Message-In-A-Bottle: Engaging Stories Around Sustainable and Safe Wine Products

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Abstract

The wine industry has evolved thanks to the introduction of digital technologies in every aspect of the wine production chain and the emerging need of the food industry for qualitative, sustainable, and safe products. As a result, the incorporation of digital services that facilitate access to related data of wine products is crucial for wine enterprises to increase their competitiveness, customer loyalty, and market share in this highly competitive domain. In this work, we present the Message-in-a-Bottle (MiB) ecosystem, which exploits multi-dimensional and multi-sourced data for creating engaging and interactive stories around wine labels. We especially focus on the sustainability and safety issues in the wine industry and showcase how MiB addresses them. The ecosystem is developed in the context of the MiB project*and has already started to be available in the market through the Lyrarakis†wine enterprise.

Keywords: wine industry; sustainability; transparency; storytelling, digital agriculture; sommelier; augmented reality

1 Introduction

There is a growing trend in fostering food awareness, that covers the safety and nutritional aspects of food, as well as the sustainability of the related processes and the environmental footprint of the food supply chain [1, 2]. This trend also applies to the wine industry, as the wine audience requires access to data and information regarding various aspects of the wine product through traceability [3, 4]. For example, wine consumers and professionals are interested in details regarding the vineyard where the grapes were cultivated (e.g., soil texture, use of water and pesticides, etc.), the vinification process (e.g., use of water, temperatures, etc.), or the ingredients and characteristics of the wine itself (e.g., sugar content). This valuable information improves the transparency and awareness of the respective wine product and brand, and can potentially increase sales and profits by strengthening customer loyalty [5]. Moreover, consumers and producers alike may want to ensure the authenticity of wine bottles.

However, the valuable information that would allow these applications is not available to the wine audience, since it is stored internally in the database management systems of wine enterprises using ad-hoc schemas. In addition, there is a lack of information systems and applications that build on top of such information for aggregating specialized wine information and creating a value proposition for the wine audience. Such systems can facilitate consumers in making informed decisions about which wine to buy by letting them navigate through the available labels. In this way, users can examine the characteristics of each label and other relevant aspects (e.g., sustainability, traceability, authenticity) to pinpoint the wine that satisfies their multi-dimensional needs. This kind of awareness builds trust in the relationship between the wine producer and the consumer, benefiting both parties.

Additionally, the concept of creating a story from the available wine data (i.e., storytelling) can maximize the level of engagement and awareness of users to a specific wine brand [6]. Storytelling can effectively communicate the core values of the wine enterprise, by associating them with the product and its area of origin in a fascinating and memorable way that can emerge emotions [7, 8]. Storytelling has also been applied successfully in the wine industry as a

*https://mibproject.lyrarakis.com/

†https://www.lyrarakis.com/en/home

strong marketing and communication technique, especially in the wine tourism domain [6, 8, 9].

In this paper, we present the MiB system that was developed in the context of the MiB (Message-In-a-Bottle) project. The aim of the project is to exploit multi-sourced data, including data from sensors, to create a unique wine story for the labels of the Lyrarakis Winery[1]. Specifically, the users enjoy interactive wine stories that incorporate sustainability data as part of the story of a wine label, among various other data like viticultural, oenological, geological, and climatic details, the profile of the producers, and cultural information of the cultivating area. In addition, the consumer can validate the authenticity of any bottle of the Lyrarakis' winery through a crowd-sourced approach, which can be gamified and incentivized, strengthening the relationship between the winery and the consumers. Finally, MiB offers a recommendation functionality through the Le Sommelier application and an Augmented Reality (AR) experience through the AR application. The system is web-accessible and platform-agnostic and thus does not require downloading any specific app. In a nutshell, MiB offers the following functionality through its corresponding applications:

- navigate through wine products and their related features by providing a storytelling-based presentation of multi-sourced data, including sustainability data (Main App),
- recommend wines to dishes or vice versa (Le Sommelier App),
- register each bottle for validating the authenticity of the product itself and for providing information about counterfeit ones (Authenticity App),
- interact with a digital label in an augmented reality experience for selected labels (AR App), and finally,
- manage the data through a user-friendly front-end for wine producers (Admin App).

To the best of our knowledge, there is no other system that exploits real data to create wine stories covering also traceability and sustainability, and offering on top of them engaging interactive functionalities like food suggestions and wine authenticity. Although the system has been developed and tested for the labels of the Lyrarakis Wines S.A. wine-producing company, it is designed to be generic and can support other wine enterprises as well. Hence, the contribution of this paper primarily resides in the distinctive amalgamation of these elements, which distinguishes MiB from current systems and approaches. Furthermore, the potential extension of MiB for utilization in various wine enterprises and similar domains within agriculture and food amplifies its significance.

This paper is an extension of the works [10, 11] that presented earlier versions of the system. Here we describe in detail the deployed system and all of its aspects, including the sustainability and authenticity-related components and information.

[1] https://www.lyrarakis.com/en/home

The remainder of the paper is organized as follows: in Section 2 we present the related work regarding storytelling, traceability, authenticity, and sustainability in the wine industry. Section 3 analyses the basic characteristics of the MiB ecosystem, and Section 4 presents the applications. In Section 5 we provide more details about the sustainability data presented by the MiB system. Finally, Section 6 discusses the challenges in the wine industry along with future directions for the MiB platform, while 7 concludes the paper.

2 Related Work

In this section, we provide an overview of relevant literature in the wine industry pertaining to the use of digital technologies in the domain, storytelling, traceability, authenticity, and sustainability. After a general overview of digital technologies in the domain, we explore previous research that has examined the application of storytelling techniques, as well as studies focusing on traceability and authenticity aspects within the context of the wine industry. Finally, we discuss sustainability, which is at the core of the current challenges due to environmental trends.

2.1 Digitalization of the wine industry

The introduction of digital technologies to the wine industry has transformed the domain in various aspects that cover marketing, engagement, viticulture, winemaking, authenticity, transparency, provenance, and sustainability. Below we provide a small overview.

2.1.1 Digital Marketing and E-commerce

Digital marketing has become the backbone for wineries to engage consumers, drive sales, create brand and label awareness, and enrich their products with interesting stories that cover multiple aspects related to each label and brand. Such digital marketing tools include social media, dedicated mobile apps, multi-modal content marketing, and collaborations with influencers that can promote the corresponding content to a broad audience [12, 13]. In addition, traditional distribution networks have been replaced by e-commerce platforms that allow the safe and easy online purchase of wines throughout the globe [14].

2.1.2 Information Systems

Information systems that integrate the multitude of winery-related information, allow wineries to manage day-to-day operations. Such systems include enterprise resource planning (ERP) systems [15], that allow the storage, retrieval, and analysis of wine production, logistic and financial data, like wine production data, cellar operations, manufacturing status, barrel lot tracking, bulk wine receipts, supply chain and shipments, quality control, and lab analyses. They are an essential tool for the digitization of wineries and there are various commercial products available. Other examples of information systems include recommendation systems [16–18], GIS applications for viticultural areas [19], and monitoring systems of wine vineyards [20]. Such systems typically manage data ingested by the users or by sensors located at the vineyards [21], and can use a variety of technologies as front-ends (e.g., web apps, mobile apps, or computer apps implementing traditional 2D interfaces, or exotic 3D interfaces immersed in AR and VR experiences).

2.1.3 Precision Viticulture

Precision viticulture (PV) uses digital information acquired through a variety of means, to analyze and make informed decisions regarding the current state of the vineyard [22, 23]. In particular, it uses satellite imagery [24], sensors [25], and unmanned aerial vehicles (UAVs) [26] to gather and analyze data of various granularity, for soil composition, vine health, pest and disease appearances, irrigation, fertilization, and weather conditions. With all this information in their hands, winemakers can optimize vineyard management processes and practices, preventing pests and diseases, optimizing the consumption of water, and reducing the use of energy, chemicals, and pesticides. In this manner, they can offer sustainable wines of exceptional quality.

2.1.4 Artificial Intelligence and Machine Learning

The current explosion and general applicability of AI technologies, which are based on the identification of patterns over huge data using Deep Learning (DL) and Machine Learning (ML) models and pipelines, has allowed the integration of such tools in every aspect of the food industries and wineries [27–29]. Such aspects include viticulture practices like grape bunch detection [30, 31], flower quantification [32], grapevine cordon shape [33], grape maturation, and sugar and pH levels in wine grape berries [34, 35], pest and diseases prediction [36–38], wine production [39], wine quality [40–42], and online sales and reviews [43]. This is a very active and promising domain that will improve the quality of wine, reducing costs, resources, and pesticides.

2.1.5 Blockchain

Blockchain technology can facilitate transparency and traceability in the wine industry since it can provide a tamper-proof track of the information related to the production, both in the vineyard and in the winery, and distribution processes of the wine. A blockchain as described in [44] is a distributed, immutable, and transparent ledger technology that can be used as a solution to applications that require security and trustworthiness. Each transaction is stored as a record in a block, while every block contains a time stamp and a hash. Moreover, each block connects to its previous block, forming a chain of blocks that cannot be altered (i.e., the term blockchain). In this manner, every transaction is recorded in a publicly visible block in the chain, and any change in the recorded information will break the chain. Regarding the wine sector, a blockchain-based wine supply chain traceability system is proposed in [45], while [46] evaluates 4 applications, showcasing the applicability of the blockchain for improving organic or fair-trade traceability from Farm-to-Fork. Finally, in [47] the authors report that blockchain facilitated the building of trust across the wine supply chain through the provision of a single source of validated data and increased supply chain visibility. However, they found no evidence to support claims that blockchain is trustless, allowing people to "trust in a system without having trust in the systems actors".

2.2 Storytelling in the wine industry

Enterprises engage in storytelling to create brand value and foster strong relationships with consumers [48, 49]. Within the wine industry, numerous case studies have examined the effectiveness of storytelling as a communication and persuasion tool for both wine consumers and professionals. Storytelling is also extensively employed in wine tourism, leveraging visits to wineries as an appealing tourist attraction. In addition, these visits are frequently enhanced in various ways (e.g., through digital tools [50]) to create a unique experience to visitors and acquaint them with the place that gives each wine its unique characteristics [51]. In the study presented by Woldarsky et al. [9], the application of storytelling in wine tourism is examined using a case study conducted in Portugal. The research primarily focuses on the narrative aspect of storytelling, highlighting how the script of the story can be transformed into a captivating and engaging narrative. The study emphasizes the significance of incorporating essential themes related to wine, including historical elements and detailed information about the winemaking process, to create a compelling storytelling experience for wine tourists.

The importance of including historical elements in the storytelling has also been proved in a study performed in Georgia [6]. In particular, this work demonstrates that utilizing archetypes and dramaturgies in storytelling can effectively establish connections with new customer groups in the wine industry. By leveraging these storytelling techniques, wine enterprises can tap into the curiosity and desire for knowledge among wine consumers. This approach facilitates the development of strong relationships with these customer groups, ultimately benefiting both the wineries and the consumers.

Mora et. al in another study [52] show that there is a link between the price level of the wine and the appropriate style of the corporate storytelling. Regarding the latter, the authors identified 13 main topics in the respective scripts. These topics include family, history, appellation, grape assemblage, winemaking techniques, financial partners, geography and geology, description of wines, wine aging, art, and culture, organic certification, customers, and technical investments. The authors propose that storytelling can be tailored to various styles of corporate communication, enabling the creation of a luxurious ambiance that can, in turn, contribute to a price premium. By adapting storytelling techniques, companies can effectively enhance their communication strategies, fostering a perception of luxury among consumers and justifying higher price points.

The adoption of technological tools for story telling has been beneficial to the wine industry [53]. For example, regarding *social media* recent studies have shown that their usage can be beneficial for attracting more wine consumers and for increasing their loyalty to the wine enterprise [54]. Similarly, winery *websites* that belong either to wine enterprises or other relevant organizations (such as wine associations) try to present an attractive wine story for the wine audience [8, 55]. Representative examples of websites exist in Greece[2], USA[3], Australia[4] and New Zealand[5], among others. However, they usually offer fixed and non-interactive stories, while the content management and data curation processes for creating the wine stories and keeping the wine data updated require significant resources.

In addition, there are several *mobile applications* targeting the wine sector. Two of the most representative such apps (according to downloads in the Android Play Store) are the Vivino app[6] and the Living Wine Labels app[7]. Such tools allow the applicability of storytelling techniques while offering extra functionalities to their users (i.e., e-commerce sales, recommendations, etc.). The Vivino app provides food recommendations based on wine, whereas the Living Wine Labels offer a storytelling experience by applying AR techniques.

2.3 Traceability & Authenticity

The wine production and supply chain consists of a number of actors, including grape producers, suppliers, wineries, wholesalers, and retailers. These actors and the processes they engage with, affect in a detrimental way the quality and taste of the wine that the consumer will experience. Such processes include how and in which place the grapes are grown, as well as, harvesting, destemming, crushing, fermenting, bottling, storage, and transportation of the final product. The lack of transparency among the stakeholders, the excessive use of preservatives, and the adulteration and counterfeiting are serious threats to the wine industry [56].

End-to-end (from the grape-to-bottle) traceability standards can impose transparency and facilitate the relationships between the various stakeholders. For example, Reg. 178/2002 made traceability mandatory for all food products in the EU, including wine. The major aim of mandatory traceability is the identification of agents that comprise the supply chain. However, it does not offer detailed and refined transparency details regarding the supply chain and the corresponding processes. On the other hand, voluntary traceability standards have been introduced to decrease the information asymmetry among the supply chain partners and to increase product quality management. As a result, voluntary traceability standards (e.g., ISO 22005) are used by wineries

[2] https://winemakersofnorthgreece.gr and https://www.winesofcrete.gr/
[3] https://www.napavalley.com/
[4] https://www.winecountry.com.au/
[5] https://www.wine-marlborough.co.nz/
[6] https://www.vivino.com/app
[7] https://play.google.com/store/apps/details?id=com.tweglobal.ar19crimes

for satisfying specific quality requirements in the supply chain and for coordinating vertical relationships through improved transaction transparency [57]. However, the level of supply chain transparency depends on the traceability rules and procedures implemented by the wineries. Current approaches also exploit the immutable nature of the blockchains.

A crucial aspect of food safety, quality assurance, and of avoiding fraud and adulteration is the authenticity of food products, especially for products like wine and olive oil [58]. Types of adulteration include the direct adulteration of wine and mislabelling. Direct adulteration of wine is typically committed by the dilution of wines and alcohols, and the addition or substitution of substances with others of lesser quality. Mislabelling is deliberately misinforming about a specific wine label. Examples include buying cheap wine, adding to it a label of a higher-value wine, and then selling it to other business operators or consumers [59]. Another example is adding a geographical indication of origin to wine that was not cultivated there or varietal misidentification [60].

In their effort to protect their reputation against counterfeit products, wineries have introduced voluntary traceability systems for determining the authenticity and varietal origins of wines [57]. The complexity of such systems depends on the strategic decisions on the rules to be implemented by each winery. Some of the most accurate but expensive approaches include analytical techniques for tracing the geographic provenance (e.g., liquid chromatography, isotope ratios of bio-elements, inductively coupled plasma mass spectrometry, etc.) and DNA fingerprinting for varietal identification of wines [56]. Regarding the provenance, authenticity, and non-adulteration of the bottle itself, most approaches are based on various authenticity tamper-evident security stickers and labels that use holograms. For example, Near Field Communication (NFC) technology available in most current mobile devices, has been used as an anti-counterfeiting tool [61]. However, such labels are generally costly, might require expensive equipment at the winery, and do not provide any kind of information to the producer about the possible counterfeit products. Finally, wine producers need to invest in marketing programs in order to spread the adoption of such technologies and raise awareness towards the importance of authenticity and traceability in the wine sector [61].

2.4 Sustainability

In the wine sector, the productivity of the wineries is challenged by environmental trends and changes, such as global warming. In addition, buyers are becoming more environmentally conscious, and the wine sector is increasingly adopting sustainability practices because of the willingness of major customers to pay for sustainable products [62, 63]. Such practices mainly focus on the environmental consequences in the vineyard and the cellar, especially regarding climate change, since grape production is highly sensitive to changing environmental conditions.

The term sustainability refers to the awareness of the impact of human activities on the planet, its climate, and its resources. The United Nations defines sustainable the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", and revolves it around three axes, the environmental, the economic, and the social [64] ones.

However, the term is not well defined in the domains of viticulture and winemaking [65], leading to many different definitions. The International Organization of Vine and Wine (OIV) and the International Organisation of Wine and Spirits (FIVS) have developed their own sustainability guidelines [66, 67] respectively. For example, OIV defines sustainable vitiviniculture as a "global strategy on the scale of the grape production and processing systems, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, products safety and consumer health and valuing of heritage, historical, cultural, ecological, and landscape aspects". In the same manner, the Sustainable Winegrowing Program and the California sustainable winegrowing workbook[8], defines 15 axes for sustainable winegrowing and winemaking practices that are sensitive to the environment (**E**nvironmentally Sound), responsive to the needs and interests of society at large (Socially **E**quitable), and are economically feasible to implement and maintain (**E**conomically Feasible).

Relevant practices like organics, biodynamics, and fairtrade, use some sustainable practices [63] that try to minimize the environmental impact of farming and food production, promoting soil health, biodiversity, animal welfare, and a fair working environment and salaries. Several studies have shown that organic farming practices have a lower impact on the environment per area unit [68–71], while biodynamics wines have been reported to be responsible for even lesser [72]. For example, organic vitiviniculture forbids the use of substances of synthetic origin, genetically modified organisms, and ionizing radiations. Moreover, organic products are usually accompanied by some kind of certification [63]. In particular, organic certification is regulated by government bodies although the certification process itself is usually outsourced. However, a product classified as organic in a given country might not get the certification in another country. For example, in the EU an organic wine can contain sulfites while this is not permitted in the USA. In the same manner, any wine produced with organic grapes does not mean it is organic, and can only mention on the label that it was made with organic grapes. The most important guidelines for organic certification [73, 74], which must have been in place for at least three years before certification can be granted, include:

- Ban of chemical pesticides, herbicides, insecticides, or fertilizers[9],
- Use of natural fertilizers only,
- Ban usage of GMO (Genetically Modified Organism) yeasts,

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[8] https://www.sustainablewinegrowing.org/swpworkbook.php

[9] Out of the ~300 pesticides permitted under EU law, only 25 are allowed that are considered natural ingredients.

- Ban or restricted sulphite addition[10].

On the other hand, there are many sustainability aspects that organic certification does not consider, like the use of resources in the field (e.g., water and energy consumption) or waste. More importantly, it does not include aspects relevant to the economic and social axes of sustainability, that consider how companies operate, looking not just at farming and production but also at the impact of the whole supply chain, and social responsibility.

The International Wineries for Climate Action[11] is a group of leading producers with the shared strategy to become carbon neutral across the whole wine value chain. They focus on the following areas: a) fuel usage, land changes, CO_2 usage, NO_x soil emissions, onsite waste (e.g., methane from wastewater), refrigerants for cooling barrel rooms and indoor spaces, b) purchased and generated electricity, and c) purchased products, packaging materials, outsourced production, business travel, offsite waste including recycling and waste, and post-consumption.

In [75], the authors investigate the carbon footprint of red and white wines, showcasing that red wine has a lower carbon footprint than white wine. Another case study evaluates the sustainability performance of a multi-criteria approach of 15 Italian red wines [76]. The evaluated criteria are Water Footprint (WF), Carbon Footprint (CF), Vineyard Indicator (VI), and Territory Indicator (TI), in a disaggregated manner. The results showcase that it could be possible to comprehensively analyze sustainability performances with few inputs which are easily collectible in the production sites, with considerable cost and time savings. Another work [77] focuses on sustainable deficit irrigation practices for different varieties and edaphoclimatic conditions across the Mediterranean, to mitigate the negative effects of climate change on wine grape cultivation and make irrigated Mediterranean vineyards more resilient and sustainable. Finally, [27] takes a more cutting-edge approach and discusses the state-of-the-art, opportunities, and challenges of AI, big data, and robotics for sustainable viticulture and for guiding decision-making.

In Italy, the SOStain Foundation[12] promotes the voluntary application of a sustainability program. Its requirements are connected to the new Common Agricultural Practices (CAP) 2023–2027 objectives [78], and companies joining the foundation can green their production practices and prepare for the challenges of future winemaking. In 2022 they conducted a study [79] among producers and consumers, in order to gather opinions about motivations, difficulties, cost, and positive effects of the SOStain certification. In addition, they were interested in their intentions to make ethical choices and their willingness to spend more for a wine with the SOStain certification. The findings showcased the effect of ethical choices over sensory likings on purchasing intentions and issues related to higher costs of production and market prices. The

[10] Sulphite addition is permitted in the EU, but with lower levels than those for non-organic wines: 100 mg/L for red wines vs. 150 mg/L for conventional wines, and 150 mg/L for whites and rosés vs. 200 mg/L. In USA sulphite addition is banned.

[11] https://www.iwcawine.org/

[12] https://www.fondazionesostainsicilia.it/

results highlighted the criticalities of the green transition for wineries and the importance of correct communication through social media.

In a study regarding the socially and environmentally sustainable practices at each level of the Bordeaux wine value chain [80], it was concluded that all actors of the value chain have different practices that depend on the core activities for which they are responsible. However, some actors share common practices, and there is pressure for market intermediaries to support sustainable practices at the wine-grape grower and wine-producer level. While the actors are more involved in environmental than socially sustainable practices, the regulatory framework shapes most socially sustainable practices, creating an alignment in terms of these specific practices.

The sustainability strategies require investments that can discourage organizational change as reported by [81]. However, at the same time they can provide wineries with competitiveness by bridging the suppliers' knowledge gaps on the economic and environmental impact of the circular economy (CE). The study provides economic and environmental evaluations of the benefits of the value constellation approach applied to the cooperative's value chain, which can also be used by investors to identify and financially support companies engaging with the CE.

3 Engaging Wine Stories - The MiB Ecosystem

MiB provides a rich ecosystem of services and applications that is able to create an interesting wine story for consumers and professionals of the wine domain (oenologists, sommeliers, and retailers). Wine producers are the administrators of the system, whereas consumers and professionals constitute the end users. Administrators can collect data related to their wine products from various sources such as ERP systems, weather stations, or even manually from people who participate in the viticulture or wine-making process. These data are injected into the system, allowing the presentation of the wine products using a storytelling technique [8] in an engaging manner [82]. The end users can then navigate through the available labels and wine characteristics and find the wine that satisfies their needs.

The MiB system has the following set of characteristics that make it easy to use for both wine enterprises/producers and consumers:

- *Easy-access* - Access to wine-related information is given by scanning a QR code located on the wine labels.
- *Platform agnostic* - The used technologies are not restricted to a specific operating system since it is web-based and accessible through any web browser. This is true even for the AR experience that uses the WebXR API.
- *Mobile and Desktop friendly* - The design follows a responsive design which is friendly for any kind of device.
- *Multilingual* - It supports multiple languages (the infrastructure supports any language; current implementation uses the English language).

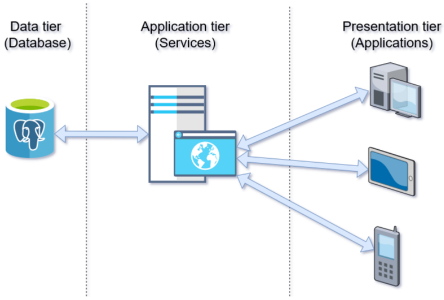

Fig. 1 The Typical 3-tier architecture applied in MiB.

3.1 Architecture & Implementation

MiB follows a typical 3-tier architecture consisting of the data tier, the application tier, and the presentation tier (see Fig. 1). Different applications reside in the presentation tier and they communicate with the database (data tier) through RESTful web services (application tier).

The *Application tier* acts as the glue between the apps and the data. Since MiB is a web-based platform, we materialized this tier using a component implementing the required functionality using Web services. We opted for RESTful Web Services since they offer reliable, fast, and scalable services due to the stateless constraint [83]. Statelessness is enforced through the use of resources. Resources are the core elements that represent any object, document, or thing that has to be stored or sent to other services. Because RESTful applications interact through standard operations on resources, they do not rely on the implementation of interfaces. The stateless constraint allows RESTful applications to achieve reliability, quick performance, and scalability, as components can be managed, updated, and reused without affecting the system as a whole, even during system operation.

In particular, we defined different resources for the entities of our model to offer the respective REST services. Each REST resource defines its functionality by means of HTTP methods. As an example, consider Fig. 2 which contains the methods of the Bottle entity that represents a single unique bottle with a QR code. Any client (having the right permissions) can use these methods to get a list of all bottles (first GET method), add a bottle (POST method), get a specific bottle (second GET method), or delete a specific bottle (DELETE method).

The MiB web services component was implemented with the Javalin framework[13], which runs on top of Jetty[14], one of the most used and stable web-servers on the JVM. Javalin also supports OpenAPI[15], thus allowing easy documentation generation and client code generation. All these factors combined guarantee that this component is lightweight, flexible, and easy to be

[13]https://javalin.io/
[14]https://www.eclipse.org/jetty/
[15]https://www.openapis.org/

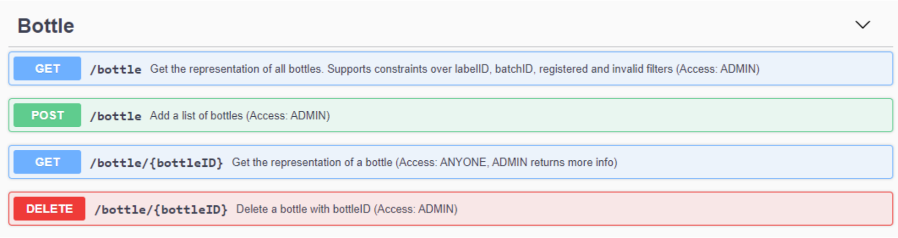

Fig. 2 Bottle Resource HTTP methods.

consumed by any other client application. The offered REST API of MiB is available online[16].

The *Presentation tier* ensures that all embedded applications will have the same look and feel in order to not distract the users from the storytelling experience. Implementation details for the presentation tier are given separately for each application in Section 4.

Finally, the *Data tier* is responsible for data access and management. The approach is based on relational databases and is implemented over PostgreSQL[17].

3.2 Data Model

The **MiB model** (Fig. 3) embraces important entities that typically appear in a wine story [6, 8, 52]. Specifically, it captures information related to the following entities:

- **Label** describes the wine label, including information such as the year, flavor, alcohol, acidity, etc.,
- **Variety** contains details about varieties, such as the color and the name,
- **Vineyard** holds vineyard information such as the altitude, location, and other viticulture details such as irrigation, ripening,
- **Producer** contains the profile of the various producers collaborating with the winery,
- **Wine Making Diary** offers wine-making details including a wine-making diary,
- **Cultural** describes historic and folklore elements,
- **Sustainability** provides sustainability information such as water management, farming soil health, manufacturing waste, etc.,
- **Meteo** provides meteorological information as captured by the installed vineyard weather stations,
- **Food, Recipe, Justification** contain food-related information, including recipes and justifications of recommendations,
- **Award** details of awards for specific years of labels,
- **Bottle** is responsible for authenticity data and whether a specific bottle has been registered.

[16] https://isl.ics.forth.gr/mib/
[17] https://www.postgresql.org

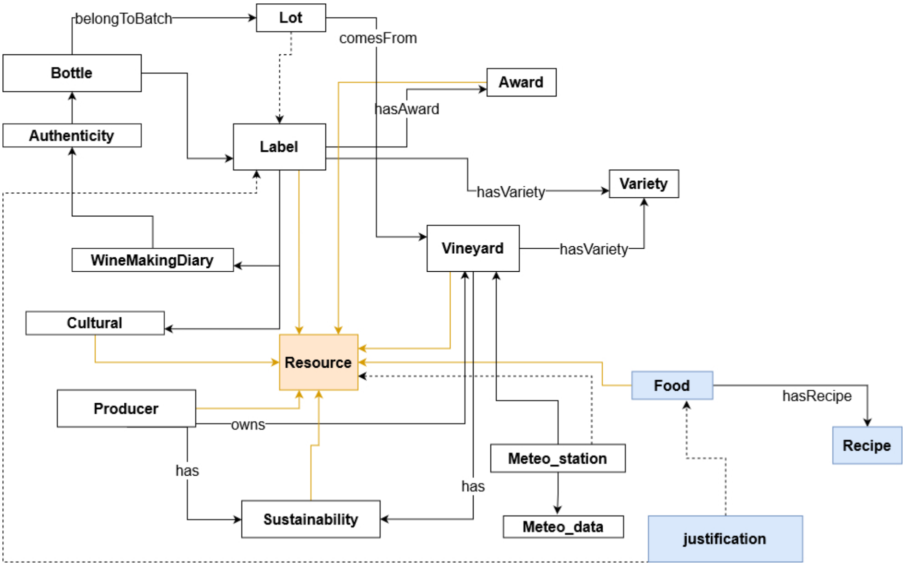

Fig. 3 The data model of MiB.

To support content in different languages we followed the approach of creating entity layers for translated fields and non-translated fields. This option is a proven approach of incorporating multiple languages across entities[18]. With this solution, the multilanguage entities are split into two layers: one for multilanguage fields, and another for non-multilanguage fields. Consequently, there is no need to join multilanguage tables if only non-translated fields are concerned, which allows non-multilanguaged fields to exhibit better data access performance. In order to make this approach transparent to the applications, we created specific language views for each entity. Database transactions (insert, delete, update) are performed using the views and not the actual database tables. This is accomplished through a set of stored procedures and database triggers.

4 Applications

The MiB system includes five applications, namely the Main, the Le Sommelier, the Authenticity, the Augmented Reality (AR), and the Admin applications. Except for the Admin application which is used for the data entry and is accessed only by authorized users of the wine enterprise, the other applications are embedded in the Main application.

[18] https://vertabelo.com/blog/data-modeling-for-multiple-languages-how-to-design-a-localization-ready-system/

4.1 Main App

The Main application, which is publicly available and reachable by any interested party and consumer[19], offers a storytelling experience upon the available wine labels of Lyrarakis Winery (see for example the "Liatiko Aggelis Label" shown in Fig. 4.

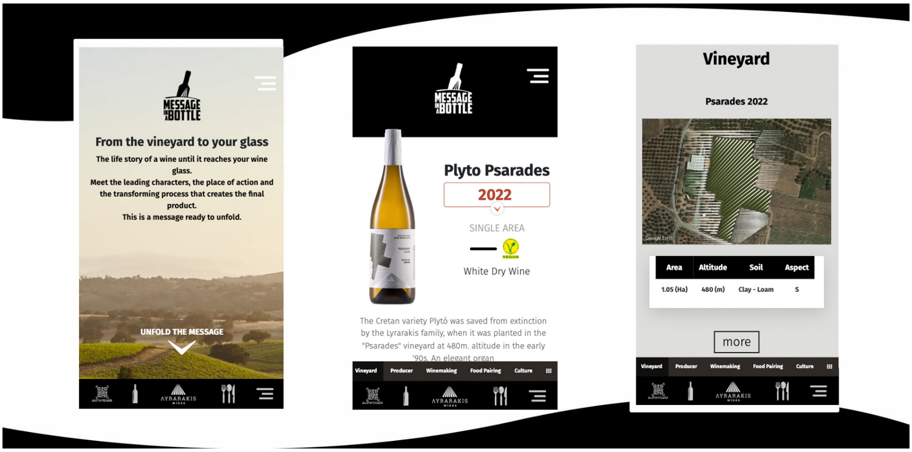

Fig. 4 The Main App.

There are two access methods available for this application: by visiting the app through a web browser or by scanning the QR codes affixed to the winery's labels. The application utilizes the MiB web services to retrieve various data, which are presented in *two layers of information*.

The first layer, referred to as the basic layer, provides users with essential information. This includes a general description of the label, details about the producer(s), vineyard information, insights into the winemaking process, the number of awards received (if applicable), food pairing suggestions, and cultural elements. Users can access this layer by scrolling through the interface. The second layer, known as the detailed layer, contains comprehensive data concerning sustainability, meteorological conditions, and geological information. Users can access this layer by interacting with call-to-action buttons placed in different sections of the interface.

The Main App includes a menu that appears in the top-right corner and the respective icons that appear at the bottom. The QR code icon activates the authentication process (Authenticity App), the bottle icon allows the exploration of the available labels of the winery, and the coutellerie icon leads the user to the Le Sommelier App. Note that the AR application has not yet been embedded in the Main App, due to its experimental nature and some issues with the current WebXR implementation in browsers.

[19] https://mib.lyrarakis.com/

The application follows a *component-based design*. It focuses on presenting the data to the end user in a consistent manner, even if a portion of the information is missing. This allows the application to have a consistent look and feel at all times, and not lose its identity and storytelling feeling. In addition, the Main Application's design is *mobile-oriented* as the whole process of scanning and authenticating a bottle is expected to be done in a mobile setting (i.e., through the camera of mobile phones). However, it is also responsive and can be browsed from any modern desktop and tablet.

The Main App utilizes the Laravel Framework[20], a web application framework written in PHP that offers a range of robust features. These features include dependency injection, expressive syntax, and optimized and scalable code, facilitating the development process. The application also incorporates a local MySQL database that stores crucial data related to the core logic of the application. This includes settings, menus, global string translations, and the location of asset files.

4.2 Le Sommelier App

The 'Le Sommelier' application (Fig. 5) is designed as a recommendation system within the MiB system. Its purpose is to assist users in *pairing wine with food and vice versa*, with the objective of enriching both the user's experience and the information they receive.

In the era of Artificial Intelligence, recommender systems are significantly influenced by the availability of large datasets; only lately has this progress started to reach the domain of wine recommendations. Relevant datasets for wine and food paring are not many, and the application of deep learning algorithms is still rather limited (e.g., see [16–18]). Le Sommelier follows a different pathway that is based on a declarative representation of experts' knowledge to avoid the cold-start problem, which can easily be coupled with data-driven methods in the future. Our system stands out by incorporating several distinctive features to simplify the task of wine pairing for the non-expert.

Le Sommelier has the capacity to suggest wines that can pair well with multiple dishes, even if the dishes have diverse flavors and characteristics. This feature is particularly useful in situations where meals are prepared for a group of people who freely choose their preferred dishes from a diverse menu of options. In such cases, there may not be a single wine label that perfectly matches all the chosen dishes. Instead, Le Sommelier aims to find a wine label that can harmoniously complement the flavors of all the selected dishes. This presents a combinatorial challenge, considering the subjective nature of wine preferences. The solutions provided by Le Sommelier are both adaptable to the user and explanatory in nature, allowing the user to understand why a given recommendation was provided.

[20] https://laravel.com/

To achieve that, we modeled domain experts' knowledge in food and wine pairing as *logical rules*, rather than hard-coding pairings as done by the majority of existing systems. We did not rely exclusively on historical data of past user choices either; such an approach would considerably reduce the creativity that a human sommelier uses when making suggestions. Le Sommelier models domain and empirical knowledge in the form of strict and weak prioritized rules, and performs logical reasoning using declarative language. Specifically, all rules are modeled in the language of Answer Set Programming [84], while reasoning is executed with the state-of-the-art Clingo tool[21], designed to solve difficult search problems. This modeling, among others, offers flexibility in modifying the set of rules that are applicable according to needs, while enhancing the explainability of the matching process.

Indeed, another distinctive feature of Le Sommelier is the possibility to accompany each suggestion with a *textual explanation* that aims to justify why a given pairing is considered suitable. The explanation may highlight aspects, such as the cooking or flavors of a dish in combination with the tannins, body or acidity of the wine (see Fig. 5). In addition to the explanation, the application provides a rating of each suggestion, enabling the user to explore different choices before finding the one that best matches her preferences. Moreover, the ability to *filter suggestions* with criteria such as wine type is also provided.

To complete the interaction experience of the end user, Le Sommelier incorporates a number of other features, such as pages with *recipes* for selected dishes. Specifically, in addition to popular dishes from various cuisines, the system suggests local dishes with peculiar characteristics whose preparation involves interesting insights into local traditions. For these dishes, the application provides recipe information, such as the ingredients, cooking process, and execution time. This feature nicely couples with the purpose of the MiB system to engage the user in a storytelling experience.

Finally, the system also supports the *inverse workflow*, i.e., for the user to choose a wine label, for which Le Sommelier will suggest matching food categories and dishes. Such information is already available on the label of each bottle, but considering the variety of dishes, the recipes, and the filtering mechanism that the system offers, such a direction has also proven important.

[21] https://potassco.org/clingo/

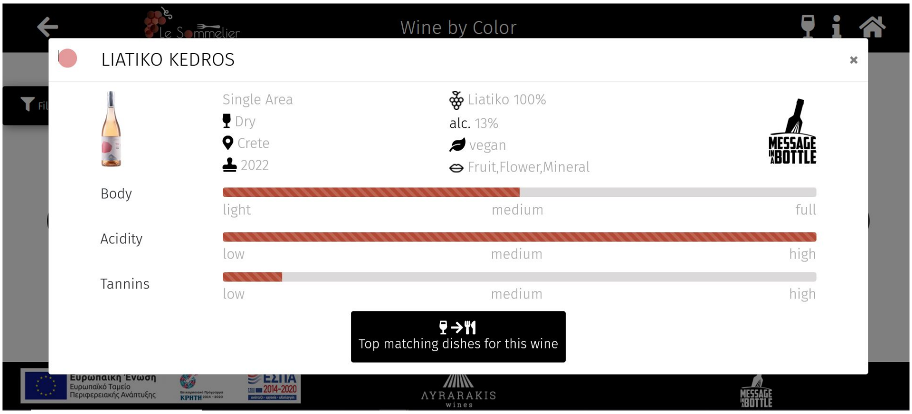

Fig. 5 The Le Sommelier App.

4.3 Authenticity App

As already mentioned, the authenticity of food products is a crucial aspect of food safety. The MiB platform offers a *crowdsourcing approach* to verify the authenticity of wine bottles. Crowdsourcing initiatives affect positively consumers engagement, increasing purchase intentions and community belonging [85]. In addition, the transparency of processes, and the availability of trusted cues and information that verify the food quality and authenticity, is helpful in strengthening trust between businesses and consumers [86–88].

In particular, our approach requires consumers to register authentic bottles by inserting to the platform the preassociated unique pairs of public and private keys, available on a double sticker on the bottle as QRs. If the pair is valid then the bottle is considered an authentic one, otherwise, the users are asked to add more information about the location/sale place of the bottle, since this bottle is treated as a counterfeit one. Since the whole process is based on plain QRs, the approach does not require specialized hardware but plain commodity QR printers. Our approach guarantees that even if someone duplicates the public and private keys of an authentic bottle to create a batch of counterfeit bottles, only one such bottle can be registered as authentic, while the rest will be reported as already registered bottles. Therefore potential consumers will be notified that they are buying counterfeit wines, even when the bottle lies on the shelf of a wine retailer.

In more detail, we use an opaque sticker on the bottle that has two QR codes, one visible and one hidden on the back side of the sticker. This is a special kind of a one-time sticker to avoid tampering (see Fig. 6). Both QRs are UUIDv4 that are generated using random numbers. A UUID is a universally unique identifier across time and space that is represented by a 32 character sequence of letters and numbers separated by dashes. A sample of $3.26 * 10^{16}$ UUIDs has a 99.99% chance of not having any duplicates, which is adequate for our use case.

Fig. 6 The sticker with the public and private keys of a bottle used for authentication. The sticker is a one-time sticker and it is visible to the consumer whether it has been already peeled off to reveal the private key.

The pairing of the QRs is done during the bottling process of a batch in the winery. To make the process even easier, error-free, and without requiring any kind of QR readers in the bottling line, we pair a list of n public unique system-generated QRs, where n is at least as large as the number of the bottles in the batch, with a pool of private unique system-generated QRs of size n. A consumer can scan the public QR in the MiB to check whether the public UUID is valid and unregistered. If the latter does not hold, then (with a very high probability) this specific bottle is not an authentic one. If this UUID is not registered, then the user can try to register it by removing the sticker and scanning the private UUID. Notice that this presupposes that the consumers are informed about the existence of such a sticker for authenticating a bottle (e.g., through the winery's web page).

If the private key is in the pool of the private UUIDs for this specific batch, then the private UUID is removed from the pool, and the bottle is registered. If this process fails repeatedly, it means that this is a non-authentic bottle and we let the consumer add more information about the status of this bottle (e.g., purchase location information, and general comments). In this way, the producer can get more information regarding the places around the world where non-genuine bottles are offered. If the Do-Not-Track header is not enabled in the client, we also keep a one-way cryptographic SHA2-256 hash of the client's IP and its browser signature during the registration process. This hash is used for notifying consumers that they have already registered a bottle and to avoid the insertion of non-valid information. Notice that the client information is stored encrypted and cannot be decrypted for privacy-preserving reasons. This interactive process creates a relationship of trust between the consumers and the producers and can be incentivized by offering rewards or a gamification approach to customers who register their bottles.

In addition, to support the winery in this process we have developed a number of tools that have been integrated into the Admin App. These tools facilitate the winery in the process of printing and pairing the public and private UUIDs. Specifically, since the winery was not able to find a printing service that could print the stickers and the corresponding UUIDs in an atomic operation (private and public UUIDs should be printed together to guarantee that the pairs are the ones provided by the winery), the process of printing the UUIDs became a 2-step process. Initially, the private UUIDs are printed on a spool of stickers, and later on, the public UUIDs are printed on the spool. This process is error-prone since the sticker spools can be cut into pieces, mixed up, or there might be errors in the printing process that can invalidate some stickers. As a result, we developed a pipeline of tools, that allow the winery to hold metadata about each public and private spool that will be printed, and facilitate the process of pairing them, by validating that the winery is pairing the correct spools. The process is done by scanning at least two of the public and private UUIDs of the spools associated with a specific batch, to identify whether the spools used for a specific batch are the ones originally intended.

4.4 AR App

Augmented Reality (AR) is a technology that creates links, direct or triggered by user interaction with a device, between the real world and the information generated by a device. AR can superimpose computer-generated information on real-world views, amplifying human perception and cognition in new and extraordinary ways [89]. According to [90] AR is anticipated to transform customer engagement by providing powerful tools for creating unforgettable experiences that foster customer loyalty and long-term value.

The AR application developed in the context of MiB is designed to provide consumers with an engaging way to interact with the digital label associated with a specific wine. In our case, the AR application superimposes a digital interactive label onto the real-world label, requiring accurate real-time tracking under various lighting conditions, through the camera of the mobile device. This ensures that the digital label remains aligned and synchronized with the physical label, enhancing the overall AR experience for users. This interaction is made possible using WebXR[22], a technology that allows for immersive experiences on the web. Currently, WebXR is integrated with Google's AR services[23], which are available on the latest mobile devices. Enabling the WebXR incubation flag in the latest Chrome and Brave browsers supports this functionality[24].

Label tracking is a challenging task that requires specific characteristics in order to successfully track images [91]. This process relies on highly-contrasted images with numerous corners and distinctive features. However, it is worth noting that the existing image-tracking algorithms typically operate solely on grayscale images, disregarding any available color information. This means that the algorithms focus primarily on the structural elements of the image rather than its color properties. Consequently, the successful tracking of labels

[22] https://www.w3.org/TR/webxr/
[23] AR services 1.29.213210223
[24] Chrome 98.0.4758.101

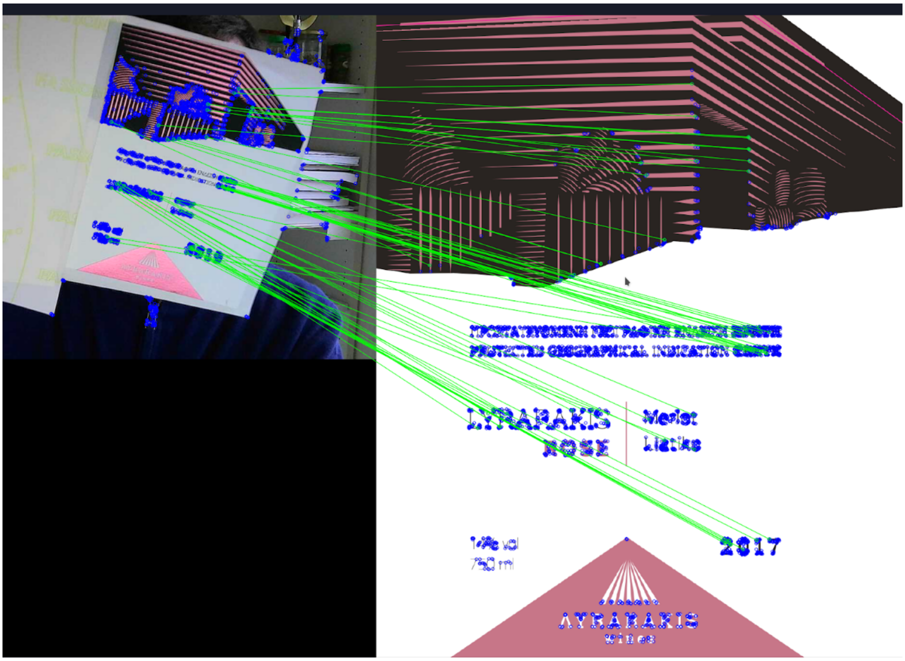

Fig. 7 With blue dots are depicted the recognized features of the labels and with green lines the corresponding mappings between the learned label features (right) and the recognized features of a real-world label (left). Notice that most of the features of the camera image are not mapped.

is dependent on the presence of prominent corners and distinctive features, which can be effectively captured in grayscale images.

The current labels of the Lyrarakis Winery, do not satisfy most of the above criteria, since they use quite similar patterns, while colors, even reflective ones like silver and gold, are used for distinguishing between the various labels. The evaluation of the labels over the various image tracking algorithms in the OpenCV library[25] (e.g., ORB algorithm), showed that most of the labels have a low image entropy value of (~ 1)[26]. As an example, Fig. 7 shows the identified label features and their incomplete mappings to the recognized label features of a real-life label through the mobile camera. Apart from the WebXR AR application we also developed a native Android application using the Unity[27] library that provides proprietary image tracking algorithms, but we found no real improvement in the image tracking quality.

Since the redesign of the labels was not an option, our efforts were focused solely on a specific subset of winery labels that yielded acceptable performance. This subset primarily comprises labels representing the Protected Geographical Indication (PGI), emphasizing the depicted vineyard fields. For tracking

[25] https://opencv.org/

[26] The image entropy value measures the level of complexity of an image and takes values from 0-5 in our case

[27] https://unity.com/

purposes, we only consider the section of the label that showcases the vineyard field, disregarding the remaining portions.

Upon successful recognition of a label, the application presents a swipeable pane that provides detailed information about the specific label. This information encompasses various aspects, including label characteristics, producer details, awards received, wine-making diaries, and other relevant information associated with the label. Users can access and navigate through this pane to explore comprehensive insights about the selected label.

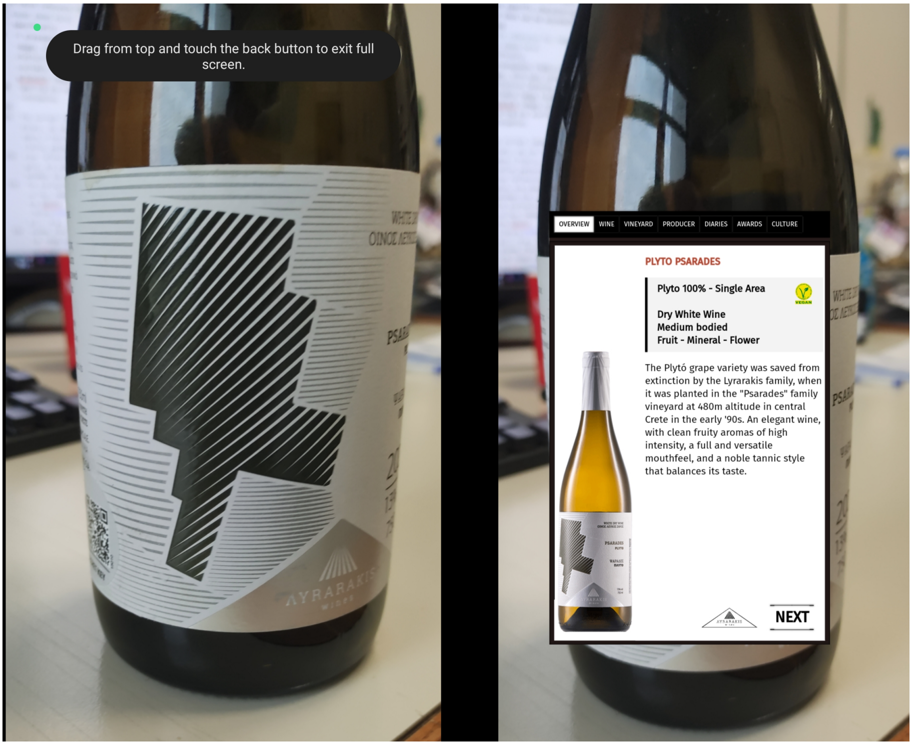

Fig. 8 The Augmented Reality (AR) application. The virtual label is superimposed over a real-life bottle using WebXR technologies and the camera of a smart phone.

Figure 8 shows an indicative screenshot from the AR application. The AR application is developed using the Javascript library babylon.js[28]. Currently, the AR app is not available due to its experimental nature and instability of the WebXR Image Tracking implementations[29].

[28] We are using the latest 5.0 version (5.57.1) that supports WebXR, and can be found here: https://www.babylonjs.com/

[29] The latest versions of Google Chrome and Brave browsers do not allow the operation of the camera's autofocus functionality, which is crucial for the Image Tracking functionality.

4.5 Admin App

The Admin UI application (Fig. 9) serves as a content management tool for administrators in the wine enterprise, providing them with the ability to manage various aspects of the MiB database. This includes handling (i.e., adding, removing, or modifying) data related to labels, wine-making diaries, cultural information, awards, producers, varieties, weather, and sustainability. Using this app, wineries can easily update and manage the wine-making diaries for specific wine labels, by adding new entries for each new year or vintage and incorporating new resources (i.e., photos and videos) that contribute to the overall wine story associated with a particular label.

Furthermore, the Admin UI app provides an exploratory service that enables administrators to monitor the presence of genuine bottles in the market. Using this app the winery can identify any instances of non-genuine bottles by leveraging the information added from worldwide customers through the Authenticity application (see Section 4.3). By offering this monitoring service, the Admin application enhances the value proposition by providing an additional layer of food security. Administrators can leverage this feature to ensure the authenticity and integrity of wine products associated with the MiB platform. It empowers the administrators of MiB with a valuable tool to safeguard the reputation and trustworthiness of the wine industry.

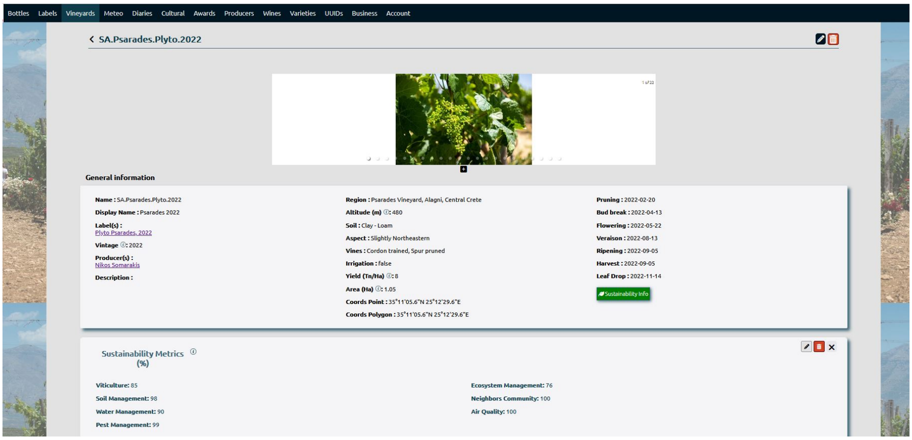

Fig. 9 The Admin App

Finally, this application offers a *pipeline of tools* that help the winery to manage the stickers spools and print the public and private UUIDs on them, as described in Section 4.3. These tools act as a gatekeeper for possible errors in the pairing of public and private keys, through a friendly user interface that scans some of the public and private QRs. The first step of the process of pairing a private subset of a spool with a public one is shown in Fig. 10.

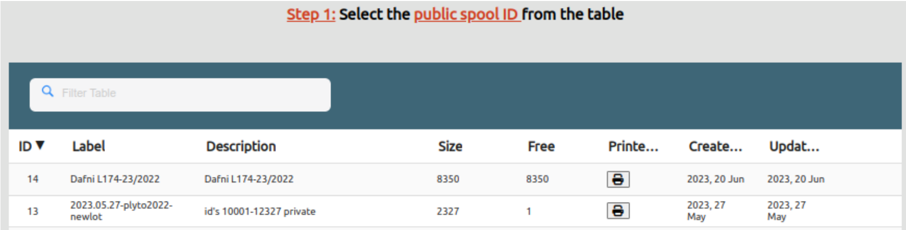

Fig. 10 The first step in associating private and public spools of UUIDs

The Admin application was implemented in React[30] and uses the available MiB services with a corresponding JWT token for authorization purposes.

5 Sustainability

In this section, we provide more details regarding the sustainability data offered by MiB. Specifically, we describe the process of gathering the corresponding information through questionnaires and discuss how MiB communicates this information to consumers.

Sustainability Questionnaires. Every year, each producer that cooperates with the winery completes a questionnaire regarding sustainability, together with the company's agronomist. The questionnaires provide a number of indicators revolving around 7 main axes, namely viticulture, soil management, vineyard water management, pest management, air quality and climate protection, ecosystem management, neighbors & community.

The axes and the indicators are originally based on a subset of the 15 axes defined in the Sustainable Winegrowing Program and the California sustainable winegrowing workbook[31]. This program defines sustainable winegrowing as growing and winemaking practices that are sensitive to the environment (**E**nvironmentally Sound), responsive to the needs and interests of society at large (Socially **E**quitable), and are economically feasible to implement and maintain (**E**conomically Feasible). These three cross-cutting principles are often referred to as the “three E's” of sustainability and provide a general direction to pursue sustainability.

However, these axes must be translated into the everyday operations of viticulture and winemaking, and have been adapted to the reality of the island of Crete. In the first design, there were 9 sections (axes), 49 KPIs, and 291 criteria (questions) which would give a maximum score of 1636. Obviously, not all sections/questions weighed equally. For example, the "ecosystem management" section doesn't weigh the same as "pest management". The idea behind the questionnaire and the definition of its axes/KPIs/questions, is to obviously lead the farmer to improve in what the Lyrarakis winery has established as the

[30] https://reactjs.org/
[31] https://www.sustainablewinegrowing.org/swpworkbook.php

main challenges on the island of Crete. In the working MiB prototype the 9 axes were cut to 7, the KPIs to 43, and the questions were reduced and 'sharpened' to 215, using the experience of the winery with its own group of farmers. Finally, the scoring weights were changed to better reflect the goals and needs of the island of Crete, with a maximum score of **1396** points. For example, in many cases, there is only so much you can do to improve the "Vineyard design (spacing, trellising)", especially in well-established and vintage vineyards, but there's a lot of work that can be done to improve all farmers in the "Pest management" and "Soil management" axes. Hence the scoring in these sections was modified accordingly.

Table 1 reports the sustainability indicators for the axes used in the MiB questionnaires that bridge the gap between theory and practice. Figure 11 shows a part of the questionnaire, which is in Greek. The shown subset concerns the viticulture axis. Specifically, it shows 7 questions regarding the vineyard design (spacing, and trellising) KPI. For each question there are specific answers that the producer can give (with the help of the agronomist). The scores for each option are listed on the right side of the questionnaire (in white), and the score for this specific producer is given in grey. The right part also holds the score of the producer and the max score for this KPI (22 and 46) and axis (88 and 190) respectively.

1. ΚΑΛΛΙΕΡΓΗΤΙΚΑ ΘΕΜΑΤΑ	**Μέγιστη Βαθμολογία Ενότητας:**	**190**
	Βαθμολογία Ενότητας από Έλεγχο	**88**
1.1 Σχεδιασμός αμπελώνα και υποστήριξη πρέμνων	**Μέγιστη Βαθμολογία ΒΔΑ:**	**46**
	Βαθμολογία ΒΔΑ από Έλεγχο	**22**
1.1.1 Έχετε εγκαταστήσει σύστημα υποστήριξης των πρέμνων;	**Αποτέλεσμα Ελέγχου**	2
- Όχι		2
- Ναι		6
1.1.2 Το σύστημα υποστήριξης διευκόλυνε την	**Αποτέλεσμα Ελέγχου**	8
ισορροπημένη ανάπτυξη της βλάστησης		8
ανεξέλεγκτη ανάπτυξη της βλάστησης		2
1.1.3 Το σύστημα υποστήριξης οδήγησε σε μια πολύ σκιερή και κρυμμένη ζώνη καρποφορίας;	**Αποτέλεσμα Ελέγχου**	0
Όχι		4
Ναι		0
1.1.4 Έγινε σωστή διανομή των βλαστών πάνω στο σύστημα υποστήριξης;	**Αποτέλεσμα Ελέγχου**	2
Όχι		2
Ναι		6
1.1.5 Υπήρξε έντονη σκίαση των σταφυλιών, ακόμη και μετά το αραίωμα των φύλλων;	**Αποτέλεσμα Ελέγχου**	6
Όχι		6
Ναι		0
1.1.6 Το **σύστημα υποστήριξης των πρέμνων** υποστήριξαν καλά τη ζωηρότητα της βλάστησης, παρέχοντας μια ανοιχτή κόμη με ...	**Αποτέλεσμα Ελέγχου**	2
μέτρια έκθεση των σταφυλιών στο φως		4
κατάλληλη έκθεση των σταφυλιών στο φως		8
υπερβολική έκθεση των σταφυλιών στο φως		2
1.1.7 Οι **αποστάσεις των πρέμνων** υποστήριξαν καλά τη ζωηρότητα της βλάστησης, παρέχοντας μια ανοιχτή κόμη με	**Αποτέλεσμα Ελέγχου**	2
μέτρια έκθεση των σταφυλιών στο φως		4
κατάλληλη έκθεση των σταφυλιών στο φως		8
υπερβολική έκθεση των σταφυλιών στο φως		2

Fig. 11 A part of the sustainability questionnaire, concerning viticulture. It shows 7 questions regarding the vineyard design (spacing, and trellising) KPI (1.1).

Presentation of sustainability scores. In Figure 12 we present an example of the aggregated spider graph that is produced through the questionnaires and presented to consumers through the MiB platform. The final score per each sustainability axis is the average score over all its indicators expressed as a percentage. In the current version of the questionnaires, all indicators are weighted the same (we plan to refine the weights in the future).

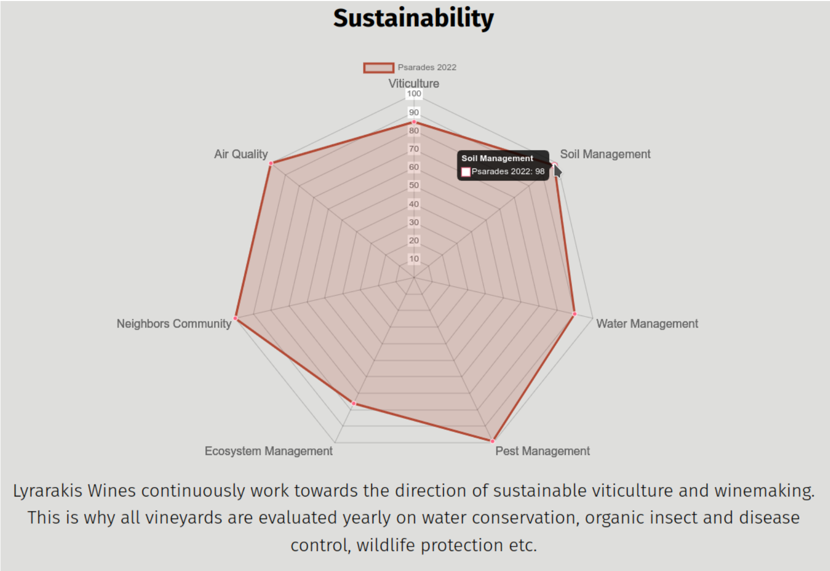

Fig. 12 A spider graph of the aggregated scores of indicators per each sustainability axis.

Through this graph, consumers can easily get insights regarding the scores of each label (in our case for the label Psarades 2022) for each of the 7 sustainability axes. In addition, they can easily get insights regarding the total sustainability score of a specific label, since the larger the area in the spider graph, the more sustainable this specific label is. By hovering the mouse over any of the axes they can get more detailed information about each score. In this way, the consumers can easily see whether the corresponding producer and the winery are progressing towards a more sustainable product, and compare the sustainability aspects of different labels.

In the future, we plan to enrich the sustainability questionnaires. We will try to encourage a more "Regenerative" approach, but at the same time keep the questionnaire manageable and practical size-wise. After all, the ultimate goal of this procedure, is to improve the farmers, their land, and the resulting wine. We will also add another view regarding the sustainability data that will provide aggregated metrics about all the labels offered by the winery through the years, allowing a cross-time evaluation of the sustainability aspects of the winery, its labels, producers, and vineyards.

6 Discussion

Wine awareness and wine safety are crucial aspects of the wine industry that contribute to consumer satisfaction, industry integrity, and sustainable production practices. Wine awareness involves understanding the characteristics, flavors, and nuances of different wines, as well as being knowledgeable about the winemaking processes and vineyard practices. It allows consumers to make

Sustainability Axis & Indicators	
A. Viticulture	5. Pruning for Canker Management
1. Vineyard design (spacing, and trellising)	6. Bunch Rot Management
2. Rootstocks Selection	7. Minimizing Risks from Fungicides for Powdery Mildew and Botrytis Control
3. Monitoring Canopy Density and Vigor	8. Portion of Vineyard Treated for Mites or Leafhoppers
4. Leaf and Shoots Removal	9. Vineyard Monitoring for Vertebrate Pests
5. Vineyard Vigor Uniformity	10. Vertebrate Pest Management
6. Conservation of Habitat for Wildlife and Pest Predators	11. Area Treated with Herbicides
B. Soil Management	12. Herbicide Leaching Potential
1. Nitrogen Management	13. Sprayer Calibration and Maintenance
2. Other Inorganic Management	14. Plant Tissue Analysis & Spray Coverage
3. Preserving or Increasing Organic Matter	15. Dust Abatement in and around Vineyards for Mite Management
4. Fertilization Recommendations from Agronomist	**E. Air Quality and Climate Protection**
5. Method of Application of Fertilizers	1. Pest Management Strategy
6. Register Fertilization Information	2. Transportation
7. Soil Nutrient	3. Agricultural Burning
8. Soil Compaction	**F. Ecosystem Management**
C. Vineyard Water Management	
1. Water Management Strategy	1. Ecosystem Processes Resource Base Ecosystem Biodiversity
2. Decision Making for Water Management	2. Habitat Enhancement for Wildlife
3. Off-site Water Movement	3. Protect Sensitive Species of Animals and Plants
4. Distribution Uniformity for Irrigation Systems	4. Ecosystem Management - Aquatic Habitats: Streams, Rivers, and Wetlands
D. Pest Management	**G. Neighbors and Community Relations**
1. Vineyard Monitoring for Insect and Mite Pests	1. Neighbors and Community Relations
2. Economic Thresholds and Pest-Natural Enemy Ratios for Leafhoppers, Mites, and Thrips	2. Awareness of Potential Neighbor and Community Issues
3. Training for Pest and Disease Monitoring	3. Environment (e.g., habitat restoration, environmental organizations)
4. Powdery Mildew Management	

Table 1 Sustainability axes and indicators

informed choices and appreciate the diversity of wines. Additionally, wine awareness promotes responsible consumption and helps consumers recognize and appreciate the cultural and historical significance of wine as a beverage.

The significance of wine safety lies in the assurance that consumers can savor authentic, safe-to-consume products, while helping wine enterprises safeguard their brand integrity and customer loyalty against counterfeit items. To achieve this goal, wine producers collaborate closely with regulatory bodies such as the European Commission. Their joint efforts not only protect public health but also uphold the wine industry's distinguished reputation for consistently delivering top-notch, secure, and delightful wine products.

Digital agriculture tools play a significant role in enhancing wine awareness and wine safety. These tools enable wineries to collect and analyze data on vineyard conditions, grape quality, and wine production processes. With the help of sensors, weather monitoring systems, and dedicated information systems, winemakers can gather real-time information about soil conditions, temperature, humidity, and pest management. This data-driven approach enhances the quality and safety of the wine by enabling winemakers to make informed decisions throughout the production process towards more sustainable grapes and wine production. Furthermore, digital tools facilitate traceability, allowing wineries to track and document every step of the winemaking process, from grape cultivation to bottling. This traceability ensures transparency, authenticity, and safety in the wine industry, as consumers can access information about the vineyard practices, certifications, and quality standards employed by the wineries they patronize.

In pursuit of these objectives, MiB presents an adaptable and expandable framework that can accommodate further valuable functionalities catering to the wine industry's needs concerning wine awareness and safety. For example, MiB can support the legal obligations that arose for wine enterprises in the EU to support access of consumers to nutritional information for each wine [92].

Our work has inspired future research plans that extend the application of the MiB ecosystem beyond the wine industry. We envision leveraging the platform's capabilities in domains such as olive oil and the beer industry. By adapting the MiB ecosystem to these contexts, we can enhance awareness, traceability, and security within these industries as well. Particularly, the authenticity application is domain and product-agnostic and can be used as is. The rest of the apps depend upon the used data model and schema and will need adaptations for each product to create the corresponding stories. The deployment of semantic technologies and food/wine ontologies like the FoodOn[32] and BEVON[33] ontologies, could provide a common vocabulary for all products. This is an option we plan to investigate in the future.

Furthermore, we recognize the potential of blockchain technologies in augmenting the traceability and security aspects of the MiB ecosystem. Integrating blockchain into the platform can provide a decentralized and immutable ledger,

[32] https://foodon.org/
[33] https://rdfs.co/bevon/latest/html

ensuring transparent and tamper-proof records of the entire supply chain [93]. This would further enhance trust and authenticity in the information presented to consumers.

Finally, the exploration of incentive mechanisms [94, 95] can strengthen the crowdsourcing approach of registering bottles within the MiB ecosystem. By incentivizing users to contribute information about their wine experiences, such as verifying bottle authenticity or providing feedback, we can harness the power of collective intelligence and engagement. This crowdsourcing approach can enhance the accuracy and reliability of the information available on the platform, ultimately benefiting both consumers and industry stakeholders.

Overall, our future research directions include expanding the application of the MiB ecosystem to other industries, integrating blockchain technology for enhanced traceability and security, and exploring incentive mechanisms to foster active user participation and knowledge sharing.

7 Conclusion

In this paper, we introduced the MiB platform as a comprehensive digital agriculture ecosystem designed to enhance wine awareness and ensure wine security. The platform offers a unique experience to *end users* such as oenologists, wine experts, and wine consumers and to *administrators* such as wine enterprises.

In particular, in MiB, users can explore detailed descriptions of winemaking processes and wine characteristics. They can also get access to vineyard-specific details like sustainability data, that enhance their understanding and appreciation of the wines they encounter, information about producers, and even historical backgrounds. Additionally, the platform prioritizes wine security by ensuring traceability, authenticity, and compliance with regulations. Through features such as label tracking, nutritional information access, and monitoring for non-genuine bottles, MiB promotes users' confidence and trust in the wines they choose to enjoy.

On the other hand, MiB Administrators benefit from the data management functionality and the monitoring of authenticity. The first allows them to curate wine stories whereas the second gives them an extra level of control, especially for receiving information on cases of non-genuine bottles.

Due to its platform-agnostic design MiB can be applied in different wine enterprises, as well as in related fields within the agriculture and food sector with minor modifications.

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