Semantic voice search in IETP: filling the gap for maintenance 4.0

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Abstract

Purpose – A framework is being developed to help Integrated Electronic Technical Publications (IETP) consultation inside and outside the aviation maintenance hangar. The expected results are the reduction in time to access the desired IETP and to assist mechanics while performing maintenance tasks using voice recognition.

Design/methodology/approach – The work is being conducted based on literature review and consultation with mechanics from the aviation industry, through questionnaires. The development will be made through study cases by building a core search engine and mobile applications to support the mechanics during the maintenance activities.

Findings – The identified problem in small maintenance shops and defence organizations suggests that IETP are not entirely accessible before and during the maintenance activity. Such organizations suffer from information and communications technology (ICT) low infrastructure capability and demand access to multiple IETP databases as they usually support different aircraft. To have access to the IETP through voice assistant application will help mechanics to access the IETP, including when they would be with dirty hands and having difficulty in using mobile devices with touch displays.

Originality/value – The framework being developed will give mechanics the ability to quickly find any existing IETP to support its maintenance task at any time and in any place with low demanding for ICT infrastructure. The architecture will support different applications, and the identified priority is for IETP viewers to the most demanding functionality of specification ASD S1000D. This approach could also help in troubleshooting activities since COVID-19 brought new demands for the social distancing for mechanics.

Keywords Information management, E-maintenance, Aviation safety, Intelligent maintenance

Paper type Research paper

1. Introduction

In the industry, maintenance is almost entirely developed by human beings who must perform tasks defined in manuals. Each task can be established in documents from different sources, either by the original equipment manufacturer (OEM), or by the system's operator or agencies that regulate the safety of maintenance activities. In each maintenance task, mechanics need to access these documents which need to be updated, accessible and organized so that a work order can be carried out correctly.

The difficulty occurs in consulting the various manuals and documents, called technical publications, due to the large volume of pages that these manuals may contain. Based on that, a technological convergence for Integrated Electronic Technical Publications (IETP) has been made available in the appropriate information systems and databases, like the specification ASD S1000D (ASD, 2018)

In the aviation sector, for example, in the United States of America alone, in 2012, there were almost 4,100 specific aeronautical maintenance companies, where more than 80% of them had less than 50 professionals to perform the tasks (Johnson, 2012). This finding means that these professionals are responsible for the diverse demands, often in more than one type of equipment, continually requiring access to the databases of technical publications regarding the aircraft they support.

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Maintenance, repair and overhaul (MRO) companies and also airliners already have computerized maintenance management systems (CMMS). CMMS have modules and, in general, have a technical publications module capable of providing technical publications to the mechanics, in digital format, connected to the digital working order. But someone must create the maintenance package for the working order to being delivered and attach to them the right publications. This approach works efficiently with preventive maintenance and when the organization has resources to do the job.

Small industries and shops cannot establish a dedicated team for that and do not have the same information and communication technology (ICT) infrastructure as the more prominent industries. Also, the small shops support general aviation that also demands a significant amount of reactive maintenance. For preventive maintenance, the task is easy to define and to deliver the right procedures, but many times, it is not possible when reactive maintenance happens. In such cases, a troubleshooting procedure has to be made in advance to schedule preventive maintenance, and Fault Identification Manuals (FIM) has to be accessed to help the mechanic to find the problem.

IETP and Integrated Electronic Technical Manuals (IETM) are published as the documentation to help mechanics and operators to keep and operate the systems. These class of documents have to be consulted during the maintenance activity and depend on the way the organization can provide the right information to the mechanic responsible for the working order (Szymanowski *et al.*, 2010). Small shops and other maintenance organizations may operate many different systems that have their IETP/IETM documents available in different databases.

As an opportunity to bring a technical solution for this necessity, the current project seeks to provide a smart search tool for maintenance activities among different databases. The benefit is to help the mechanic to find the correct maintenance task among the various collections of manuals and existing advisory guidance for the system of interest, keeping maintenance activities safe and reducing access time to relevant information.

The proposed framework is in development and uses the specification ASD S1000D (ASD, 2018), which is becoming the Industry 4.0 standard for technical publications access (Szymanowski *et al.*, 2010). The search engine will use voice recognition, allowing the mechanics to have the information, even with dirty hands that would prevent a search in traditional mobile devices with virtual keyboard interfaces. It is expected that the approach will help reduce the technological gap in organizations not ready for the Industry 4.0 paradigm.

The paper is structured in four sections after the Introduction. Section 2 describes the researcher's perception based on a survey in the defence area. Section 3 will show the state of the art in terms of technical publications integration and search engines. Section 4 describes the proposed framework, while Section 5 presents the conclusions and future work.

2. Context and motivation

In the aviation sector, maintenance plays an important role to keep the aircraft available for flights. With COVID-19, maintainers have to sanitize the plane during the turnaround time, and to do it in the right way is as vital as any other maintenance activity. Also, the maintenance activity suffered from social distancing, reducing the possibility of using many mechanics in the same working order if only one is necessary. Because of that, the remote access to experts and IETP became current as the preferable way to work in shops and MRO, reducing the possibility of contamination by paper manipulation and transfer of knowledge by talking to each other in the same environment that may be a closed space.

The mechanics have many tasks to execute during a week, and some of them support more than one aircraft model. Even when the mechanic has experience with the system, he/she must check the maintenance task list in the technical publication because the task could have been changed since the last time the maintainer executed the same procedure.

Because of that, every time a work order is generated, the task procedure must be accessible to the maintainer to be consulted. The big MROs and airliners use maintenance systems that are capable of producing paperless work orders with digital links to digital technical publications. Most shops and small MROs do not necessarily have this capability. To help those companies that are not prepared for the Industry 4.0 paradigm, the current project is working to generate a framework to support mechanics to find the right publication, promptly, reducing the technological gap and improving safety and revenue for those companies.

Another identified scenario for maintenance aviation is in the defence sector. Many military maintainers have to work on legacy systems that were manufactured decades before and are still using manuals in paper or files in older formats that are not easy to handle in digital systems. Also, their environment does not have the same ICT infrastructure as the challenging commercial aviation industry does. As new commercial aircraft demand a robust ICT infrastructure, it is easy to find modern solutions in the airliners. However, this is not so usual in the context of the military and general aviation.

This project was initiated based on the survey from a military organization that has mechanics that support more than one air asset. The findings identified in the questionnaires answered by 24 mechanics are described in Figures 1 through 8 and briefly discussed. The environment is not prepared for the Industry 4.0 paradigm, having poor ICT infrastructure and no Internet of things (IoT) utilization to support the maintenance processes.

The maintainers' group is considered to be very experienced and also mature. All mechanics are male, and the majority work is inside the hangar, at different shops. The study received 24 answers from 54 professionals in total. The shops that attended the questionnaire were from air armament, avionics, structures, flight equipment, cells, hydraulics, inspectorate and engines. From the 24 mechanics, 15 of them (62.5%) have more than 40 years of experience, while only 3 (12.5%) are aged under 30 (see Figure 1). Only 5 of all the 24 have less than ten years of experience in maintenance activities.

Only seven from the 24 (29.17%) are qualified to work in all the assets they are supporting. The organization takes care of three different aircraft, and all the aircraft have more than 20 years of the project lifetime. One of them has received a mid-life upgrade in the avionics, but

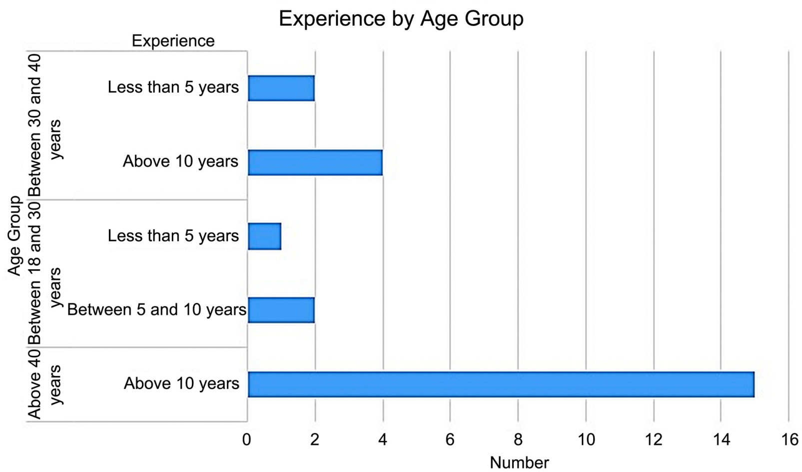

Figure 1.
Experience by age group

the rest of the model's system remains the same. In this case, the mechanics from the avionics system have to learn everything about the new modules, as nothing about the old ones has remained the same.

In such situations, one mechanic who has taken the course must be present with the not-qualified ones during the maintenance activity. Not necessarily, the mechanic who does not have the asset course is not prepared for the task or is not experienced in the asset. This situation happens when the mechanic does not have the opportunity to take the course but help others in the maintenance activity in the aircraft he is designated for (see Figure 2). The demand for IETP consultation increases in this scenario.

Figure 3 shows that almost 42% of the mechanics have difficulties in accessing the intended technical publications, giving the localization or unavailability of a computer or printed manual.

Even when the computer is available to print the necessary pages for the working order, the desired topic is not always easily found. As Figure 4 presents, 58.3% of the mechanics have difficulty to find the right topic to execute the maintenance task. There is no team to prepare the working orders with the printed manual pages or with the manual's digital version.

Another aspect that shows the necessity to help such an organization is the way it handles the technical publication during the task execution. Depending on the printer and mobile devices available, the mechanics have different ways of behaviour. From the 24 professionals, 15 (62.5%) consistently print the manual procedure to use during the maintenance activity (see Figure 5). In other answered questions, the mechanics responded that they prefer to use mobile devices, but the ICT infrastructure is not prepared for that.

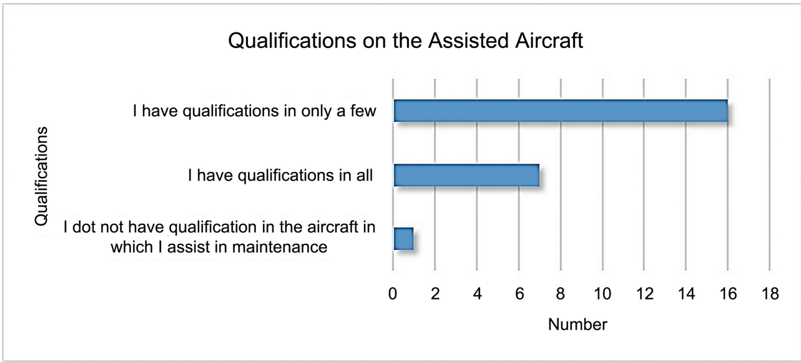

Figure 2.
Qualifications on the assisted aircraft

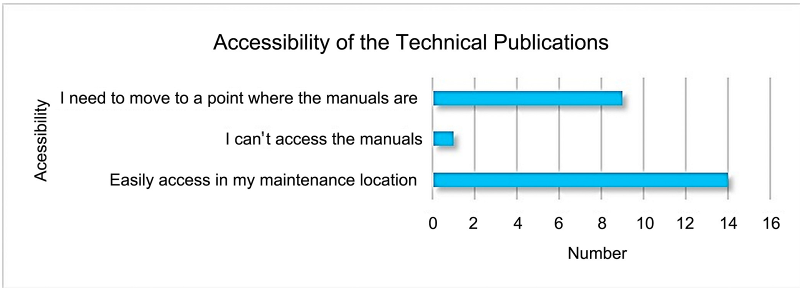

Figure 3.
Accessibility to the technical publications in the mechanics environment

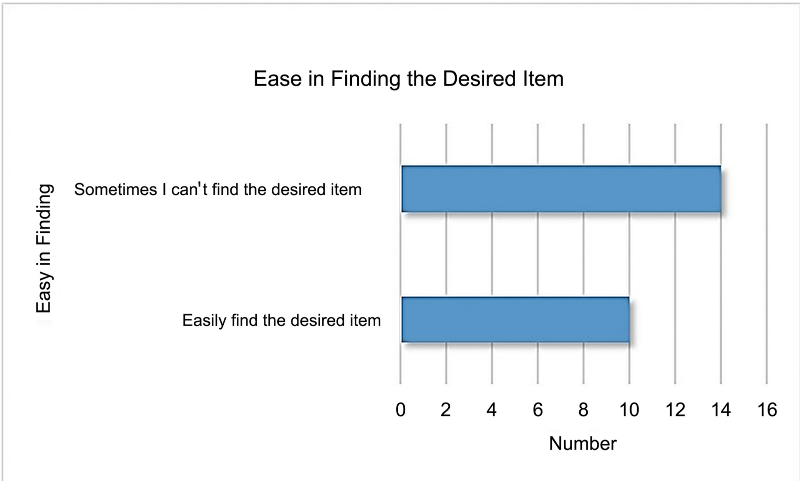

Figure 4.
Ease in finding the desired information

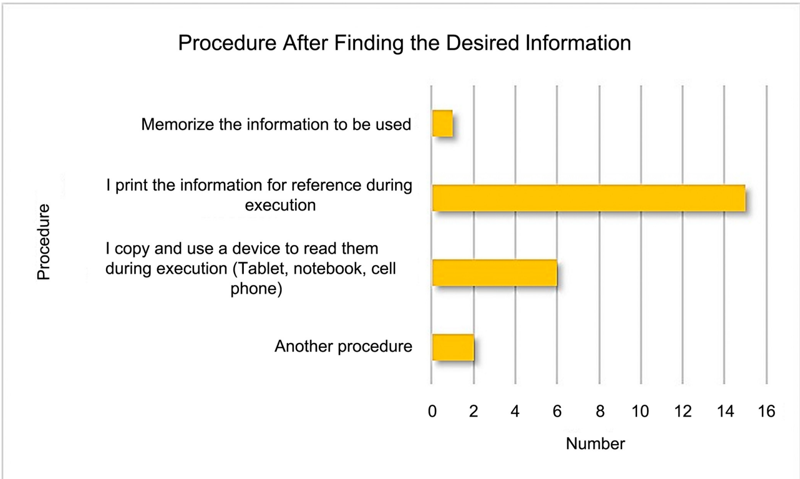

Figure 5.
Technical publication handling during the maintenance task

Figure 6 presents the time spent performing maintenance. The majority of the mechanics work more than 3 h a day in maintenance tasks, and almost 55% have to consult the publications for more than 30 min while working on the activity (see Figure 7). The amount of time provides an important finding that the mechanic has to manipulate the manual in different situations. Many times they are working inside the aircraft structure with low light and constrained space, and many times they are lying down under the aircraft. Depending on the situation and the task complexity, the mechanic has difficulties in handling printed pages. There are several alternatives such as remote human assistant, augmented reality devices and text-reading digital assistant, but all of them need an improved ICT infrastructure.

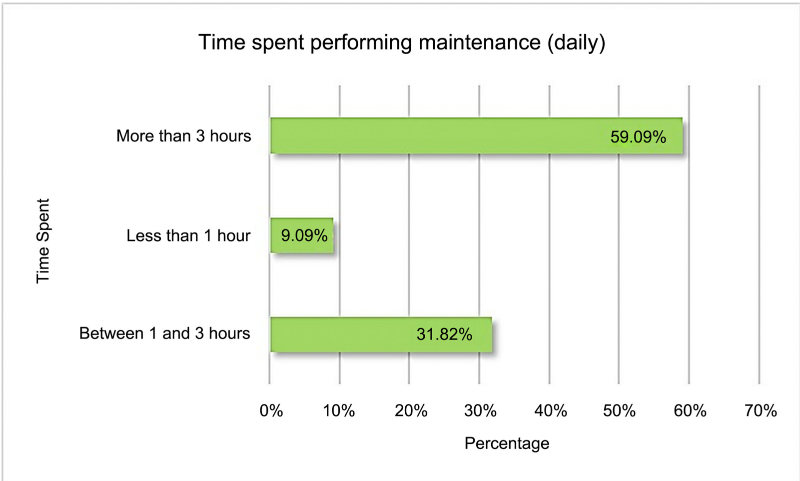

Figure 6.
Time spent performing maintenance

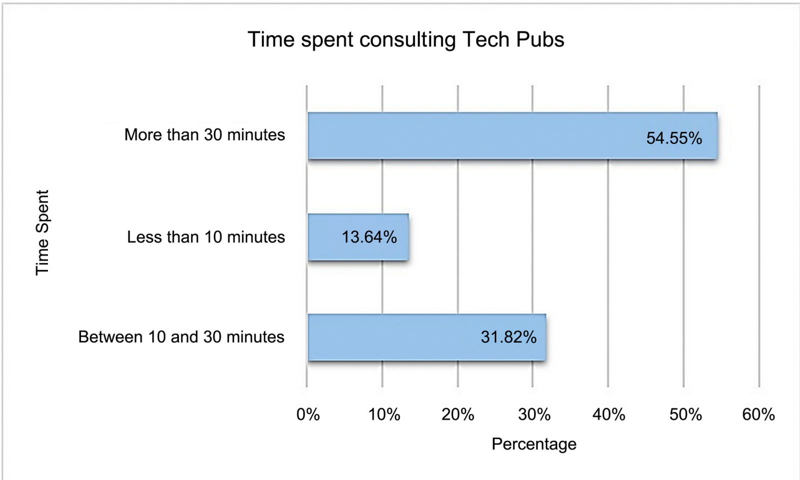

Figure 7.
Time spent consulting technical publications

The mechanics showed the interest in using mobile devices to access the IETP/IETM content during their service execution, and the study is being conducted to identify the possible gaps in IETP/IETM accessibility in a maintenance environment.

Based on the possibility to have IETP/IETM being delivered to mobile devices, the researchers are looking at the IETP viewers' capabilities. IETP viewers are used to accessing the documents in many kinds of devices, including notebooks, smartphones, smart goggles and tablets. The viewer allows the user to interact with the digital content, depending on its capabilities.

However, mobile devices could bring another problem to the maintainer. Depending on the platform, the search engine interface's text size may induce some difficulties to the user. More than 58% of the professionals make use of corrective lenses to work (see Figure 8). This problem was also identified in other industries, and not only in the maintenance role

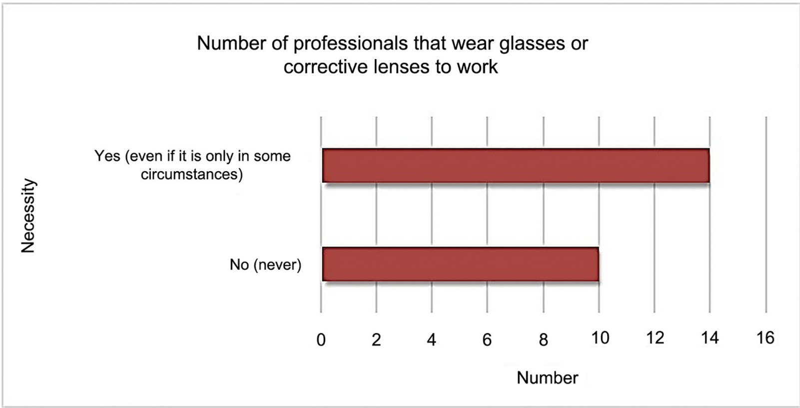

Figure 8.
Use of corrective lenses to work

(Martinetti *et al.*, 2019). Because of the age, this is not something that we may ignore, and the possibility to use voice, instead of writing, could increase the efficiency during the consulting phase of the IETP.

The chapter 6, issue 5.0, of the specification ASD S1000D (ASD, 2018) presents a functionality matrix in chapter 6 for issue 5.0 of the specification. The matrix also declares the degree of complexity of each function that a viewer could exhibit. It suggests that use of voice for content access and to search across multiple databases is most complex in terms of functionalities for a viewer to implement, with the exception to be capable of producing a fully formatted book version of the manual. Because of the way the electronic devices make use of digital content (hyperlink, video and audio) available in an IETP/IETM, it is harder to produce a conventional book, even in electronic format.

Figure 9 shows the IETP publication process and consultation. The present work is aimed to help applications that demand a viewer to present the available content to the users, depending on their profile. Applications must provide content to maintainers during the execution of the task, and the viewer is the interface with which the user can interact with the IETP.

The survey also asked professionals about the use of voice in the search engine for mobile devices. The result was a significant consensus on the use of technology. Only two had doubts about whether the use of voice in the search engine can help their work.

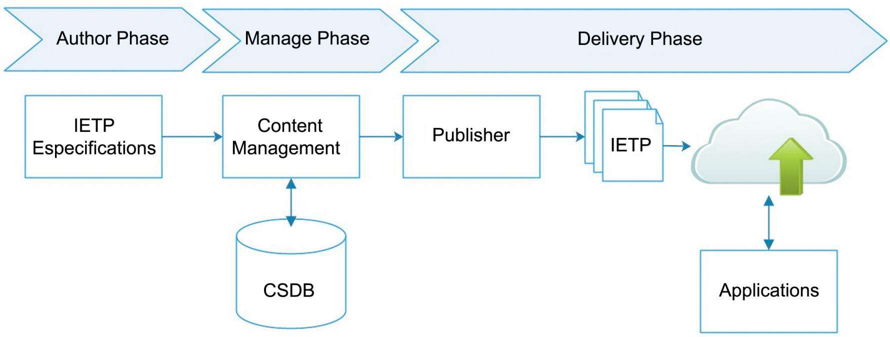

Figure 9.
IETP publication process and consultation

As seen, it is necessary to identify the ICT infrastructure to help solve the organization's problem in terms of technical publications accessibility. The proposed framework is an attempt to improve the accessibility and reduce the effort of the mechanics during the publications consultation while executing the maintenance tasks. The next session will provide some literature review about the state of the art in terms of ICT infrastructure and smart search engines by voice activation.

3. Literature review

The present section addresses the necessity to identify solutions to support the viewer development with voice. The literature review is divided into two topics that describe the ICT infrastructure and the search engine to enable the solution to the declared problem at this level of the framework development.

3.1 Information and communication technology infrastructure

Defining a reliable ICT infrastructure is essential to consider a couple of factors in terms of people, processes and tools as presented in the previous section analysis. This section explores similar approaches and available ICT tools and services to support smart and ease of access to technical documentation.

The current state of cloud computing provides the research community and solution providers with a wide range of tools and services which can be combined into solutions for almost any research/business problem today. It is essential to mention the available service offering and responsibilities each model applies.

In terms of cloud service offerings, NIST (Mell and Grance, 2011) defines three cloud computing models: software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS). In the SaaS model, the consumer does not manage or have responsibility for the underlying cloud computing capability provided. In PaaS and IaaS models, respectively, the consumer has more in-depth control of the underlying platform and infrastructure assets as well as the responsibility to manage.

For small industries and MRO shops, a SaaS-based offering would be a better fit. Since the application runs remotely, it reduces the need for support and maintenance, and there is no need for complex installation and setup in the customer's computers and datacenter.

There are a couple of recent trends in information technology, which are relevant to this research: microservices in a service-oriented architecture (SOA), serverless computing and voice assistants (conversational interfaces).

Microservice architecture can be considered as an evolution of SOA, whereas the software is a breakdown in smaller pieces of functionality, working independently of each other. This approach reduces the coupling of the modules of the software application as opposed to the large monolith applications. Also, software maintenance and support tend to facilitate due to this isolation of functionalities and responsibility.

Serverless computing is a cloud model in which the cloud provider has all the capabilities to manage the virtual machines as necessary to serve requests. Also, the organization that owns the system does not have to purchase, rent or provision servers or virtual machines for the backend code to run on.

Voice user interfaces (VUI) is present in everyday life, embedded in personal computers, smartphones and dedicated voice assistant devices. Some popular examples available are Apple's Siri, Amazon's Alexa, Amazon's Echo, Microsoft's Cortana and Google Home. They can understand what people are saying, in different languages, make calls, play games, buy goods and control VUI-enabled home electronics. Porcheron *et al.* (2018) present a study on home usage of VUIs in how they become a seamless part of the home instead of an isolated event.

There has been lots of progress on VUI in terms of the effectiveness of natural language processing (NLP) in Application Program Interfaces (API) and Software Development Kits (SDK) to support such applications. Nonetheless, there are a lot of research opportunities on novel approaches to the use of technology, which is not limited to conversational interfaces or smart homes. The aim of the present work is an application of voice technology in a maintenance shop.

The voice assistant is also a possible user interface that can help technicians to continue their work when handling mechanical parts with grease-stained hands. The mechanics complained that they sometimes have to stop and wash their hands to be able to pick up manuals or devices. The work of Böğürcü (2019) showed how hard it might become to use displays with virtual keyboard interfaces to input text for search in IETM interfaces.

In the field of e-Maintenance, Kour *et al.* (2014) propose a cloud-based environment to support railway maintenance decision-making based on condition monitoring and online data acquisition. The workloads of filtering, fusing and analyzing data, as well as integration, are processed in the cloud. A key point in the designed architecture is the use of XML (eXtensible Markup Language) as a means of data interoperability and provision of web services for integration between consumers. Also, the following modules compose the cloud infrastructure: computer servers, SQL database server, FTP server, web server and messaging server.

Also, in the railway industry, Weijiao *et al.* (2015) address an integrated solution of technical information management for China's high-speed trains from authoring to delivery phases. The proposed IETP is an adapted solution from their work and is based on XML open standards and the international specification ASD S1000D (ASD, 2018), which is relevant to the aviation industry. One of the benefits of this approach was to publish both a PDF format adapted to different customer needs and an electronic IETP format data targeted at web/mobile interactivity, and fundamental technical information transfer to other information systems and integrations. The smart search tool, to be discussed later, will be indexing the content of this kind of IETP data to improve user effectiveness while looking for technical data.

Based on the ASD S1000D specification (ASD, 2018), technical publications are designed in modules. Data modules (DM) store the decomposed technical information in a hierarchical structure as XML or Standard Generalized Markup Language (SGML). Each DM is an independent unit of information, and it can contain a variety of information related to the equipment or its parts such as descriptions, procedures, repair information, checklists and diagnostic information.

Peng *et al.* (2015) present an application of IETM design to assist in intricate troubleshooting work. The authors claim to have significant improvements in equipment's supportability. The proposed infrastructure consists of a three-tier application architecture: presentation, business (domain) logic and data access tiers. On the data layer, a Common Source Database (CSDB) was implemented using a traditional relational SQL database.

The use of a search mechanism for IETM information retrieval is proposed by Wu *et al.* (2016), and as it points, the search results are efficient, fast and have high accuracy. The architecture consists of the components: IETM database, IETM file storage and a search index database based on Apache Lucene. Lucene is a free, open-source, full-text search framework (Apache, 2020). It has been widely adopted by commercial and open-source solutions such as Apache Solr and Elasticsearch. Nevertheless, due to the approach limitations, the authors recommend future work on improvement of semantic integrity and precision.

Based on the literature review reflections, a cloud-based architecture for maintenance applications is being developed, as shown in Figure 10. The cloud should be built using auto-scalability features, microservices and serverless services whenever possible. Doing so will

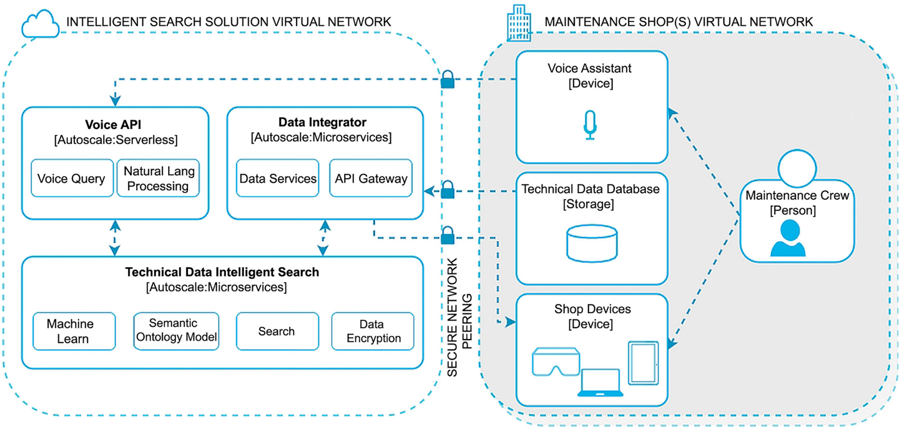

Figure 10.
Cloud architecture for maintenance applications tied to IETP intelligent search

allow access to the cloud to multiple tenants while minimizing costs and the need for support. The main idea is not only to support IETP viewers but also many services that can use the same ICT infrastructure.

In the architecture, the connection to the cloud environment should rely on open standards using HTTPS protocol and REST-based XML Web Services. Representational State Transfer (REST) is preferable architectural style due to less payload size, and it targets fast performance. Also, a secure virtual private network (VPN) is recommended to establish peering connections through a secure channel.

Regarding the proposed modules, Data Integrator should be responsible for providing services to expose the system services through an API Gateway and to retrieve up-to-date IETP/IETM information available on the shop's network. In addition to web services, it should also be capable of integration through file servers such as FTP. Voice API integrates with assistant devices. The selected framework should provide the following capabilities: multi-language support, conversation framework for user interaction and web services end-points to combine with the intelligent search.

The Technical Data Intelligent Search is the core component of the solution as it securely stores the indexed content based on a machine model of IETM/IETP ontology. Also, it provides API end-point for information retrieval and filtering the results. The following section presents a brief literature review on information retrieval.

3.2 Search engine

Bhopale and Tiwari (2020) declare that the power of swarm intelligence and advances in data mining techniques can solve the information retrieval (IR) problem in a rapidly growing digital content. They proposed a swarm optimized cluster-based framework with frequent pattern mining techniques to retrieve specific knowledge from extensive document collections.

According to Arroyuelo *et al.* (2020), there exists a wide range of valuable time-space trade-offs for implementing positional ranking functions. And, in alignment with Merrouni *et al.* (2019), with the growth of electronic data, existing retrieval data and systems ignore information about the user and the context. Considering this scenario, Merrouni *et al.* (2019) emphasizes the importance of context in information retrieval to improve the retrieval systems and proposes a framework to break down user context characteristics and model them into the information retrieval system.

During the study conducted by Marchesin *et al.* (2020), two state-of-the-art Neural Information Retrieval (NeuIR) models were reproduced and tested: the Deep Relevance Matching Model (DRMM) and the Neural Vector Space Model (NVSM). Trying to replicate the DRMM and NVSM, they noticed the importance of sharing the tool used for document pre-processing.

According to Guo *et al.* (2019), ad hoc retrieval seems to be the most suitable technique when leading with IETMs and IETP. It is a classic retrieval task in which the user specifies his/her information needed through a query which initiates a search (executed by the information system) for documents that seem to be relevant to the user. The term ad hoc refers to the IR from documents which remain static while queries are submitted to the system continually. The retrieved information is returned as a ranking list through a model where those that are highest ranked are more likely to be relevant.

3.2.1 Ad-hoc algorithm formulation. Since the search for content in the IETP/IETM takes place in a highly dynamic operational context such as the maintenance hangar, that is, in an environment where safety is primordial, the mechanic's queries must be answered in as precise and as correctly as possible. In this scenario, semantic searches, which consider the searchers' intent, context and query meaning, are recommended for this framework.

Indeed, the unified formulation, reviewed by Guo *et al.* (2019) to substantiate the neural network ranking model structure and use, addresses this requirement proposing a solution that considers both semantics and context from the textual query. Also, the word embedding model, described in depth by Harris (1954), is particularly useful to map the meaning of the question considering the context. In addition to it, as previously stated, semantics and context are essential to produce a significant search result, not only because of the highly dynamic operational environment aforementioned but also because of the World Wide Web not being the primary source of information. In fact, in this work context, IETP are the primary sources of information.

As described by Guo *et al.* (2019), the neural ranking model with deep neural networks has demonstrated remarkable results in an operational scenario in which context and semantics are paramount to obtain an effective information retrieval (IR) system. The formulation, for the ranking function ”*f*” here adopted, is the same proposed by Guo *et al.* (2019), which is as follows:

$$f(s,t) = g(\psi(s),\ \phi(t), \eta(s,t)) \tag{1}$$

(1) *s*: generalized query set (textual natural language questions or input utterances);

(2) *t*: generalized document set (IETP, IETM or electronic documents);

(3) *f*: ranking function;

(4) ψ: representation function which extracts information from *t*;

(5) ϕ: representation function which extracts information from *s*;

(6) η: interaction function which extracts features from the pair (*s*, *t*);

(7) *g*: evaluation function which computes the relevance score based on the representations and interactions;

According to Chen *et al.*, (2009), for most neural network approaches, functions ψ, ϕ and η are usually fixed manually defined functions. The evaluation function *g* can be a machine learning algorithm, such as logistic regression or gradient boosting decision tree. All four functions ψ, ϕ, η and *g* will be encoded in the same network structures, and the inputs will be raw text and input utterances that will be transformed in word embeddings.

3.2.2 Algorithm architecture. Based on the reported results by Guo *et al.* (2019), in general, the asymmetric-document split format, interaction focused and multi-granularity architecture work better with the ad hoc model. According to Robertson and Jones (1976), splitting the source document used to identify the answers, in our case the IETM or IETP, makes sense since a long document is probably partially relevant for a specific query, and having the document already divided improves search efficiency.

A study case has been presented by Fan *et al.* (2018), demonstrating that the split format can significantly outperform state-of-the-art ad hoc retrieval models. In this specific study, the function η was defined as the cosine similarity, while the evaluation function *g* was used to include the local matching layers and global decision layers. As also described by Guo *et al.* (2019), interaction-focused architecture has achieved remarkable results in the ad hoc information retrieval. The underlying assumption is that relevance is in essence about the relation between the input texts, so it is more effective to learn from interactions rather than from individual representations directly. This model defines the interaction function η rather than the representation functions ϕ and ψ, and uses a complex evaluation function *g* usually in the form of deep neural networks to perform the interaction and produce the relevant answer.

According to Guo *et al.* (2019), another option is the multi-granularity architecture, which assumes that relevance estimation requires multiple granularities of features. So, the representation functions ϕ, ψ and the interaction function η are no longer black-boxes to *g*, and the language structures in *s* and *t* are considered.

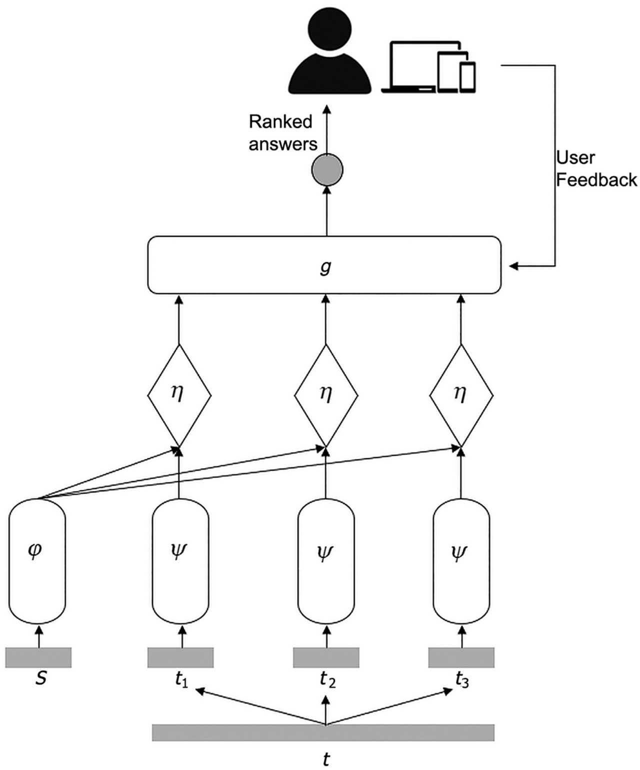

Figure 11.
Ad hoc hybrid information retrieval architecture supported by reinforcement learning

Based on the asymmetric-document split format, interaction focused and multi-granularity architecture, we propose an ad hoc hybrid information retrieval architecture supported by reinforcement learning, as illustrated in Figure 11. Since the operational scenario in which the ranking algorithm will operate lacks historical and training data, the learning process will have to take place over time through the usage of the algorithm itself.

The source document t used to identify the answers is split ($t1$, $t2$, $t3 \ldots tn$) to improve search efficiency. Once the query set s is informed, representation functions ϕ and ψ extract information from s and t, respectively, using word embedding models. Thus, the information is analyzed and compared by the interactive function η that sends the results to the evaluation function g, which computes the relevance score and makes available the ranked answers to the user.

The user employs the selected information and sends the feedback to the intelligent agent, that is, the evaluation function g, about the efficiency of the answer. With the feedback, the evaluation function readjusts the ranking model in a continuous learning process fed, overtime, by the user and the environment.

The ad hoc hybrid IR architecture supported by reinforcement learning presents the following comparative advantages in comparison with previous models:

(1) Context-aware: the algorithm, using word embedding models, is capable of analyzing the context during the interpretation of the query;

(2) Efficiency: by splitting the document source information, it is more efficient in terms of process time and searches result;

(3) Learning process: it does not need a large amount of historical data to train the model since it uses the reinforcement learning technique. Thus, it can be used in those operational environments in which the historical or structured information is not available.

The algorithm will run in a cloud environment to be rapidly accessed by the user through voice and text searches on commercially available multiplatform devices connected to the Internet. Based on the identified ICT and search algorithm in the literature review, the next section will show the proposed framework to tackle the IETP viewer infrastructure solution for multi-database search.

4. Intelligent search tool

The proposed approach to help maintainers in the challenge to find the required IETP is the Intelligent System Interactive Voice Search Tool. Its core is the Intelligent Search Tool that is composed of a semantic search engine, a query database and a machine learning task identification. The other elements that support the solution are an Intelligent Data Integrator, a Machine Learning Test Box, a Multilingual Technical Dictionary and a Voice Assistant. The application will be accessed by different devices in the maintenance place, depending on the mechanic necessity and the available ICT infrastructure. Figure 12 provides a schematic of the approach.

The solution should provide the capability of IETP consultation through IETP viewers and is agnostic to the viewer technology. The approach gives freedom in the implementation and also the opportunity to be reusable. The viewer application could be embedded in any kind of device for the maintenance purpose, as shown in Figure 12, in the maintenance place.

IETP include not only texts but also photos, audio files and videos. In such circumstances, the files must have metadata to help the search engine. Depending on the system complexity, an ontology should be provided to facilitate the search engine fine-tuning and context

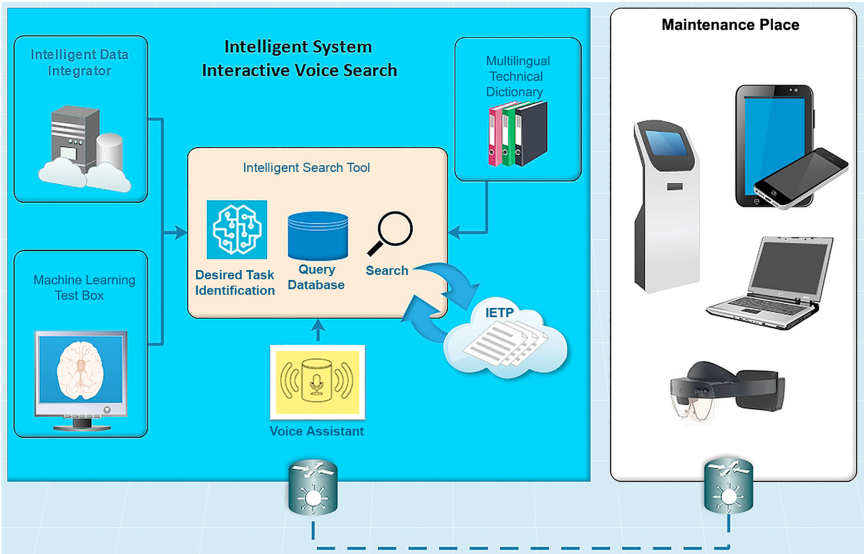

Figure 12.
The intelligent system interactive voice search approach

analysis. The ontology description will be part of the Technical Data Intelligent Search microservice, as explained in Section 3.1.

The Machine Learning Test Box is responsible for helping the development team to adjust the parameters in different scenarios of usage. Depending on the IETP and IETM metadata availability, the parameters may be modified, and the application could help the user to learn. In scenarios like that, if each mechanic has its profile, the viewer app would be selective for the type of user activity, such as a custom application.

The diversity of devices is another challenge. As an example, smart glasses like Microsoft Hololens 2 are capable of voice assistant usage, and the display interface of the viewer could show the 3D model animation of the desired task execution overlayed in the real object. There is no limit for the IETP viewer utilization, but it demands a lot of implementation. Not all mechanics are familiarized with holographic animations, and the use of smart glasses in heavy maintenance is still many years ahead because of the price and level of integration needed for the solutions.

The Intelligent Data Integrator is responsible for the framework capability to access multiple databases. Depending on the user query, the integrator will identify the right database to acquire the desired information. If the information is based on a specific system, the rule manager will connect to the OEM database. If the information is regarding advisory guidance, the safety agency database or the airliner database will be accessed.

It is important to note that the framework is not capable of declaring if specific advisory guidance is the valid one or the latest defined by the authorities, but it can identify if it is the latest available in the database. So, the framework is not responsible for validating any kind of IETP available in the multiple databases.

The multilingual Technical Dictionary is a proposal to help the mechanics with manuals in languages other than their mother language. As manuals from the majority of aircraft are published in English, it is easy to understand that not all the mechanics are fluent in the publication language and will need some help with dictionaries. It is the responsibility of the mechanic to translate, not the viewer's, but to have the dictionary available can reduce the time the maintainer will loose trying to find a translation.

Some activities are developed far away from a hangar, and to find a dictionary to have certainty about the procedure may increase safety but reduce time. The approach is to not learn about the mechanic's difficulty with language, and machine learning will not be utilized to support the technician language learning skills.

The voice assistant may be any available in the market. The ICT framework should be capable of integration, depending on the user interface. The service has to be developed for multiple APIs support. The assistant is an improvement in terms of search capability in the IETP viewer. While it is not new in terms of technology and usage for search engines into the Internet, for IETP, it is not usual to find such functionality.

A proof of concept of the voice assistant had been developed using a subset of the ICT framework (Figure 13). In this prototype, a voice-activated drone application was implemented to execute a predefined route for aircraft inspection in a simulated environment.

This test scenario allowed a better understanding of the existing capabilities, potential bottlenecks and issues of integrating voice and other devices. In the communication between the cloud provider and the shop floor, both Voice API and Data Integrator components utilize standard HTTPS protocol over TCP. In terms of sub-components, the implementation used serverless computing for dispatching the Voice API commanded to be processed asynchronously on the API Gateway and relayed to the IoT device (i.e. drone).

Considering the integration was inherently asynchronous, this approach is limited to non-real-time applications since the real-time communication cannot be guaranteed. Nevertheless, no delays were noticed between the voice command and the activated IoT device as a preliminary result. A key consideration in the framework implementation is to address not only the bandwidth requirements but also keep network latency as low as possible.

The cloud-based framework with voice interaction capabilities provided a robust development platform and high capability of recognizing speech in different languages, as Brazilian Portuguese and American English. To give an ease-of-use and smooth experience, the design of the voice interaction should consider the definition of supported commands, confirmation prompts, outcomes feedback, supported languages, additional synonyms for desired outcomes and user voice authentication.

Other criteria to use the voice assistant is to have a device that is capable of noise reduction. As maintenance hangars are prone to be noisy, if the device cannot filter the noise, the functionality would not work. Because of that, the proposed application also has the text interface as a backup.

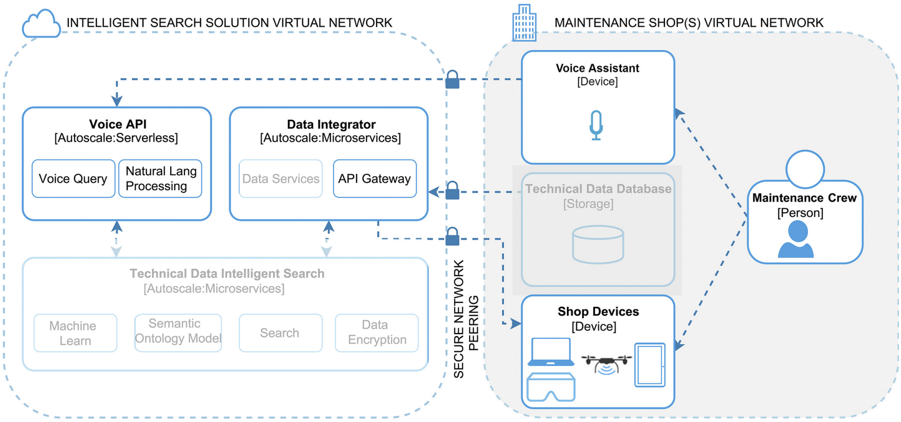

Figure 13.
Application using voice interaction with an inspection drone.

5. Conclusions and future work

The solution framework is a work-in-progress as informed in the introduction section. It is an approach to support IETP viewers to improve functionalities that are hard to implement. Because of the nature of IETP and IETM, there are not only text and index for a search engine to search. Depending on the files included in each digital document, the search engine would make use of metadata to achieve effectiveness.

The work was established based on a literature review about ICT infrastructure to support IETP and IETM search engines for viewer applications. The viewer app is capable of enabling visualization and navigation through published IETP/IETM and has to comply with ASD S1000D specification to show the desired content. The ASD S1000D presented a functionality matrix providing the complexity of each function that a viewer could have. The voice navigation and searching in multiple databases are challenging tasks that many viewers still do not have.

The solution presented is an attempt to answer the IETP viewer challenge. The main contribution of the approach is to provide a cloud-based service that can be utilized by different applications, as viewers, and with the ability to be voice-activated. The functionality can help technicians that make use of corrective lenses and have to use small displays to access the desired information. The voice application used in conjunction with a drone was implemented to identify the required capabilities to be integrated into the framework.

As future work, the IR algorithm will be developed as an intelligent agent using and being tested in real-world queries with IETP and IETM sources. Successively, the following steps will be the algorithm integration with the cloud system, information sources and voice search devices. The last phase would be to test the integrated solution in the operational environment.

It is expected that a real task could be implemented, and technicians could evaluate the solution and answer another set of questionnaires to identify if the solution brings efficiency to the process.

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