of specific information which are largely processed thanks to infrared sensors. 5 players operating in the Italian perimeter offer this kind of solution. The second offer of cameras is related to the RGB cameras, able to process images combining red, green and blue colours. They allow to collect a lower amount of data with respect to thermal cameras but they are employed anyway following a more “traditional” way. 4 players offer this second type of solutions. Once again in the perimeter of the energy waves detection as the case of infrared cameras, there are companies offering solutions for more specific processing of the images within the light spectrum beyond the visible light. It is the case of multispectral cameras, providing higher range of waves detected (as well as the level of information transmitted): 3 players offer cameras able to perform this kind of data collection process. The last category of cameras retrieved from the market offer an extension with respect to the multispectral collection: hyperspectral allows to process the images shotted following the continuous spectrum. This level of detail enables to collect data without the constraints

imposed by the waves length. Just 1 player in the Italian market proposes in its core business this type of sophisticated camera.

The drones are likely to be attached with one or more of these cameras combined among them in order to achieve all the tasks related to inspections. They represent the enablers for the digital modelling process to which software offer is dedicated.

Second category of tools which is largely involved in the drones' operations is related to the laser technology: laser scanner is the tool enabling the LiDAR technology, which is a widespread laser scanning activity performed by drones. Standing for Light Detection and Ranging, it is a remote sensing method used for Earth surface examinations. 3 payload producers are found in the Italian perimeter offering this kind of solutions to drones operators. Together with cameras the laser scanners concurs in the creation of a detailed digital model of the reality inspected. Beyond the visual and energy dimension that the cameras are able to provide, laser technology adds information such as the depth and the distance, crucial in certain specific operations.

Regarding the geographic information retrieved there is the radar attached to the drone as the enable tool: 1 player offers it in the Italian market. Within the categorization are included all the tools attached with sensors able to emit radar impulse.

In the area of control of the surrounding areas, such as in case of disaster management, the air platform is attached to a sensor able to detect information on presence of gas, radiation or other substances. It is attached to a chemical sensor which produces a reaction through an electric current when it comes in contact with a defined gas which provides a trigger. The main goal of the sensor is monitoring the air quality and providing an alert in case of danger. 3 companies from the list are found to propose this technology.

The tools proposed listed above addressed to collect data, therefore behind the physical tool there must be a system of transmission and processing of these data, actions triggered by sensors. That is why they are categorized as sensor based payloads.

Stepping into the analysis of the payloads which are not attached with sensors and that are not addressed to data management two different categories are selected according to the offer retrieved from the Italian market: it is the case of more operative tools addressed to specific goals.

The first category recognized includes the tools related to liquid, dust and granulate dispenser, tool which is becoming widespread for example in the agricultural environment for crops spraying acting in remote way. 2 players in the market offer this kind of tool.

The last one is a tool attached to the drones which are addressed to perform transportation missions: this category of payload is related to the logistics role for which the drone is step by step becoming more employed for different purposes. This category has become widespread also during COVID-19 pandemic due to the many cases in which the medical provision has had to occur avoiding contact between people.

In the Italian market 1 company offer solutions addressed to enable the cargo transportation.

In the Italian market from the previous categorization just 3 companies are recognized as solely payload producers, meaning that it is a very restricted business segment.

For what concerns the business field analysis most of the solutions are addressed to comply with all the considered business' requirements. The only case categorized as mono-sectorial is the one related to distribution purpose in transportation area.

The others solution are flexible enough to be extendable to multiple purpose: the cameras are attached to every kind of drones, therefore they are multi-sectorial. Moreover some companies do not even include the possible use cases of their solutions, implying that it is more related to the approach of the user rather than a solution provided for specific scope.

Once again in the final assessment of the business field covered by the payload solutions is found that the most covered area is the agricultural one, with at least 7 companies providing payloads addressed to this purpose. Right after it, with 6 cases, there are the utility sector and the disaster management are. Many companies, in term of percentage of the overall Italian offer, provide solutions also for the construction sector, with a sample of 6 providers.



Figure 15 - Italian drone market - Payload offer

The Italian categorization shows a restricted offer provided by just few players both in the software and payload side, with some specific cases interesting to be deep dived for the integration of the Artificial Intelligence within the business proposal.

The next paragraph is addressed to build up a benchmark for understanding the overall offer present in the market, through an analysis of the companies scouted by DRONEII in 2019.

3.3 Offer side: International market

DRONEII, relevant source on drone insights, performs annually a scouting and categorization of the drone's environment, including in the assessment providers of software and payload. For the purpose of this thesis is interesting to proceed in the analysis of the companies considered by DRONEII, for which is joined an analogue approach as the one employed for studying the Italian perimeter offer. The only difference is that in this case no business segments analysis is performed. This has two objectives: on one hand it is built up a

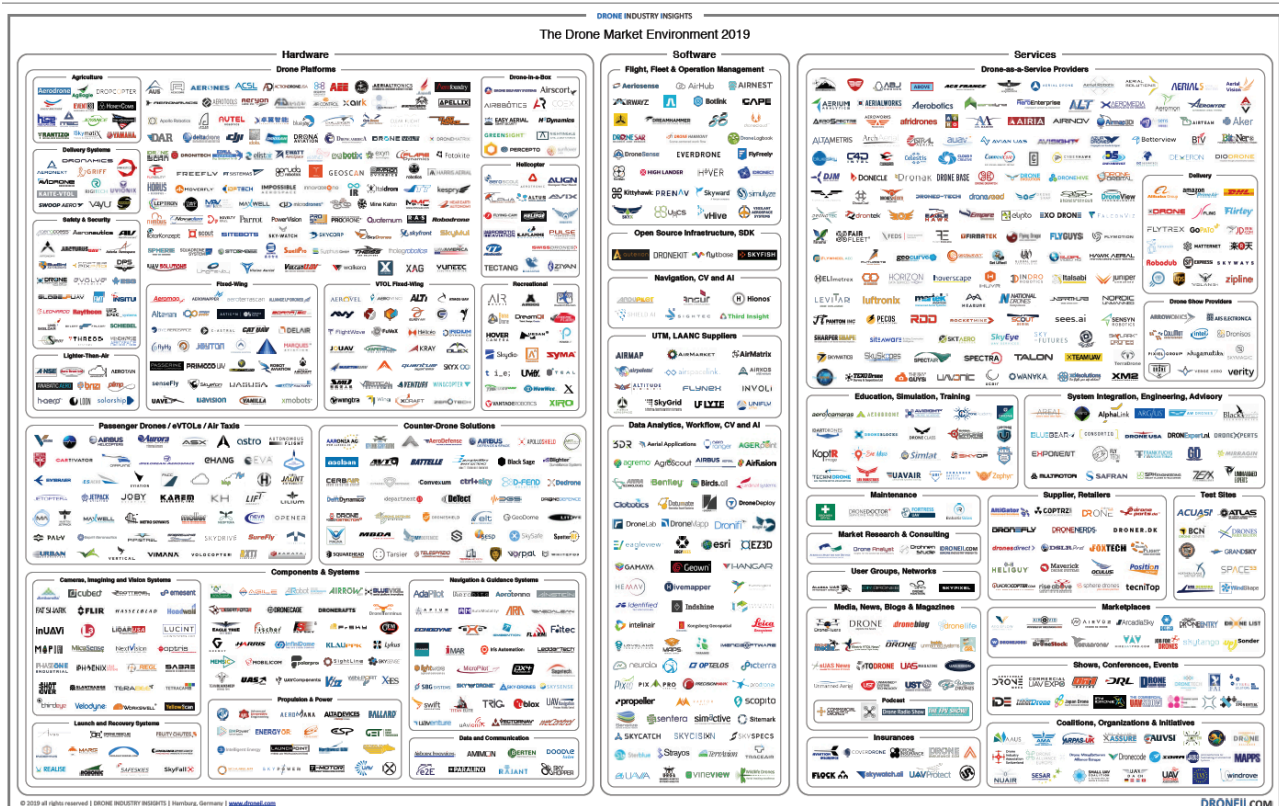


Figure 16 - The Drone Market Environment 2019 (DRONEII)

benchmark for the values collected by the Italian analysis of the offer, in order to understand the state of art of the Italian market; on the other it is useful for deep diving the relevance of the Artificial Intelligence involvement within the drone's business proposal. Moreover it provides a view on where the activities related to drone's world are located.

The starting point is a mapping of the companies analyzed posted by DRONEII (figura): from the mapping just the companies included in the software and payload categorization are

considered. Once built up the list of companies of interest each website is analyzed and the approach employed for the national evaluation is replicated.

3.3.1 Software proposal

The map built up by DRONEII shows a specific category for software providers dedicated to the drone environment. 5 categories are included in this sections, and from this categorization has represented a trigger for the categorization proposed in this thesis: flight, fleet & operations management; open source infrastructure; navigation, CV & AI; UTM, LAANC suppliers; data analytics, workflow, CV and AI.

A sample of 106 companies is obtained and for them it is surfed the website looking for relevant points of analysis. Since the last document freely available is dated 2019 it is easily understandable that, also due to COVID-19 pandemic, some companies are not found in the web search. For them it is assumed a default occurrence or an acquisition by external players. This is the case of 12 companies which are excluded from further analysis.

The final output is a list of 94 companies currently operating in the provision of software solution in the drone's international market.

Once again it is assigned a "core category" which represents the best description of the company's offer, but in most of the cases more than one category is attributed to the solutions, considering that the solution reaches more goals.

The most represented category is the "DATA ANALYSIS" one, as well as in the Italian perimeter, with 55 companies providers of this type of solution.

The second most widespread type of solution is addressed to the "MISSION PLANNING", with 25 companies offering it. With 8 companies each "NAVIGATION" and "UTM" software providers are the less represented. This first result of categorization is analogue in term of

percentage of offer for each category to the one coming from the Italian analysis: the major part of the software providers focus on data analytics, joined by solutions for managing the missions enabling to perform large variety of different tasks, and at the end the solutions addressed to the navigation and to keeping safe the surrounding aerial space.

Disaggregating the data with respect to the categorization it is obtained that 65 companies on 94 offer solutions for data analytics, 34 for mission planning, 15 navigation and 17 for Unmanned Traffic Management.

Within the international categorization is included the nation state of the company, in order to provide a view on the states which are more developed and active in the drone market.

With 44 cases, representing the 41% of the total, United States are the largest provider of software solutions, followed by Canada with 10 companies. The North America itself represents therefore, according to DRONEII survey, half of the overall offer of software addressed to drone employment. From the rest of the world there are “active markets” in Switzerland, Israel and Australia, respectively with 7, 6, and 5 companies.

Italy is considered in the DRONEII survey with 1 company scouted (MENCI Software) which is listed also within the Observatory Database.

3.3.2 Payload proposal

Once analyzed the software side the focus is switched to hardware side. The mapping of DRONEII divides two big macro categories of hardware: on one hand there is the flying platform, with the proviso of the different typologies of drones with different layouts; on the other there is the section named “Components and systems”, which includes all the solutions that are attached to the flying platform. Following the idea of categorization performed by the Observatory the focus is on the section “Components and systems”.

In this section there are defined 5 different sub-categories: cameras, imaging and vision systems; launch and recovery systems; propulsion & power; navigation & guidance systems and data & communication. The categories navigation & guidance systems and propulsion & power are excluded from the payload categorization because are considered not in scope for the payload analysis since they are more related with the functioning of the flying platform. Some companies are excluded because they are no more active, either for default occurrence or for third parties' acquisition.

Once defined the perimeter the analysis is performed on 37 companies: results show cameras provision of 16 players, representing the 43% of the market. Among them the 75% offer thermal solutions, 56% offer RGB cameras, 31% multispectral technologies and just 6% offer hyperspectral systems. Also in this distribution the Italian trend is replicated with the highest offer addressed to the thermal and infrared systems, followed by traditional processing cameras and by beyond visible light tools.

The second common tool offered by companies from the international market are the laser scanners, with 27% of payload providers offering this kind of solution. Radar systems, with 14% of the players follow the laser scanners in term of providers numbers.

The least common sensor based payloads provided are gas, radiation & substances detectors with just 2 players offering them (5%) and at the end there are payloads not addressed to the data management with 1 player offering dispensers and 1 offering distribution solutions. As well as the case of software producers also for payload it is included an analysis with respect to the state of origin of the companies. The state from which there is more offer of payload is the US, with 41% of providers (15) scouted by DRONEII coming from there.

In this case the second state with more payload providers is France, from which comes the 11% (4 companies) of payload producers. Germany and Australia follow the France offering 3 companies each (8% each).

Italy is not considered in the DRONEII survey, despite at the current stage there are some companies operating in this market. Though they are likely to be relevant within the national perimeter, or not yet with a strong offer as the one proposed by American companies.

3.4 Demand side: applications database 2019-2021

In the introduction chapter, studying the state of art of the drones and Artificial Intelligence it is proposed a first assessment on the distribution in the market of the combination of these two technologies. Thanks to the first study performed on the web articles it is proposed a categorization applied to the software and payload solutions in the previous chapters.

The detailed categorization performed on the use cases retrieved by the Drone Observatory from sources dedicated specifically on studying the drone environment, such as UAS

ID	Nome	Link	Descrizione	Settore	Dettaglio	Ambito 1	Ambito 2	Ambito 3	Categoria operazione	Stato	Anno	Data	Continente	Paese (di utilizzo)	Azienda/ente utilizzatore	Provider del servizio	Altri attori coinvolti	
1	Un drone per la polizia locale di Palermo	https://www.droneobservatory.it/2019/07/16/un-drone-per-la-polizia-locale-di-palermo/	Acquisto di un drone da parte della polizia locale di Palermo per fornire supporto agli agenti sul territorio nella rilevazione di incidenti stradali in tempo brevi	Pubblica Amministrazione	Polizia	Sicurezza e sorveglianza	Sicurezza territorio e persone	Monitoraggio e gestione del traffico	n.d.	Sperimentato	2019	02-gen-19	Europa	Italia	Polizia locale di Palermo	n.d.		
2	Scoperti e droni: le immagini mozzafiato del Kadisti Pilat, il "Piatto della Vita", la chiesa più inagibile del mondo	https://www.droneobservatory.it/2019/09/04/drone-e-droni-le-immagini-mozzafiato-del-kadisti-pilat-il-piatto-della-vita-la-chiesa-piu-inagibile-del-mondo/	Relati tramite drone del monastero alla cima del monte che ospita alla propria sommità l'Ermo di Kadisti. Il drone è stato utilizzato per la protezione di questo sito.	Arte e cultura	Edifici storici	Ispezioni e sopralluogo	Rilevi e mapature	Mappeatura patrimonio culturale	n.d.	Operativo	2019	05-gen-19	Asia	Georgia	Agencia per la protezione del patrimonio culturale georgiano	GST Reggio Emilia		
3	Drone, Canadair ed Elicotteri per l'incendio del monte Merica a Varese	https://www.droneobservatory.it/2019/08/29/drone-canadair-ed-elicotteri-per-l-incendio-del-monte-merica-a-varese/	DJI Mavic Pro 1 utilizzato dal nucleo SAPPI del Vigili del Fuoco per effettuare una mappatura dettagliata dei fronti di fuoco nell'incendio boschivo del Monte Merica (Varese).	Pubblica Amministrazione	Vigili del fuoco	Ispezioni e sopralluogo	Ispezioni post disastri ambientali o incidenti	Ispezione in caso di incendio	n.d.	Utilizzo una tantum	2019	08-gen-19	Europa	Italia	Vigili del fuoco	n.d.		
4	96 km fatti da un drone in Svizzera per consegnare pacchi postali	https://www.droneobservatory.it/2019/08/16/96-km-fatti-da-un-drone-in-svizzera-per-consegnare-pacchi-postali/	Prima consegna postale in Europa con un drone. 96 km percorsi, da Centroni a Wolfershausen in 1 ora e 15 minuti in completa autonomia e sicurezza.	Logistica	Merzi	Trasporto	Consegna di pacchi postali	Consegna last-mile	n.d.	Sperimentato	2019	11-gen-19	Europa	Svizzera	n.d.	n.d.	Logistics: Dedicam GmbH, Team Blacksheep Aviation	
5	Un drone per scavare buchi nel suolo? Meglio con due (e con un paracadute)	https://www.droneobservatory.it/2019/08/16/un-drone-per-scavare-buchi-nel-suolo-meglio-con-due-e-con-un-paracadute/	Due droni utilizzati per perforare il terreno. Un drone effettua il trasporto, l'altro la perforazione vera e propria.	Utility	Attività minerarie	Trasporto	Consegna di strumenti o materiali	n.d.	Sperimentato	2019	15-gen-19	America	Stati Uniti	Università del Nebraska	NIMBUS Lab, Università del Nebraska			
6	Usando un Drone con camera termica la Polizia cattura uomo nasconduto sotto ad un mulo dopo aver proccacciato la sua ragazza in USA	https://www.droneobservatory.it/2019/07/16/usa-usando-un-drone-con-camera-termica-la-polizia-cattura-uomo-nascondito-sotto-ad-un-mulo-dopo-aver-proccacciato-la-sua-ragazza-in-usa/	Polizia di Swinomish (Washington) ha catturato un uomo sospettato di aver tentato di interrompere la propria fidanzata grazie all'impiego di drone dotato di camera termica.	Pubblica Amministrazione	Polizia	Ricerca e soccorso	Ricerca di persone	Fuggitivi a seguito di reato	n.d.	Utilizzo una tantum	2019	15-gen-19	America	Stati Uniti	Polizia	n.d.		
7	In Australia i caffè viene consegnato a domicilio dai droni	https://www.droneobservatory.it/2019/07/16/in-australia-i-cafe-vengono-consegnati-a-domicilio-dai-droni/	Sperimentazioni su sistema di consegna di caffè e coperture tramite droni a casa dei residenti a Berrigan, sobborgo di Canberra.	Large consumo	Ristorazione	Trasporto	Consegna di cibo	Consegna last-mile	n.d.	Sperimentato	2019	17-gen-19	Oceania	Australia	Kickstart Espresso di Berrigan	n.d.	Alphabet, Project Wing	
8	I droni della Polizia Locale effettua la prima multa per fuoco abusivo	https://www.droneobservatory.it/2019/07/16/i-droni-della-polizia-locale-effettua-la-prima-multa-per-fuoco-abusivo/	Identificazione, tramite droni, dell'accesione illegale di un fuoco per smaltire rifiuti vegetali.	Pubblica Amministrazione	Polizia	Sicurezza e sorveglianza	Attori di sorveglianza pubblica	Sorveglianza di attività illegali	n.d.	Utilizzo una tantum	2019	18-gen-19	Europa	Italia	Polizia locale di Campino	n.d.		
9	A Roma fotografata per gli affaristi celebrativi della vittoria della Grande Guerra	https://www.droneobservatory.it/2019/07/16/a-roma-fotografata-per-gli-affaristi-celebrativi-della-vittoria-della-grande-guerra/	Impiego di droni per il restauro delle importanti opere commemorative presso una casa storica in Piazza Adriani a Roma in occasione del centenario della fine della Prima Guerra.	Arte e cultura	Restauri opere	Manutenzione	Manutenzione opere d'arte	Affreschi	n.d.	Utilizzo una tantum	2019	21-gen-19	Europa	Italia	Associazione Nazionale Murali ed Invaldi di Guerra	Air Drone Service	Edelab, Laser PC Italia	
10	Ulfar Hunter un cacciatore di rifiuti marini che si avvale di i riproge di droni	https://www.droneobservatory.it/2019/07/16/ulfar-hunter-un-cacciatore-di-rifiuti-marini-che-si-avvale-di-i-riproge-di-droni/	Progetto Little Hunter: utilizzo di droni aerei per sorvegliare l'area ad alta frequenza di rifiuti di mare marittimo per effettuare la catturazione e lo stoccaggio.	Pubblica Amministrazione	Governo	Sicurezza e sorveglianza	Tutela territorio ad infrastrutture	Controllo dei rifiuti	n.d.	Utilizzo una tantum	2019	22-gen-19	Europa	Italia	n.d.	n.d.		
11	L'Onid applica i droni nella logistica	https://www.droneobservatory.it/2019/07/16/l-onid-applica-i-droni-nella-logistica/	Sostituzione di sollevatori a colonna per la realizzazione dell'inventario con droni di Hardi Group.	Logistica	Merzi	Inventario	Inventario di magazzino	Scansione dei prodotti	n.d.	Operativo	2019	24-gen-19	Europa	Francia	L'Oréal	Hardis Group		
12	Il Come la consegna dei droni cambierà il volto della logistica globale	https://www.droneobservatory.it/2019/07/16/il-come-la-consegna-dei-droni-cambiera-il-volto-della-logistica-globale/	Studenti di una scuola elementare hanno ricevuto i loro libri e i loro materiali scolastici consegnati da un drone.	Pubblica Amministrazione	Scuola	Trasporto	Consegna di strumenti o materiali	Consegna last-mile	n.d.	Sperimentato	2019	24-gen-19	Asia	Indonesia	JD.com	n.d.	Scuole elementari di Jagabita	
13	PRV il drone Taxi autonomo della Boeing ha spiccato il primo volo (Video)	https://www.droneobservatory.it/2019/07/16/prv-il-drone-taxi-autonomo-della-boeing-ha-spiccato-il-primo-volo-video/	Effettuato primo test di decollo, breve volo e atterraggio di un veicolo autonomo per il trasporto di passeggeri.	Mobilità	Persone	Trasporto	Trasporto di persone	Trasporto di persone in area urbana	n.d.	Sperimentato	2019	25-gen-19	America	Stati Uniti	Ampla scala	Boeing		
14	Softico di TerniEnergia cresce nel settore delle ispezioni di centrali fotovoltaiche con i droni	https://www.droneobservatory.it/2019/07/16/softico-di-ternienergia-cresce-nel-settore-delle-ispezioni-di-centrali-fotovoltaiche-con-i-droni/	Incremento del capitale sociale con ottenimento della maggioranza da parte di Softico, digital company del gruppo TerniEnergia, nella startup.	Utility	Energie rinnovabili	Ispezioni e sopralluogo	Ispezioni infrastrutture	Ispezione impianti solari	n.d.	Sperimentato	2019	31-gen-19	Europa	Italia	TerniEnergia	Softico		

Figure 17 - Application Database Observatory

Vision(1), Quadricottero News(2), CBI Insight(3), Dronezione(4), Unmanned System Technology and Inside Unmanned Systems(5).

The list of use cases includes 816 websites and journal articles on which it is performed an analysis by Observatory's group. Specifically, many different dimensions of analysis are included, such as deep dives on the sectors and goals for which the drones are employed in every use cases and benefits reached. In so doing the aim is to involve a managerial

observation of the cases, for providing practitioners indications on the possible enhancements provided by drone's employment for certain operations.

Alongside the strategical view of the cases it is deep dived also the technical dimension included in the employment of drones in the use cases exposed by the articles.

For the focus of this thesis once again it is of interest to look at the categorization of the involved payloads and software.

For the software due to the difficulties that may rise in fully understanding the proposal it the articles categorized under this section just in case of presence of Artificial Intelligence.

Once reviewed of the whole sample of articles the use cases, the cases in which the Artificial Intelligence is involved are selected and furtherly analyzed.

The goal of this selection is to include a view related to more practical cases retrieved from concrete business uses in order to compare them with the first theoretical evaluation performed in the literature review chapter.

Among the articles reviewed, 46 show examples of combined employment between drones action and Artificial Intelligence enhancements of certain aspects of the operations.

The cases selected are categorized joining the following logics:

- **Artificial Intelligence presence:** for the purpose of this thesis is essential to integrate the literature review conclusion on state of art of drones and AI with examples of practical cases. There are plenty of different examples of employment of AI in drones' processes under a theoretical point of view, but the reality is that the combination of these technologies still finds obstacles in term of regulation and acceptance, resulting still in low spreading among practical cases. The assessment with regard to inclusion in the practical cases of Artificial Intelligence results in understanding the sectors which are more developed and have more freedom in term of regulation with respect to the others.

A further detail added to the AI presence is related to the future employment: in case the AI is used for practical case it is flagged, otherwise in case of it represents just a future idea or it is in development it is labelled as “Future”. 5 cases on the overall 46 selected are related to foreseen employments in future applications.

- **Real time vs Ex post:** joining the time level categorization used for distinguishing software typology, it is performed a categorization for understanding the state of art of the usage of data collected. The timing dimension applied to practical cases is useful for understanding and generalising the demand which could occur for software depending on the time they need to present the final output of data collected. On this regard again there are cases in which it is required a real time result that has to be used for contingent decision making, such as in cases of rescuing and inspection, or there are cases of data stored and processed ex post, in case there is a need of further analysis for other purposes decision making. The distribution on this regard is divided among 22 cases in which the data collected by the platform is suddenly used for decision making purposes, 18 cases in which the data collected are subjects of human ex post assessment and 5 cases in which is not well defined this distinction.
- **Type of software:** the categorization proposed for the offer side of the software is used again for the use cases in which there is relevant involvement of Artificial Intelligence software. The cases are in fact divided according to the purpose of Artificial Intelligence involvement among data analysis, mission planning, navigation and UTM. The distribution of solutions among the use cases show the evidence that AI is currently used for the majority for data analysis: in 29 cases studied the Artificial Intelligence algorithm are somehow addressed to managing and processing the data obtained by drones’

explorations. In 8 cases software are employed in the reality for mission planning and fleet management, while in 5 cases the AI is addressed to navigation purposes. No evidence is retrieved for UTM software. 4 cases are not categorized due to the fact that the Artificial Intelligence is cited but the purposes are not clearly specified.

Thanks to the categorization performed by Drone Observatory other 4 levels of analysis are selected and analyse for deep diving in the drones' applications.

In order to understand the on going trend it is assumed to be useful to include the year when the use cases are recorded.

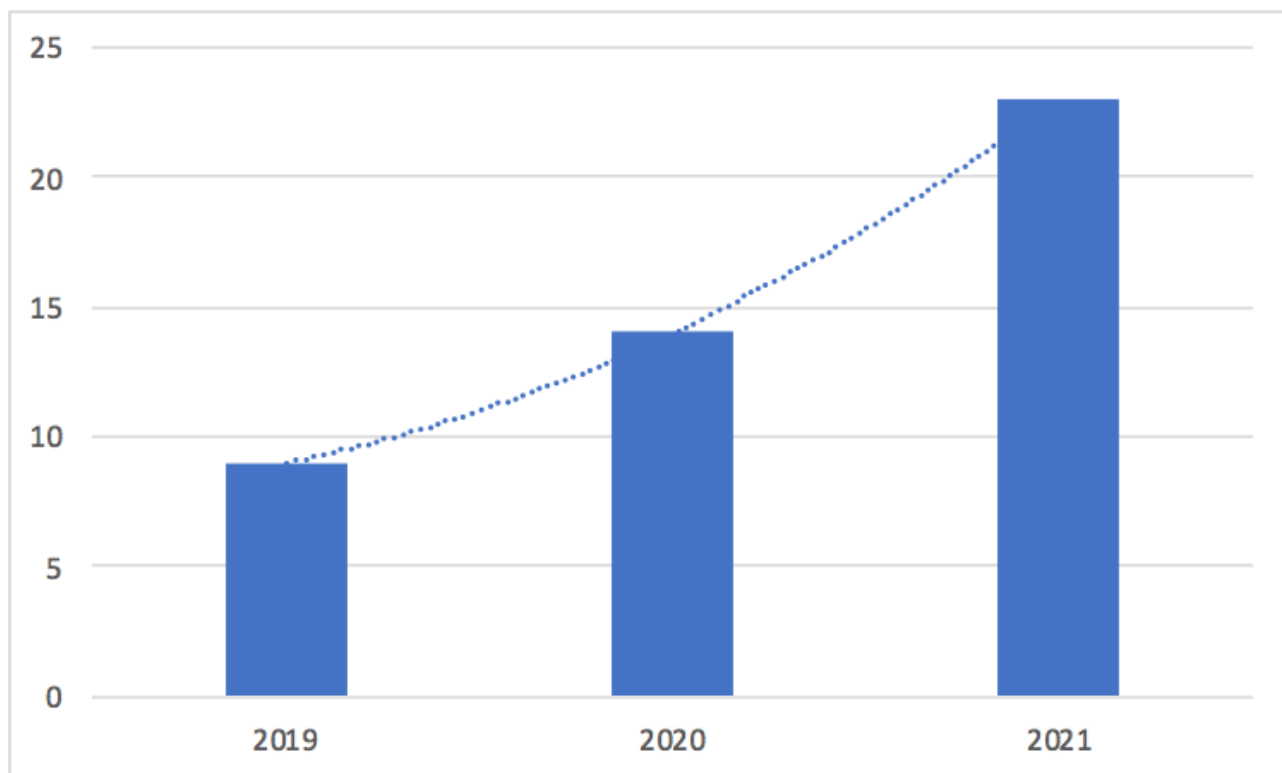


Figure 18 - Applications cases - # per year

During the years 2019-2021 it is obtained a growing trend of cited cases of drones operations integrated with Artificial Intelligence solutions. Number of citations can be used as a proxy of the technological development and spreading of the combined solutions.

From the Observatory database 9 cases of Artificial Intelligence integrated with drones' operations in 2019, increasing to 14 for 2020 and arriving to 23 cases in 2021.

The need and requirements for operations acted by remote have been triggered by COVID-19 pandemic starting from 2020, therefore the help of Artificial Intelligence algorithms which can decrease the human presence is met with favour by practitioners within the business field.

The second relevant factor resulting by the analysis retrieved from the Observatory study is the distribution of the use cases under geographic point of view: the articles considered show the highest presence of drones' employment in Italy (due to the fact that many sources from which the articles have been retrieved are Italian), with the 24% of the cases. At the second place there is United States with 21% of cases and at the third Australia with 8% of the cases. Around the left half of the cases are splitted among Austria, Spain and other nations of which there are just some examples of drones and Artificial Intelligence combination.

For the Italian market it is an interesting result due to the fact that it shows a national interest and players offering innovative solutions.

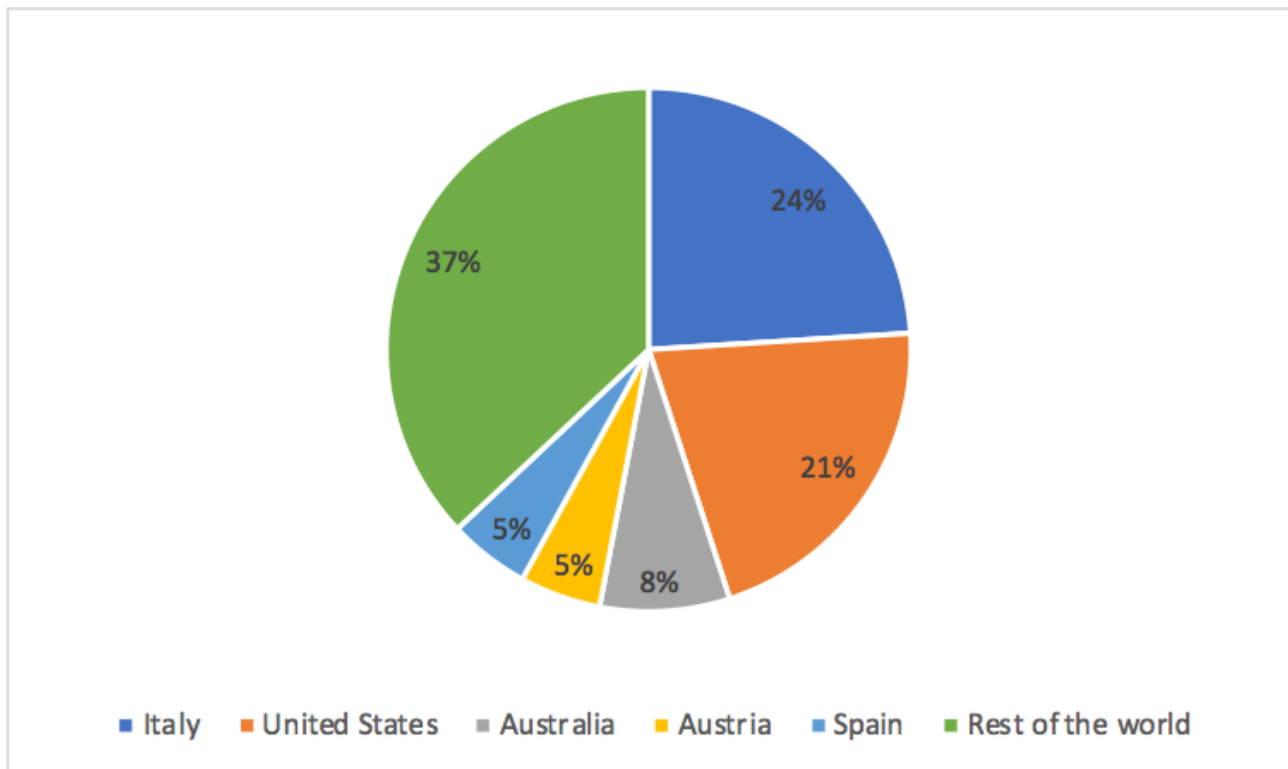


Figure 19 - Application cases - Geographic distribution

The third factor to be attached to the current analysis regards the business segments covered by articles' reporting.

The most cited areas of drones and Artificial Intelligence combined involvement are, as shown in the graph (figure 19), the disaster management (including the environmental

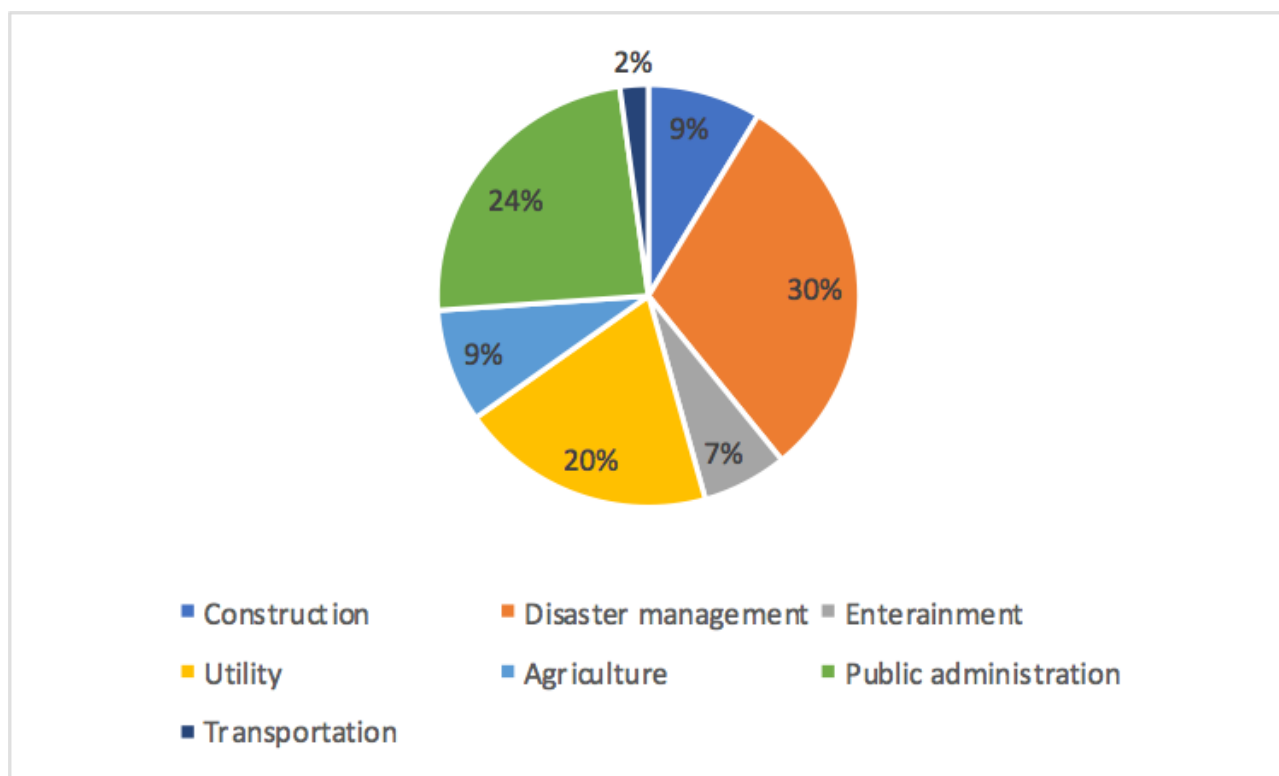


Figure 20 - Application cases - Business segments

safeguard addressed to prevent possible future disaster), with 30% of the cases. Public sector joins with 24% of citations present in the articles' sample and with 20% there is business involvement of utility segment. Unexpectedly agricultural sector is far behind the 3 segments above dealt with, with just 9% of the selected articles covering the area. In all the analysis performed until this point agriculture has always resulted as a business segment largely impacted by drones and Artificial Intelligence combination, mainly considering the analysis performed on the offer side.

The last dimension to be included for the demand side analysis is related to the scope reported by Observatory group related to the articles use cases exposed. This allows to understand under a practical point of view for which activities the focused technologies are

employed and assessing which benefits may raise from the involvement of Artificial Intelligence algorithms with respect to the human intervention.

Six main activities are retrieved from Observatory categorization: the drones are recognized to be used in inspections, which can be of natural but also industrial sites; in surveillance activities, due to safety purposes, by either police or public administration; search & rescue activities, area largely covered and approached also during the software and hardware analysis; inventory, due to the fact that drones and AI are increasingly being employed within industries' big warehouses for assessing the stocks; recording, in the area of media and dispensing in agricultural world.

The distribution, as shown in the figure , reveals a massive employment for inspection purpose, with 58% of the cases showing cases in which the UAVs are dedicated to this activity. Surveillance and search & rescue activities are documented by respectively 20% and 9% of the articles considered.

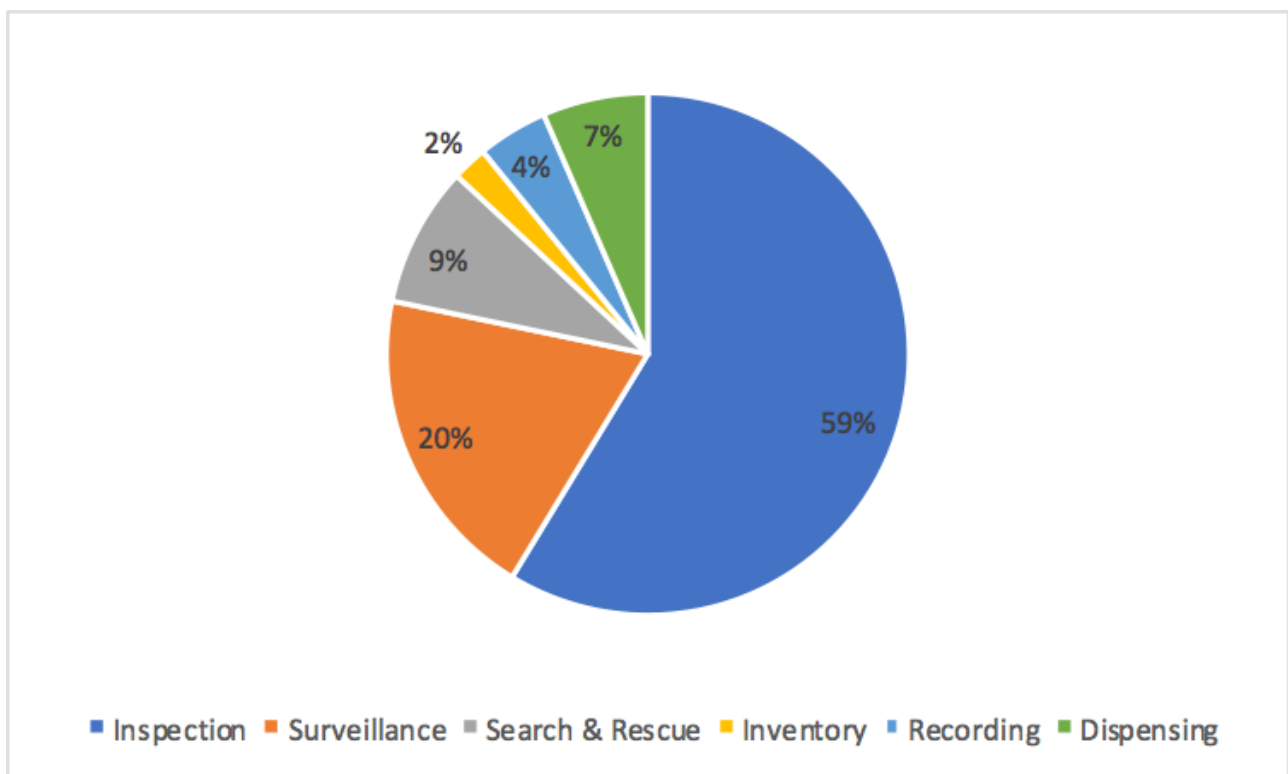


Figure 21 - application cases - Purposes

CHAPTER 4: MARKET SURVEY

The following chapter is addressed to show the approach followed for aggregating the questions to be asked to the Italian market's players operating in the drone environment by Drone Observatory. After the analysis of the academic literature with respect to the topic of "knowledge recombination", some points of interest are retrieved and considered relevant for the combination of drones and Artificial Intelligence. The goal is to retrieve from the market a model employed for innovating towards the development of intelligent systems.

During this chapter are provided the assumptions applied for organising the survey with respect to the section of interest.

The chapter is organized as follows:

- First part dedicated to deep dive on the questions relevant for building up a model of innovation addressed to the development of intelligent systems in the case of drone companies;*
- Second part dedicated to the results obtained by the survey which are employed for building up the model which answers to the Q2 of research.*

Thanks to the results of the survey, considering the sections in scope for this thesis, on one hand it can be enhanced the study thread of "knowledge recombination" with the specific application of the drones and Artificial Intelligence case; on the other studies performed by DRONEII with respect to the state of art of these technologies can be integrated and compared.

4.1.1 Drone Market survey: Artificial Intelligence

The first question of interest regarding the Artificial Intelligence for the companies is whether they current involve it within their proposed solutions: a question of this kind obviously enable to set apart the companies of interest for this thesis purpose, excluding companies which don't integrate the Artificial Intelligence software within their drones' solutions. The answers propose trigger moreover the companies to consider whether in the medium term (around 3 years) they are willing to include it or it is a strategical choice to avoid its employment.

The players which answer positively to the first question are then asked to deep dived with some features of interest. With respect to the typology of Artificial Intelligence developed with the software proposed the companies are asked to specify which kind of algorithms they employ: starting from the analysis of the AI itself software of computer vision, Machine Learning (ML) or Deep Learning (DL) are retrieved as employed within the drone environment. Through the ML drones are able to succeed in tasks without specific indication whether the DL extends the ability of the machine decision making capacity thanks to the involvement of neural networks.

Another point of interest is the goal for which the Artificial Intelligence is employed, area on which application cases and offer solutions are already categorized. Proposing again the categorization addressed to the software classification is indeed required to the companies to explain to which purpose are developed the software attached with AI: if for data analysis, mission planning and operations management, navigation rather than UTM.

Last specific question related to the AI employment by companies is related to the timing on which it acts: on one side it is expected to have companies developing real time proposal that

can be used during a mission; on the other some companies may expect software developed to process data collect for ex-post purposes.

These dimensions of analysis replicate the logics used in the market categorization.

4.1.2 Drone market survey: innovation strategy

Following the logics retrieved from a deep analysis of the academic literature with respect to the innovating approach of search and recombination of existing technologies, it is aimed thanks to this section to apply these logics to the drone and AI environment.

The academic literature on this topic is massive, and in the development of this thesis it is tried to extract meaningful hints that can enhance the study of a young market as the drone one is, where thanks to the recombination of technologies are being developed new use cases.

This section is dedicated to approach the innovation strategy followed by the companies which currently integrate Artificial Intelligence within their proposal, or they are aimed to, in order to understand if there is a common pattern among the companies operating within this market and eventually which strategy can be considered a successful one.

The first point regards a quantitative estimation of the companies expenditures in Research & Development area: in the knowledge recombination study field it is assessed that the level of investments undertaken in R&D influence the learning capabilities of the firm.

The second question proposed regards the area of the firm on which these investments are concentrated, proposing as possible answers the software development, hardware development, process optimisation and management training rather than marketing. This section raises from the assessment by scholars which propose that solely product development without a dedicated training for the people involved may be detrimental. The innovation according to the scholars has to occur in accordance with the development of the

individuals, who should be trained to interact with the new practices (such as the Artificial Intelligence replacing human activities is). This process builds up the absorptive capacity of the firm, which is finally ready for embrace relevant changes.

In order to understand the position of the company and the role which it has with respect to the technological development of the technologies of interest it is asked to the company whether the approach chosen is technology push rather than market pull. On one hand there is therefore a market need to be satisfied by the company, which offer a product relying on the requirements of the users; on the other there could be a logic of technological development addressed to create new needs in the customers. By definition there are factors as the risk appetite of the firm in joining a way rather than another one, such as the capital availability. The aim of the request is to understand whether within the sample of companies there is a dominant approach that allows to understand managerial logics behind strategical management.

The different roots of the technological development, as in case of drones and Artificial Intelligence which combines technologies requiring different knowledge and soft skills, triggers the analysis towards the relationships occurring between the developer companies and external sources of knowledge. In the academic literature this topic is referred as “knowledge network”, a network built up by different companies and entities which actively exchange information regarding a certain topic.

On this regard relevant is the involvement of the universities and research centres, as well as the public administration which may be interested in the development of a certain project or other companies with which some projects may be jointly run.

A last relevant point which follows the network analysis is the geographical dimension of the network: it is asked to the companies whether in case they are embedded on a network context, they are located within the national perimeter, European one or worldwide

distributed. This is relevant due to studies related to knowledge recombination which propose that the geographical closeness can facilitate the value creation due to cultural similarities. At the same time retrieving knowledge from far places may be a winning strategy for what concerns the technological development.

This set of questions is asked to the company by the Drone Observatory through the annual survey performed for studying its enhancements.

During this year edition it is added a section dedicated both to study the involvement of Artificial Intelligence, theme of interest for this thesis, and a section dedicated specifically to the innovating approach joined by the companies.

4.2 Drone market survey: results

For the purpose of this thesis are here presented just the results related to topics faced during the previous chapters.

First section of the survey is dedicated to the scouting of the Italian market addressed to integrate the current knowledge of the drone environment for enriching the databases analyzed in the previous chapters.

With respect to the role of the companies scouted it is retrieved from the market that on a sample of 80 companies which have replied the largest majority acts as operator (91% of them present themselves with an operative role with respect to the drone employment), followed by integrators (with 20% of representatives) and platform producers (16% of representatives). According to the database values already analyse it is again retrieve a little sample of companies which propose software development (9% of companies) and payload production (6% of companies). Numbers retrieved by the survey are consistent with the quantitative analysis performed on the Politecnico database.

Deepening the last two categories of companies (software developers and payload producers), on the software side it is retrieved that 3 players (43% overall) offer solutions addressed to the flight and operation management, 4 players (57% overall) for the navigation and 2 (29%) for data analysis. None in the survey perimeter scouted offer solutions for the safety of the aerospace, categorized as UTM solutions.

Among them 2 players (29% of the sample) have included the Artificial Intelligence in their proposed software development, 4 (57%) are planning to do that within the next 3 years and just 1 (14%) is currently not interested in considering it. With respect to the 2 players involving Artificial Intelligence both rely on algorithms of Deep Learning and 1 of them use also Machine Learning techniques.

The algorithms developed by the scouted players are fully addressed to data analysis purposes and employed for the real time processing directly on board the flying platform.

On the business side, the majority of the companies operate in the infrastructure (deploying the inspection activities

Once analyzed the offer side of the drone environment the focus is switched to the survey questions which are related to reach the goal of analysing the reconfiguration of drones and AI technologies joining the study thread of "search and recombination of innovative technologies".

The first assessment considered comes from the questions related to the involvement of Artificial Intelligence in the operations performed by the companies.

1.11. Nello svolgimento delle operazioni con droni la sua azienda si avvale di soluzioni basate su Intelligenza Artificiale (IA)? (possibile più di una risposta tra i sì)		
	#	%
Sì, il software di pianificazione del volo, gestione della flotta e delle operazioni include IA	8	12%
Sì, il software di navigazione include IA	8	12%
Sì, il software di analisi dei dati include IA	15	22%
No, ma abbiamo intenzione di implementarne entro i prossimi 3 anni	22	32%
No e non abbiamo intenzione di implementarne al momento	25	36%
Tot. Rispondenti	69	100%

Figure 22 - drone market Survey - Artificial Intelligence involvement

A sample of 69 companies has replied to this question (*figura*), with a distribution of 8 companies (12% overall) including Artificial Intelligence employed for the management of the fleet during the operations; 8 companies (12% overall) including the Artificial Intelligence algorithm in the navigation area and 15 (22% overall) for the analysis of the data collected. The larger sample of companies currently isn't employing Artificial Intelligence within their proposal, but 22 (32% overall) foresee to insert it within the next 3 years. The remaining 25 companies (36%) do not consider Artificial Intelligence as a possible implementation and development of their solutions.

With respect to the business segmentation of the drone players, it is asked to the companies in which sectors their clients operate, and the result show that the last majority covers the infrastructure sector (with 78% of companies providing solutions of this typology), followed by art and culture (75%) and agriculture (44%). Respectively with the 41% and 38% of companies, environmental safety and utility sectors are largely covered by the drone solutions. The result is consistent with what analyzed in the previous chapters, implying the inspection purposes as the main activity performed, which cover all the sectors listed above. For assessing the company's size it is asked the number of employees working on each on. Results show a market in which at maximum the companies employ from 10 to 49 employees (therefore to be included within the SMEs segment), for 10 answering players (16% overall). The majority, with 41 representative players (41%), employ from 2 to 9 employees, while the remaining part (10 players being 16% of the total) are individual firms.

1.15. Quanti dipendenti (compreso il/gli imprenditore/i che lavora/no in azienda) ha la sua azienda nel 2021?		
	#	%
1	10	16%
Da 2 a 9	41	67%
Da 10 a 49	10	16%
Da 50 a 249	0	0%
Oltre 250	0	0%
Tot. Rispondenti	61	100%

Figure 23 - drone market Survey - Number of employees

It is a crucial point the analysis on how many employees are involved to the operations because it shows how much the market is still in a developing phase, which can be triggered thanks to the involvement of other technologies such as the Artificial Intelligence one.

A last point on the section addressed to study the companies' overview relevant for the analysis of this thesis regards the technologies which are foreseen as priority for the future and the development. Answers show the majority of respondents recognising the need of the operations autonomy as the most important one (34 companies for the 63% of the overall respondent). This assessment leaves space to think that Artificial Intelligence may be step by step be included for reaching this target.

Stepping into the section 3 of the survey, it represents the core basic for the studies performed along this thesis.

This section is addressed to provide a view on the innovative approach employed by the companies operating in the drone environment, and the questions asked on this regard are formulated after the processing phase of the literature review analysis on “search and recombination of innovative technologies”. The answers of this section are aimed to formulate a model containing indication with respect to the results of some impacting dimension on the possible recombination performed by drone players with algorithms of Artificial Intelligence.

First assessment provide information on the triggering impulse during the product development: on one hand there are companies which develop according the market needs and companies which innovate trying to create and boost new ones. Some of the answering companies join both the lines, though the majority try to have a more conservative approach responding to the current market needs (40 repliers as the 75% overall). 30 players target is to anticipate possible future trend (30 repliers being the 57% overall), aiming to disrupt the market.

One of the core part of the whole study research regards the presence of a network as a variable for the integration of different technologies. As a part of the survey there is the question regarding the company's embeddedness in a system involving different players that, through knowledge sharing, enables the development of the whole market. On 55 repliers, 23 answered that at the current stage the innovating process remains internal. On the other hand, the remaining 32 companies shows involvement on an external network. Deepening the analysis on the answers, the highest level of relationship is found with other companies operating in the sector (19 companies representing the 35% overall) and with universities and research centres (18 companies representing the 33%). As others relevant actors involved in creating the network there are ICT vendors and sources (8 companies), startups and consuming firms (5 companies for each one), institutions and public administration (4 companies) and sector associations (3 companies).

For approaching the geographical component which is part of the network and the studies on "search and recombination" topic, it is asked to the companies whether their "innovation partners" come either from their own national or international market. The question is addressed to the companies which have positively replied to the embeddedness question.

On this regard 13 companies (42% overall) find partnerships in the European market and 11 (35%) from the global market. Instead 9 companies (29%) don't have at the current stage active partnerships in the international market but are planning to establish them within the next 3 years. On the other way round 5 companies (16% overall) don't have active relationships in the international market and plan to keep them within the national perimeter.

A last crucial point in the analysis of the company's innovation strategy is retrieved directly from a quantitative analysis with respect to the research and development expenditures

addressed to drones. The approach chosen for this question is asking to the companies an high level estimation on the investment level as a % of their R&D expenditures.

3.1. % spesa in R&S investita sui droni	▼ #	%
	0	5
	3	1
	4	1
	5	3
	10	5
	20	3
	25	1
	30	6
	35	2
	40	3
	50	1
	60	2
	90	1
	100	5
(blank)		
Grand Total	41	

Figure 24 - drone market Survey - R&D investment % on drones' development

As shown in the table (figure 24) companies are spread among the scale, with 5 companies at the two different poles (0% and 100% of investments addressed to drones). Computing on the results it is found that around the 50% of the companies deploy less than 25% of the R&D expenditures to drones and the left half deploy more than this quota.

CHAPTER 5: DRONES & ARTIFICIAL INTELLIGENCE - ECONOMETRIC MODEL

The following chapter is addressed to show the approach followed for aggregating the results of the survey in order to reply to the research question 2. The resulting model provides some evidences useful for describing the innovating process of the drones firms, in particular for the ones integrating Artificial Intelligence within their business proposal for extending as much as possible the possible usages and tasks which a flying platform is able to perform.

The chapter is developed as follows:

- First part dedicated to describe the technical approach for aggregating the survey results in order to make them usable for building up an econometric model;*
- Second part dedicated to show and describe the resulting model.*

Thanks to the econometric model built up starting from the theoretical evidences retrieved from the search and recombination of knowledge it is provided an answer to the research question on the recombination performed by the technologies of drones and Artificial Intelligence

5.1 Introduction and methodology

A quantitative approach is chosen for addressing the research question on the innovating activities performed by the companies operating in the drone market.

The path chosen implies the creation of a model describing the impact of some specific characteristics cited in the literature studies of the scholars on the recombination of drones and Artificial Intelligence technologies.

The fundamental assumption on which the model is built up is that the Artificial Intelligence, according to the researches' evidences, is among the technologies which enable the drones to obtain step by step more autonomy that turn into solutions for an increasing number of application fields.

Artificial Intelligence algorithms increase the efficiency of the drones operations due to the increasing speed on data processing which can be suddenly re used by operators.

Therefore Artificial Intelligence technologies are considered innovating trigger of the drones' market: in this sense the recombination of the technologies can be allocated in the study field of "search and recombination of innovative technologies".

The approach joined is to turn the questions asked to the companies regarding the innovating approach (deriving from the main study thread of "search and recombination") into independent variables which are expected to have an impact on the presence or absence of the reconfiguration in scope.

The function chosen for describing the model is the type $y = f(x_1, x_2, x_3 \dots x_n)$, being y the dependent variable and x_n the independent variables which are assumed to have an impact on the y .

The starting point regards the variables chosen, with the dependent variable retrieved from the question 1.11 of the survey: "Does your company rely on Artificial Intelligence solutions

in performing drones' tasks?". The dependent variable selection is addressed to highlight the firms which are included in the "recombination area" from the ones that are currently not deploying Artificial Intelligence as solution for their business proposal.

In order to have variables which can feed a model building software, the answers of the single companies are turned in Boolean variables with the values of 0, corresponding to the answer "no" and 1, corresponding to the answer "yes".

As the independent variables some questions are proposed as sources for the model creation. The first one regards the inclusion of the number of employees, considered as a proxy for the firms dimension: the aim of this variable inclusion is to understand how much the dimension of the firms within this market could impact an eventual enhancement under a technological point of view. Survey result to this question show that 100% of the replying companies employ less than 49 individuals within their workforce, with 16% of the companies being individual companies, 67% small companies employing between 10 and 49 employees and the left 16% part representing companies which are more structured, with from 10 to 49 employees. The variables are assigned distinguishing the two categories of companies with less than 9 employees, to which it is attributed the value of 0, and companies with more than 10 employees, to which it is assigned the value of 1.

The second variable assumed to be of impact for the model of Artificial Intelligence integration comes from the third section of the survey: it distinguish the companies which innovate triggered by a market pull approach against the ones which join a technology push one. The choice of this variable is made for clarifying the innovating approach of the firms which have performed the reconfiguration in scope. Some of the replying companies have shown a double tendency on this respect: on one hand they try to innovate disrupting the market, on the other they follow the customer needs. As a result of the literature analysis it is chosen to assign the value 1 to all those firms which show a propensity for the technology

push approach (both in case of unique path and in case of mixed approach with market pull). The goal of the inclusion of this variable is to understand how much the inclusion of the Artificial Intelligence is the result of a technological development rather than a way for satisfying the customers' needs.

Other three variables are included in the model for approaching the level of impact which the networking of the firms have in the technological recombination under investigation.

First variable involving the network analysis is retrieved from the answers to the question regarding the network inclusion of the firms. For the ones replying that they currently have active partnerships with external players it is assigned the value of 1, while to the ones employing an internal approach for what concerns the innovation activities are attributed the value of 0. This first variable which introduces the concept of network inclusion comes from the study area of the knowledge recombination which states that the embeddedness in an external network may enhance the creation of disrupting products and services thanks to the availability of different sources of knowledge.

A second step within this same field is related to the actors involved in the network of drones' companies. Among the list of different categories of actors named by the companies in the survey there are two examples of innovating partners which triggers the technological enhancements: universities and other startups. One variable of the model distinguish the companies which have active partnerships with these two categories of players from all the others, in order to verify if a network of this nature has an impact in the reconfiguration. The value of 1 is assigned to all the companies having active partnership with universities and startups and the value of 0 assigned to all the companies which currently don't have it.

From a geographical point of view it is included in the model the variable coming from the question of the presence of foreign partner: the distance between two collaborating players is one of the points analyzed by the literature review. Due to the fact that being distant means

being provided with a different technological and cultural background, the recombination of knowledge coming from distant companies may trigger the creation of disrupting solutions. The value of 1 is assigned to all the companies having active partnerships with foreign players, both European and extra European ones, against the companies which either don't have partnerships or keep them limited to the national perimeter, case with value 0 assigned. One last variable of impact is identified for feeding the model: firms' investment in innovation are assumed to have an impact on the final product and the technologies included obtained. The question on the expenditures in research and development of the firms is turned into a variable performing a quantitative analysis of the answers. It is obtained that around 50% of the repliers employ less than 25% of their investment in drones' research and development, while the remaining part of the companies dedicate more than 25% of they investment on drones' enhancements. This information is turned into a boolean variable assigning the value of 1 to the companies employing higher amount of investments on drones and the value of 0 to the remaining part.

AI presence	Technology push	Network	Universities-startups	Abroad network	More than 9 employees	>25% drones R&D
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	1	1	1	1	0	1
1	0	1	1	0	0	0
1	1	1	1	1	0	1
1	1	0	0	0	0	0
1	0	1	1	0	0	0
0	1	1	0	0	0	1
0	1	1	1	1	0	1
1	1	1	1	0	0	1
1	0	0	0	0	0	0
1	0	1	0	1	0	0
0	0	1	1	1	0	1
0	1	1	0	1	0	0
1	1	1	0	0	1	0
0	0	1	0	0	1	0
0	1	0	0	0	0	1
0	1	1	1	1	1	0
0	0	1	1	0	0	1
0	0	0	0	0	0	0
1	1	1	1	1	0	1
0	0	0	0	0	0	0
0	1	1	1	1	1	1
0	1	1	1	0	0	1
1	1	1	0	0	0	0
0	0	0	0	0	0	0
0	1	1	1	1	0	1
1	0	0	0	0	0	0
0	1	1	0	1	1	0
0	1	1	1	0	0	0
0	1	1	1	1	0	1
0	0	0	0	0	0	0
0	1	1	1	1	0	1
0	0	0	0	0	0	0
0	1	1	1	1	0	1
0	0	0	0	0	0	0
0	1	1	1	1	0	1
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Figure 25 - econometric model - variables representation

Considering the companies for which are available the whole set of information, it is aggregated a sample of 55 companies on which the model is built (figure 25).

Thanks to the aggregation and transformation of the survey answers into boolean variables, the data are ready for feeding a dedicated software for analysing the interactions between the identified variables.

5.2 Computation of the econometric model

The processed results of the survey are saved on a dedicated Excel sheet which represents the feeding source for the statistic software Stata. The first step is importing the sheet through the dedicate functionality of the software (Import -> Excel spreadsheet (*.xls;*.xlsx): the excel sheet containing the elaborated survey results is displayed within the software. In order to make the model smoother the variables names are called by their initial letters, as shown in the table (figure 26).

Variable considered	Variable in the model
AI Presence	AI
Technology Push	TP
Network	NT
Universities-Startups	US
Abroad connections	AC
Number of employees	NE
Research & Development	RD

Figure 26 - econometric model - variables names

The model called in the software is the Probit regression one: it is a regression employed for modelling binary outcome variables. In this model the inverse standards normal distribution of the probability is modelled as a linear combination of predictors.

The dataset has a binary response which is represented by the variable AI, and 5 predictors are selected in order to understand which of the different dimensions identified have an impact on the recombination between drones and Artificial Intelligence.

All the variables have the a binary outcome, either 1 or 0.

In order to describe the results of the survey it is relied on the Stata function “summarize”, which shows the means and deviation the answers for each option (*figure 27*) with respect to the predictors.

```
. summarize TP NT US AC NE RD
```

Variable	Obs	Mean	Std. dev.	Min	Max
TP	55	.5454545	.5025189	0	1
NT	55	.5818182	.4978066	0	1
US	55	.3636364	.4854794	0	1
AC	55	.3090909	.466378	0	1
NE	55	.1636364	.373355	0	1
RD	55	.3818182	.4903101	0	1

Figure 27 - econometric model - predictors

Concerning the dependent variable the distribution has the frequency and percentage shown in the figure (*figure 28*)

AI	Freq.	Percent	Cum.
0	40	72.73	72.73
1	15	27.27	100.00
Total	55	100.00	

Figure 28 - econometric model - variables distribution

The focus of this thesis is on the positive occurrence of the recombination (15 observations with value 1) and on the variables that show an impact on this regard.

```
. probit AI TP NT US AC NE RD
```

```
Iteration 0: log likelihood = -32.227394
Iteration 1: log likelihood = -25.58477
Iteration 2: log likelihood = -25.389986
Iteration 3: log likelihood = -25.389894
Iteration 4: log likelihood = -25.389894
```

Probit regression

```
Number of obs = 55
LR chi2(6) = 13.67
Prob > chi2 = 0.0335
Pseudo R2 = 0.2122
```

Log likelihood = -25.389894

AI	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
TP	.029403	.4925956	0.06	0.952	-.9360668	.9948727
NT	1.327283	.6503991	2.04	0.041	.0525241	2.602042
US	.1341894	.639526	0.21	0.834	-1.119259	1.387637
AC	-.2333467	.5509224	-0.42	0.672	-1.313135	.8464413
NE	-1.45095	.7180559	-2.02	0.043	-2.858313	-.043586
RD	-1.4322	.6462313	-2.22	0.027	-2.69879	-.1656096
_cons	-.754054	.3495242	-2.16	0.031	-1.439109	-.0689991

Figure 29 - econometric model - Stata outcome

Once having described the source values for the data model thanks to the software functionalities, the software is triggered on the data model creation joining the profit regression model.

In the figure (figure 29) it is shown the model resulting from the statistical profit regression triggered in the Stata software. Some elements are considered for analysing the result:

- **Iteration:** the probit regression is performed by the software thanks to maximum likelihood, an iterative procedure which is producing the final result. At the beginning of the iteration there is the so called bk coefficient, a value which combined with the model and the data produces a log-likelihood value Lk, value that iteration by iteration grows until finds its maximum. The first iteration provides the result of the “null” model, which is the one without predictors. From the second iteration (iteration 1 in the model) the predictors are included, and as shown in the figure n there is significant difference

between the first and the second log likelihood related to the iterations. From the iteration 1 to the iteration 4 the log likelihood differences are reduced, when they are small enough the model is stated to have converged and the log likelihood is optimised. The log likelihood in the current model is optimised at the fifth iteration, with a value of -25.389894. This value has no meaning if not compared to the nested models, specifically models in which it is kept just a subset of predictors for verifying they could better define the model itself.

- **Number of observation:** Stata software automatically deletes one observation in case not all the values are present. In this case the model shows that for achieving the final result all the 55 observations are employed, due to the fact that the input dataset provides a complete sample of values for all the observations.
- **LR chi2(n):** this is the likelihood ratio (LR) chi-square test, it is obtained by the formula $-2 \times (\text{iteration 0} - \text{iteration n})$. The highest the value the farthest the result model is going from the “null” case, the one without predictors. It is considered when then is computed the p-value for assessing whether this value is statistically significant and can be accepted against the possible “null” hypothesis. “n” in brackets represent the degrees of freedom which the model has: in this case there are 6 variables considered therefore the value retrieved is 6.
- **Prob>chi2:** this value represents the probability to obtain the likelihood ratio in case the null hypothesis is true, meaning that there is no effect of the independent variables on the dependent one. It is the *p-value* of the model, and it is compared to a critical value

$$y = b_0 + b_1 * x_1 + b_2 * x_2 + b_3 * x_3 + b_4 * x_4 + b_5 * x_5 + b_6 * x_6$$

according to the significance level specified. For example in case of a chosen significance level of 95% the model has statistical relevance due to the fact that the null hypothesis can be considered, the p-value has to be lower than the value of 0.05. 5% is represents the probability threshold that the relationship between the variables may be randomly produced.

- **Coefficient:** represent the coefficients attached to the independent variables which build up the equation for predicting the dependent variable. The values are expressed in log-odds. Odds is the ratio between the probability of success on the probability of failure. The log-odd is the log of the odd ratio. Therefore the equation joins the following shape: The estimations contained in the equation related to the independent variables provides indication on the increase in the predicted log odd of the dependent variable that would result from a 1 unit increase in the predictor, keeping constant the other variables. In the model there could be some variables which are not significant: this fact is reflected within the equation by low values of the coefficients.
- **Standard error:** representing the standard errors related to the coefficients calculated by the software. It is considered for sizing whether a parameter significantly differs from 0. Dividing the parameter obtained with the related error it is obtained the z-value, useful indication for evaluating the variables' significance.
- **z and P>|z|:** columns related to the significance assessment of the variables considered in the model. The p-values related to coefficients allow to evaluated whether a coefficient

significantly differs from 0. Once again it has to be defined a threshold value α which represents the maximum value for which a coefficient can be considered statistically significant. All the variable with this value over the threshold don't show evidence on being significantly different from 0.

5.3 Results of the model

In order to evaluate the statistical significance of the model it is assumed an α value of 0.05: in case of occurrence of value lower than this critical amount it is sufficiently unlikely that the relationships of the variables involved are due to a random event.

Being an explorative observation of the variables also an α level of 0.1 could be employed, but as a first trial it is relied on the 0.05 threshold.

The starting point for the results analysis is the comparison between the *p-value* of the model with the significance threshold. From the previous analysis on the technical output of the software it is retrieved that for the dataset in input results a *p-value* of 0.0335. Being lower than the assumed significance level of 0.05 it can be refused the “null” hypothesis and the statistical significance of the model.

Analyzing in detail the involved variables, once again it is relied on the *p-value* comparison with the significance threshold.

In light of previous paragraph the equation on the dependent variable under a quantitative point of view has the shape of:

$$AI = -0.754054 + 0.29403*TP + 1.327283*NT + 0.1341894*US - 0.2333467*AC - 1.45095*NE - 1.4322*RD$$

Deepening the analysis on the independent variables, there are three which distribution is statistically significant: NT, NE and RD. For the other three variables considered it is accepted the hypothesis that they have no impact on the dependent variable, therefore assuming there is random relationships between them and not a statistical impact.

NT (network presence) shows a *p-value* of 0.041, which standing below the defined threshold of 0.05 is evaluated as statistically relevant. This fact is reflected also in the coefficient (1.327283), that shows a positive correlation with the dependent variable.

NE (number of employees) shows a *p-value* of 0.043, once again statistically relevant if compared to the threshold. In this case the coefficient (-1.45095), shows a negative correlation between the predictor and the dependent variable.

RD (research & development investment on drones) shows a *p-value* of 0.027, for which cannot be accepted the “null” hypothesis. The coefficient (-1.4322) shows negative correlation with the dependent variable.

These three variables allows to make some considerations on the process of combination between the technologies of drones and Artificial Intelligence

5.3.1 Explanation proposal

One of the currents of study which can be retrieved from the academic literature on “search and recombination of knowledge” is, as shown in the academic literature chapter, the presence of a network in which the different players of a business sector exchange their competences. This can result in enhancements on technologies employed and satisfaction of the different needs both for the final customer and for the same companies.

The network itself can be analyzed under different point of views: it can be either external or internal, depending on the dimension that is wanted to consider.

For the study of this kind of recombination, it is chosen to start the analysis from the external involvement in a network, due to the fact that during the thesis project there have been performed some activities addressed to a possible network partner of the drones' companies, Drone Observatory.

From the model it is obtained a positive correlation between the involvement of a network, correlated to the presence of partnerships with external actors, with the employment of Artificial Intelligence in the perimeter of drones' operations. This is a result expected, since the involvement of a different technology implies the collection and a deepening in knowledges necessary for effectively including it. From the studies on "search and recombination" is retrieved that when new knowledge has to be included within the competences of a company, the involvement of external actors could enhance the process, since they can offer their expertise and experience in the field.

This result is a starting point for approaching the topic of the networks in the drones' business environment since many different variables may be attached to this analysis: in this thesis are not deep dived the reasons why a network of knowledge in this case is positively correlated with the reconfiguration process. A possible open point is a deepening in the analysis on the Artificial Intelligence software houses and the way they offer their products, which may impact on the choice of drones' firms to rely on external players for enhancing their activities.

Another point is the analysis on different actors assumed to be present within the network: a first trial in the model creation of investigating on a possible positive impact of the partnerships between the companies and universities and startups (assumed to be innovating triggers) on the Artificial Intelligence involvement. Though, the results have not shown statistical evidences on this regard.

A second dimension retrieved by the academic literature chapter is the relationships between the recombination and the dimension of the companies.

On one hand there are small companies which have lower possibilities in term of investment but which have higher flexibility and resilience in changing the processes, on the other there are bigger companies that have capital availability but face difficulties in innovating due to the high number of stakeholders that are involved in the changing process. In order to perform an analysis addressed to include in the model the “size of the firm”, it is chosen to rely on the number of employees distribution. The drones companies which have replied on the survey are, in 100% cases, employing less than 50 employees, therefore it is limited the division between small and big firms. Though, a distinction is done between the firms employing less than 9 individuals and the ones employing between 10 and 49: it is assumed to be a proxy for the level of growth that firms have reached and a possible indication of the maturity of the companies.

From the model, it results a negative correlation between the firms with more than 9 employees (largest ones in the sector) and the recombination of technologies.

Two possible explanations for this result are proposed: the first possible assessment is that the dimension of the companies may be an obstacle for the combination of these two kind of technologies. Another possible reason would be that smaller firms, on a development stage behind the others, may be born directly offering solutions which combine Artificial Intelligence within their operations perimeter. Once again the explorative purpose of this thesis has raised a possible theme of analysis to be deepened in future studies, focusing on this regard on the dimension of the drones’ firms with Artificial Intelligence algorithms.

The third variable showing statistical validity for the model is related to R&D expenditures undertaken by the companies addressed to the drone’s business.

From the academic analysis, the level of investment in R&D may either help in the recombination process or, on the other hand, may also be high due to the difficulties occurring trying to combine technologies with low level of affinity or in a difficult environment. The model shows significant result, with a negative correlation between the R&D investment addressed to drones and the presence of reconfiguration.

Some possible explanations are here proposed in order to enhance future discussions on this area: a first possible analysis could be that, evaluating the two technologies in scope, they show high level of affinity, turning into low expenditures needed for their combination. The affinity may be technological, meaning for example that the possible enhancements of the drones operations due to Artificial Intelligence involvement don't show particular needs under a technological point of view, as for example development of new features. On the other hand the affinity may also be related to cultural heritage of the company: highly different technologies may trigger the growth of internal obstacles within the firms' individuals. The lack of affinity generally results in an increase of the costs addressed to the combination of the technologies, fact that for drones and AI seems not to be the case. A second possible explanation is related to the fact that, according to the survey results, the large majority of companies operating on this sector are not the AI software developers but in case of employment, they rely on external solutions. This is reflected in a lower needs of investments for "managerial" reasons: in case the drones' operators developed vertically the product, the involvement of new technologies would likely result in an increase of the investment needed. In this case, leveraging on external actors, the investment related to capabilities enhancements are limited.

Third possible solution is related to market reasons: due to the fact that it is a market in a early growing phase the companies are likely to employ their investments in other areas. From the survey, the areas with higher level of attention in investments by the companies are

addressed to marketing purpose and to the internal organizational process. In this phase of the market, the companies could be likely to prioritise an increase in term of market share rather than some technological enhancements on their proposals.

One last point that could raise from this analysis is related to the Artificial Intelligence nature itself: thanks to the enhancements provided by the algorithms to the operations, in term of data acquisition and learning experience, its involvement may result in a reduction of R&D expenditures needed due to the fact that the machine itself is able to perform some activities and to provide some evidences which could otherwise be costly for the company.

This last chapter provides some possible open points for future analysis: for each one of the independent variables resulting from the model creation there is space for valuable deep dives which can further explain the growing trend of drones and Artificial Intelligence recombination.

CHAPTER 6: CONCLUSIONS

This chapter is addressed to sum up the activities performed during this thesis project. The answers to the questions raised after the analysis of the state of art of the academic literature and technologies in scope are proposed. Some hints for future analysis are proposed and summarized after the assessments provided on the econometrics model results.

6.1 Contribution to academic literature

The starting point of this thesis was the need of understanding how the drone market is developing towards the direction of solutions involving Artificial Intelligence as a replacement and enhancement of the human intervention. Together with the Drone Observatory of Politecnico di Milano it has been chosen to join the academic study field of “search and recombination of knowledge” for immersing and directing the analysis of the combined utilization of drones and artificial intelligence. Thanks to a deep dive on the academic literature, starting from the schumpeterian idea that combining two different technologies may lead to the creation of something innovative, together with an analysis addressed to reach an first understanding on the state of art of drones and Artificial Intelligence, two research questions are proposed to be answered:

- *RQ1: which is the state of art of the drone solutions’ providers market?*
- *RQ2: which characteristics of the drones’ companies are related to the inclusion of Artificial Intelligence within their business proposal?*

In order to reach the goal of answering these two questions a double operative thread has been joined. For addressing the first question, together with the activities and events taken during the year by Drone Observatory of Politecnico di Milano it is performed an analysis with a specific focus on the solutions provided in the market which integrate the flying platform. The first outcome is a categorization proposal both for the hardware, the part of the drone related to data collection and operative actions, and for the software, algorithms addressed to data analysis and computation.

In light of the categories obtained by the analysis of hardware and software solutions of the companies operating in the market, provided by Drone Observatory of Politecnico di Milano, the categorization itself is applied to the application cases.

The application cases represent an indication of the current state of art of the effective employment of the drones solutions for operative purposes. Therefore two main outcomes from their analysis is in scope for this thesis:

- Drones' hardware and software solutions state of art: information on the tools employed for performing activities by drones are collected from the journal articles citing cases of drones' employment present in the Drone Observatory of Politecnico di Milano database. The previously proposed categorization of these tools is applied in order to understand the current presence in the market of such solutions and their main involvement purposes, both under task performed and business area point of view. This analysis finally allows a comparison with the starting point research from publicly available sources on the drones' market;
- Artificial Intelligence inclusion and trend: the most relevant information for this study collected by the analysis of the application cases regards Artificial Intelligence involvement in the operations described. A quantitative analysis allows to understand the trend among the years: database articles cover a time range of two years, from 2019 to 2021. The number of articles citing cases of Artificial Intelligence within drones' operations show a growing trend during this years, relevant fact for the recombination analysis: number of citations can be used as a proxy of the technological development and spreading of the combined solutions. The other point of interest of Artificial Intelligence is referred to the goal reached by this kind of

software involvement, that may be addressed to analyze data collected by the flying platform as well as to operative or navigation tasks.

This first point of focus allows to enrich and to provide updated hints on the currently available public information on the drones and Artificial Intelligence technologies, both under a technical and under a business point of view.

The second research question is developed after the analysis of the academic literature on the “search and recombination of innovative technologies” study field: drones and Artificial Intelligence are among the technologies part of the Industry 4.0 which is aimed to disrupt the market thanks to innovative solutions. The “search and recombination” field provides theoretical dimensions that impact company’s innovation strategy: they can be integrated within the drones’ environment in order to understand which variables may affect the Artificial Intelligence reconfiguration. Thanks to the annual Drone Observatory Politecnico di Milano survey addressed to drones’ players and to the players’ themselves answers, an econometric model is computed combining predictors, retrieved from the literature review, with the dependent variables stating the presence of Artificial Intelligence among companies’ business proposal.

According to the model outcome, the following three variables can be considered significant:

- Network inclusion: one of the main points stressed by scholars among their studies is that the inclusion within a “network of knowledge” can have an high impact on the companies’ business. It is a dimension strictly related with an open innovation strategy, where the different players, both from national and from the global market, create partnerships where ideas and expertise are exchanged. An innovative and growing environment as the drones’ one perfectly fits this idea, and the model in

particular shows a positive correlation between the network embeddedness and the Artificial Intelligence reconfiguration;

- Number of employees: a proxy proposed for including the size of the companies is reflected on the number of employees. This variable, according to the scholars studies, may impact the innovative activities of the companies due to many different reasons, such as the obstacles run by the firms when introducing changes in the business proposal that impact social aspects. The model outcome shows negative correlation between the number of employees and the reconfiguration performed on drones including Artificial Intelligence;
- Research and Development: the third observation collected by the model regards the R&D expenditures of the companies dedicated to drones' innovation. Scholars highlight how developments starting from the combination of different other technologies may be expensive due to the difficulties faced by companies in putting together different sources of knowledge. Two technologies not affine between themselves may lead to a raise in term of costs for the firms, both under technical and organizational points of view. In this case, the model shows negative correlation between the level of R&D investments in the drone area and the employment of Artificial Intelligence.

At the current stage the literature on “search and recombination” topic is developing including an increasing number of different use cases. At the same time there is no evidence of a conducted analysis on the recombination between drones and Artificial Intelligence, therefore this study proposes an explorative method to approach the topic. The previous

studies have been analyzed and immersed in the world of drones, including assumptions for the reasons of their involvement and explanations on the obtained results.

Instead, more academic papers that technically approach the Industry 4.0 technologies, among with drones and Artificial Intelligence play a central role, are found. Though, none of them deepen the analysis on what concerns the development of the combined use of these technologies employing the point of view here proposed.

The evidences resulting from this study enrich both these fields, on one hand proposing an explorative method for approaching the analysis of an innovative segment; on the other hand the Industry 4.0 literature is enriched through a managerial analysis with respect to the event of recombining two of the involved technologies.

6.2 Limitations of the research and future developments

The choice of performing the analysis of an innovative segment as the drones' one, under a point of view retrieved by the involvement of the current of "search and recombination of knowledge" is both challenging and risky.

It is challenging due to the fact that the combination in scope is quite different from the cases proposed by precedent scholars who have approached the area: the common basic idea was that two completely different knowledge fields combined between them may lead to a completely new one that may be disruptive for the market. In this case it has not analyzed how different the technologies are, assuming as the starting point that they come from different sources.

Moreover, most of the cases involving recombination use cases include the patenting approach: the variables involved are analyzed considering possible patents as result. In this case there it is not joined this way due to the fact that the recombination doesn't lead to a patent obtaining, therefore the evidences of the literature are revisited joining subjective

considerations. Patents involve a quantitative dimension in the result, while in this thesis also qualitative information are processed to be included within the econometric model.

It could be also seen as a risky approach since there was not strong evidence that the model proposed by “search and recombination of knowledge” could have been applicable to the drones’ environment. Instead, some of the considerations collected by the literature review enhance the analysis on some specific areas which could boost the environment development. The involvement of subjective factors in building the model open the points that a change in some of the assumptions could lead to different results.

Most of the companies belong to the category of “startup”: this fact implies a lack of historical data that may lead to more aggregated and quantitatively supported results.

The survey used for building up the model present some questions that may be replied in biased and imprecise mode: some answers provided on the innovation strategy may be guided by the gut feelings of the responder rather than by a concrete reason. This also because since the young age of the market the companies aren’t on a maturity phase yet, which implies not having a clear image on the change management and innovation strategy. The econometric model variables themselves are aggregated joining subjective approach: the answers of the questions are organized joining some assumptions which, in case changed, may lead to a different result.

As an explorative thesis, it is here presented a first approach towards this business field analysis which includes specificities from the academic topic of “search and recombination of knowledge”. Some possible future improvements are here proposed: first of all not all the themes of “search and recombination” are included in the analysis. They cover many aspects of the business area of a company, therefore there is space for approaching them one by one and immersing in the drones’ environment.

As research method it is employed a survey proposed by Drone Observatory of Politecnico di Milano: some of the points approached may not have been exhaustively addressed by the questionnaire. Involving the company strategy analysis, a direct interview with some interesting players could be effective for the purpose.

A possible developments may be related to the round largening: the model is built up thanks to the answers of 55 players, largening the round may lead to new specificities not evidenced by the current study.

In light of what obtained by this study research a point of analysis could be a deep investigation on the drones' network: many different hints are provided by the literature with respect to the different shapes that a network may have. In fact there are points both on the internal network, meaning the individual roles within the firms, and external network, meaning the players currently operating along the firms for enhancing the technologies.

It will be of interest the analysis on the results for the firms of the occurred recombination, showed by the analysis on the companies' financial fundamentals.

On this regard a focus could be put on the costs needed for the effective recombination of the technologies in scope: from this thesis it results a negative correlation between high R&D investment and the AI inclusion, but further studies may develop and deepen the analysis in order to reach a solid answer for a possible positive result of the Artificial Intelligence involvement within the drones' operations.

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