Applied Ontology -1 (2020) 1–17
DOI 10.3233/AO-200239
IOS Press

Representing wine concepts: A hybrid approach

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Abstract. Wines with geographical indication can be classified and represented by such features as designations of origin, producers, vintage years, alcoholic strength, and grape varieties; these features allow us to define wines in terms of a set of necessary and/or sufficient conditions. However, wines can also be identified by other characteristics, involving their look, smell, and taste; in this case, it is hard to define wines in terms of necessary and/or sufficient conditions, as wine concepts exhibit typicality effects. This is a setback for the design of computer science ontologies aiming to represent wine concepts, since knowledge representation formalisms commonly adopted in this field do not allow for the representation of concepts in terms of typical traits. To solve this problem, we propose to adopt a hybrid approach in which ontology-oriented formalisms are combined with a geometric representation of knowledge based on conceptual spaces. As in conceptual spaces, concepts are identified in terms of a number of quality dimensions. In order to determine those relevant for wine representation, we use the terminology developed by the Italian Association of Sommeliers to describe wines. This will allow us to understand typicality effects about wines, determine prototypes and better exemplars, and measure the degree of similarity between different wines.

Keywords: Representation of concepts, formal ontologies, conceptual spaces, wine classification, wine concepts

Accepted by: Barry Smith

1. Introduction

There are, of course, many possible ways to classify wines corresponding to different pragmatic purposes: by style (red, white…), price, country/region (France, Italy…/Bordeaux, Bourgogne…), vintage years, etcetera (Deroy, 2008). That being said, there is also a much firmer classification of wines, which reflects laws regulating wine trading and sales, and is expressed on wine labels (Borghini, 2012). In this respect, wines can be *prima facie* classified and represented by a set of necessary and/or sufficient conditions; for example, their designations of origin, producers, vintage years, alcoholic strength, and grape varieties. Unfortunately, even if this kind of classification is very helpful to univocally identify a particular wine (as each wine has one and only one label), it does not take into account some key features that are particularly relevant at the commonsense and social level, that is, the wine look, smell, and taste.

Describing wines in this way, however, makes it difficult to define them in terms of necessary and/or sufficient conditions, as wine concepts clearly exhibit typicality effects. This is a setback for the design of computer science ontologies aiming to represent them, such as FoodOn (Griffiths et al., 2016; Dooley et al., 2018), since the knowledge representation formalisms commonly adopted in this field (i.e., description logics) do not allow for the representation of concepts in terms of typical traits. To solve this problem, we propose to adopt a hybrid approach in which ontology-oriented formalisms are combined

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with a geometric representation of knowledge based on conceptual spaces. As we shall claim, this will allow us to better understand typicality effects about wines, determine prototypes and good exemplars, and measure the degree of similarity between different types of wines.

The rest of the paper is organized as follows. In Section 2, we summarize the European classification of wines, with a special focus on the Italian one, taken as a case study; in this case, wines with geographical indication can be *prima facie* classified and represented in terms of designations of origin, producers, vintage years, alcoholic strength, and grape varieties – that is, in terms of a specific number of necessary and/or sufficient conditions, as demanded by the classical theory of concepts. Nevertheless, when wines are approached from the taster's point of view, they are identified by other relevant features, related to their look, smell, and taste; in this case, wines cannot be defined in terms of necessary and/or sufficient conditions, as they clearly exhibit typicality effects.

In Section 3, we briefly introduce description logics (DLs), a widely adopted class of logical formalisms that allow the representation of nets of concepts in terms of sets of necessary and/or sufficient conditions. In principle, DLs, as also the logical formalisms used by FoodOn, are able to represent wines in terms of designations of origin, producers, vintage years, alcoholic strength, and grape varieties (or any other similar set of necessary and/or sufficient conditions), but, like all knowledge-representation systems based on the classical theory of concepts, they cannot account for the typicality effects exhibited by wine concepts. Since a conceptual representation that cannot account for typicality effects is inadequate for both descriptive and technological purposes, we shall propose to adopt a hybrid approach, in which a classical representation formalism is associated with a non-classical component based on conceptual spaces. We then present conceptual spaces, a geometrical framework for the representation of concepts proposed by Peter Gärdenfors, in Section 3.1. In brief, a conceptual space is a metric space in which entities are characterized in terms of a set of quality dimensions. As we claim that conceptual spaces would be able to represent wines in terms of their look, smell, and taste, it is essential to determine the relevant quality dimensions for wine concepts.

For this purpose, in Section 4 we exploit the terminology developed by the Italian Association of Sommeliers (AIS) to describe the look, smell, and taste of wines (Associazione Italiana Sommeliers [AIS], 2013). This terminology can be particularly useful to our case, as most descriptors are translatable into quantitative terms and thus measurable, a key aspect that allows us to regard them as quality dimensions in a conceptual space. Finally, in Section 5 we summarize some advantages of adopting a hybrid approach to represent wine concepts.

2. Classifying and representing wines

The Italian classification of wines can be easily traced back to the European one, as both are based on geographical indication.[1] We can think about those classifications in terms of a pyramid (see Fig. 1). At the lowest level of the pyramid, we find wines without any indication of origin, the so-called *Vini da tavola* (VDT) in the Italian classification, which are divided into generic wines and varietal wines in the European classification. At a higher level, there are wines with indication of origin. European legislation divides these wines into two categories: PGI wines (i.e., wines with protected geographical indication) and PDO wines (i.e., wines with protected designation of origin). In the Italian classification, the PGI category corresponds to IGT wines (i.e., wines with indication of typical geography), while the PDO category is divided into two subcategories, the DOC category, including wines with controlled origin

[1] For a critique, see work by Borghini (2012).

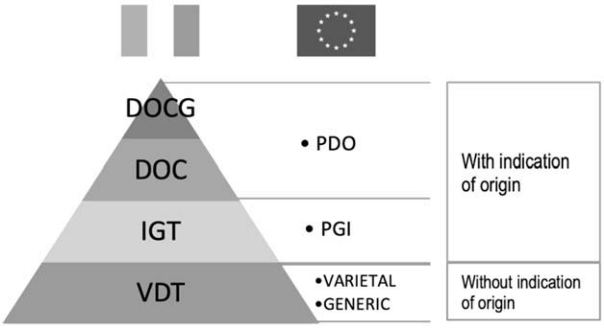

Fig. 1. Italian and European classification of wines.

denomination, and the DOCG category, including wines with controlled and guaranteed origin denomination. In some cases, it is possible to add to PDO wines the indication of a sub-zone (denoting, for instance, a more restricted area or the name of the vineyard) and/or sub-denominations (e.g., *Riserva*, *Superiore*). Wines at the highest levels of the pyramid are regulated by increasingly stringent production standards, which specify the zones of production, grape varieties, fermentation techniques, bottling restrictions, minimum alcoholic strength, and so on.

Before going on, a few remarks are necessary to understand our choice of focusing on the European classification system and, in particular, on the Italian one. First, addressing PGI and PDO wines only, as regulated by European legislation, means focusing exclusively on wines with strict and quite precise production standards, which indicate all the necessary and/or sufficient conditions that a certain wine must meet to belong to a particular geographical indication (for instance, a particular Barolo, in order to be an instance of BAROLO DOCG, must be produced in a very specific area of Piedmont, with Nebbiolo grapes only, and have a minimum alcoholic strength of 13°). Defining wines in terms of necessary and/or sufficient conditions of application is pivotal to argue that wine concepts can be *prima facie* thought of and represented in terms of the classical theory of concepts. According to this theory, in fact, concepts can be characterized in terms of sets of individually necessary and jointly sufficient conditions. For example, something is a SQUARE if and only if it is a regular polygon with exactly four sides; somebody is a BACHELOR if and only if he is a human, unmarried, adult male; being human, adult, unmarried, and male are each individually necessary conditions to be a bachelor; being human *and* adult *and* unmarried *and* male are jointly sufficient conditions to be a bachelor. That being said, our proposal can easily be accommodated to encompass wine classification systems used outside the European Union and not based on geographical indication, as long as they are regulated by production standards that are able to specify, *at least*, the necessary conditions that a certain wine must meet to belong to a particular wine category. Should such production standards not be present, it would be much more difficult (and to a certain extent probably impossible) to represent wine concepts in terms of classical theory, that is in terms of necessary and/or sufficient conditions of application; in this case, however, our proposal to integrate a classical representation of wine concepts with a non-classical one, based on the look, smell, and taste of wines, would be much more needed, as the latter would possibly be the only one at our disposal.

Second, our choice of focusing on the Italian classification system should be seen merely as a case study; thus, our proposal can be easily accommodated to address other classification systems within the European union (and, as explained above, outside it), as long as they are disciplined by specific production standards. Of course, choosing another classification system, it might happen that different necessary and/or sufficient conditions of application would be individuated. For instance, according to the German classification system, which is one of a kind, wines are classified based on the level of ripeness that the grapes have achieved by their harvesting time (the riper the grapes, the higher the wine quality);[2] this means that the grapes' level of ripeness enters as a necessary condition to establish whether a particular wine belongs to a certain wine category or not.

Going back to Italian PGI and PDO wines, they can be classified and represented by a specific number of necessary and/or sufficient conditions: their designations of origin – as indicated by the particular IGT, DOC, or DOCG category, with the possible addition of sub-areas and sub-denominations – producers, vintage years, alcoholic strength, and grape varieties. For instance: Barolo DOCG, Sarmassa, Giacomo Brezza, 2014, 15°, Nebbiolo 100%, and Chianti Classico DOCG, Borgo Salcetino, 2016, 13°, Sangiovese 95%, Canaiolo 5% unambiguously denote two different types of wines. This means that wines can be classified and represented through an explicit definition, as demanded by the classical theory of concepts. Of course, even considering Italian PGI and PDO wines only, there may be disagreement about the specific conditions to include in the definition; for instance, some could argue that indicating the grape varieties is superfluous, as they can be inferred from the production regulations of PGI and PDO wines (e.g., if one considers Barolo DOCG, he or she already knows that the grape variety is Nebbiolo 100%), while someone else could claim that indicating the grape varieties is still necessary, as some production regulations admit certain degrees of freedom (e.g., if one considers Chianti Classico DOCG, he or she only knows that Sangiovese must be between 80% and 100%, while other grape varieties can be used up to 20%). Still, we can eventually converge towards a definition in terms of necessary and/or sufficient conditions.

However, even if similar definitions are certainly important to categorize wines, they do not exhaust their classification and representation, especially at the commonsense and social level, where the wine style is generally taken to be much more relevant. In fact, when one approaches wines from the taster's point of view, he or she is more interested in their visual aspect, bouquet, and taste-olfactory characteristics.[3] In fact, it is not by chance that the wine tasting process adopted by an association like the AIS is divided into three main steps: first, a visual examination; then an olfactory analysis; and, finally, the taste-olfactory evaluation (AIS, 2013).

In this case, however, it is hard to classify and represent wines in terms of necessary and/or sufficient conditions, as they clearly exhibit typicality effects. For instance, Barbera del Monferrato DOC generally has a high acidity and low tannin content and is a still wine; yet, acidity can sometimes be less perceivable and tannicity more pronounced (if the wine has spent some time in a barrel), or the wine may even be sparkling. But why should the presence of typicality effects be a problem for wine representation?

3. Classical concepts, typicality effects, hybrid representations

As seen before, according to the classical view, concepts can be defined in terms of sets of necessary and sufficient conditions. In the field of artificial intelligence, various representation systems implicitly

[2]In the German classification, the PGI category corresponds to *Deutscher Landwein* (i.e., German land wines), while the PDO category is divided into two subcategories, the QbA category, including quality wines, and the QbP category, including wines with special attributes; within this last category, wines are further divided into six sub-categories, corresponding to ascending levels of ripeness: *Kabinett*, *Spätlese*, *Auslese*, *Beerenauslese*, *Eiswein*, *Trockenbeerenauslese*.

[3]Of course, even considering these latter features, some relevant aspects of wine tasting are still left out (Burnham & Skilleas, 2008; Perullo, 2016; Todd, 2012).

adopt this view. As an example, consider DLs, a class of logical formalisms that allow the representation of nets of concepts in terms of sets of necessary and/or sufficient conditions (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2010; Baader, Horrocks, Lutz, & Sattler, 2017). Nowadays, DLs are widely adopted, especially in the field of ontologies. For example, the OWL (Web Ontology Language) system is a formalism in this tradition that has been endorsed by the World Wide Web Consortium for the development of the semantic web and also by the two main ontologies in the food field, that is FoodOn and LanguaL.

The information concerning wine concepts presented in Section 2 can easily be represented in terms of DL constructs and thus integrated with FoodOn so to provide new content to cover gaps in the representation of wine and wine-related concepts. Let us consider a simple example (see Fig. 2). The main constructs of DLs are concepts (terms) and roles (properties). For example, in a wine knowledge base, there could be such concepts as GRAPE WINE, GRAPE PLANT, GRAPE WINE BY REGION (already present in FoodOn), and GRAPE WINE BY PRODUCER (to be added to FoodOn), and such roles as *derives from*, *produced by* (already present in FoodOn), and *originated in* (to be added to FoodOn). Graphically, a DL knowledge base can be depicted as a network in which concepts figure as nodes and roles as links connecting concepts. For example, the fragment of the network in Fig. 2 depicts a DL knowledge base according to which a GRAPE WINE *derives from* a GRAPE PLANT, *has an alcoholic content of* a number represented by an INTEGER in the range 9–15 (or 7–24, if we rather map FoodOn classes instead), is *produced by* a PRODUCER, and so on. A GRAPE WINE WITH INDICATION OF ORIGIN *is a* GRAPE WINE, and NEBBIOLO GRAPE PLANT *is a* GRAPE PLANT: thick arrows in Fig. 2 depict subsumption links, which represent the class/subclass relation between concepts. Concepts (consider, e.g., BAROLO DOCG) inherit all the properties of their super-concepts (in this example, DOCG GRAPE WINE, GRAPE WINE WITH INDICATION OF ORIGIN, and GRAPE WINE). DLs allow one to specify whether the information associated with a given concept must be intended in terms of necessary, sufficient, or both necessary and sufficient conditions. In any case, it is evident that most of the concepts in Fig. 2 can be characterized in classical terms. For example, something is BAROLO DOCG if and only if it *is a* DOCG GRAPE WINE (and thus it *is a* GRAPE WINE WITH INDICATION OF ORIGIN), *is a* NEBBIOLO WINE (i.e., it *derives from* NEBBIOLO GRAPE PLANT), and *is a* BAROLO WINE (i.e., it *originated in* BAROLO REGION).[4]

The classical theory of concepts was dominant in philosophy and psychology until the second half of the last century, when both philosophical analyses (Wittgenstein, 1953) and empirical results (Rosch, 1975) demonstrated its inadequacy for ordinary, commonsense concepts. In fact, many familiar concepts can be characterized in terms of typicality and resist the possibility of being defined in classical terms. All the psychological theories of concepts developed in recent decades take typicality effects in conceptualization into account (Margolis & Laurence, 2019; Murphy, 2002).

As we saw at the end of the previous section, when wines are considered according to their look, smell, and taste, it is hard to define them in terms of necessary and/or sufficient conditions, as they

[4]As we said, FoodOn is in principle compatible with our proposal. Of course, some adjustments would be necessary as our proposal provides new content for the representation of wine and wine-related concepts. To begin with, the FoodOn class GRAPE WINE should be supplemented with the sub-classes GRAPE WINE WITH INDICATION OF ORIGIN (along with the sub-sub class DOCG GRAPE WINE and relevant sub-sub-sub classes, such as BAROLO DOCG, CHIANTI DOCG, etcetera) and GRAPE WINE BY PRODUCER (along with relevant sub-sub classes); moreover, the sub-class GRAPE WINE BY REGION should be enriched to account for the zones and sub-zones specified in DOC and DOCG production standards, such as the Barolo region (BAROLO WINE), and sub-zones, such as Sarmassa (BAROLO SARMASSA WINE). Finally, the FoodOn class GRAPE PLANT should be enriched to include relevant grape varieties, such as Nebbiolo (NEBBIOLO GRAPE PLANT); correspondingly, the classes RED WINE and WHITE WINE should contain relevant sub-classes such as NEBBIOLO WINE.

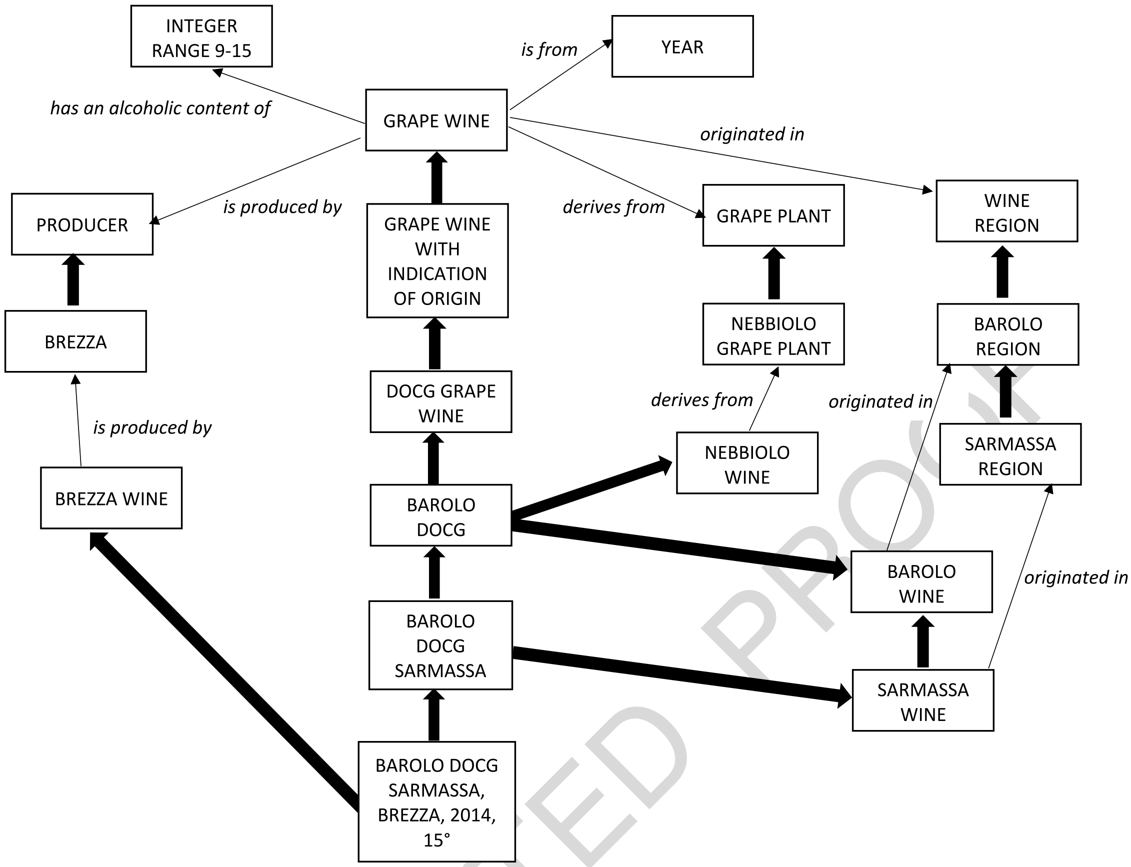

Fig. 2. A fragment of the network depicting a wine knowledge base according to the Italian classification of wines; wine concepts are represented in terms of DL constructs.

clearly exhibit typicality effects. Let us consider in more detail some specific aspects of the role of typicality in concept representation:

– *Relevance of typical traits in characterizing concepts*. In many cases, typical (or prototypical) traits, which do not correspond to necessary or sufficient conditions, are relevant to characterize concepts. For example, a flying ability is a trait associated with the concept BIRD, but it is not a necessary condition to be a bird (there are birds that are not able to fly). However, knowing that typical birds are able to fly is constitutive of the knowledge of BIRD: if somebody does not know that birds usually fly, we shall conclude that he or she does not have full mastery of the concept. Similarly, a typical CHAIR has four legs; typical WATER is a tasteless liquid; and so on.
– *Concepts exhibit graded structures*. Certain individuals count as “better” or “worse” exemplars of a category. In general, more typical exemplars are “better” (i.e., more representative of the category) than atypical ones. For example, a flying bird (e.g., a robin) is a better exemplar of the BIRD category than, say, a penguin or an ostrich; a four-legged chair is more representative of the CHAIR category than, say, Saarinen’s Tulip chair. This is not relevant in the case of classical concepts, in which all the exemplars of a given category are at the same level.

– *Vague boundaries of categories*. In some cases, it can happen that non-classical categories, unlike classical ones, do not exhibit distinct boundaries. In the case of less typical exemplars, it might be unclear whether they fall within a given category. For example, sometimes it could be impossible to discriminate between an atypical CHAIR and a STOOL, or between an atypical CHAIR and an ARMCHAIR. We encounter similar problems with chromatic categories, which are standard examples of non-classical categories.

As for wines, when they are considered according to their look, smell, and taste, all three aspects above of the role of typicality are present. To begin with, typical traits are surely relevant in characterizing wine concepts. For instance, BARBERA DEL MONFERRATO DOC typically has a high acidity and low tannin content, which makes it a good accompaniment to grilled steaks. If someone ignores these typical features, we should conclude that he or she does not have full mastery of the concept, even though, of course, high acidity and low tannin content are not necessary conditions for being a BARBERA DEL MONFERRATO DOC (when the wine has spent some time in a barrel, acidity is less perceivable and tannicity more pronounced). Moreover, wine concepts clearly exhibit a graded structure, as a still BARBERA DEL MONFERRATO DOC is certainly a better exemplar of the category than a sparkling one, which is, in fact, fairly rare. Finally, wine categories often have vague boundaries; for instance, sometimes it could be impossible to discriminate between, say, an atypical CHIANTI DOCG and a CHIANTI CLASSICO DOCG.

DLs, and thus ontologies like FoodOn and LanguaL, like all knowledge representation systems based on the classical theory of concepts, nevertheless cannot account for typicality effects. In DLs, the representation of concepts does not admit exceptions, and the properties of a given concept must be inherited by more specific concepts and by all their instances. For example, if the ability to fly was associated with the BIRD concept, then all particular birds (including penguins and ostriches) should be able to fly.[5]

However, a conceptual representation that cannot account for typicality is inadequate for both descriptive and technological purposes. From the descriptive point of view, decades of empirical psychological research have shown that many commonsense concepts exhibit typicality effects. From the point of view of ICT applications, artificial intelligence systems aimed at simulating human capabilities have to master prototypical concepts, which are essential for many cognitive tasks (Frixione & Lieto, 2012). On the other hand, there are aspects of conceptualization that cannot be easily accounted for in classical terms (as we already saw before in the case of wine concepts). A possible solution consists of the adoption of a hybrid approach, in which a classical representation formalism (e.g., a DL system) is associated with a non-classical component, based on some different formalisms that allow us to account for typicality. In this spirit, in the following section of this paper, we adopt a hybrid approach, in which for the non-classical component we embrace a representation based on conceptual spaces[6] (Frixione & Lieto, 2012; 2014).

3.1. Conceptual spaces

Conceptual spaces are a geometrical framework for the representation of concepts (Gärdenfors, 2000; 2014; Lieto, Chella, & Frixione, 2017). In brief, a conceptual space (CS) is a metric space in which entities are characterized in terms of a set of quality dimensions. Each dimension represents a quality

[5] Various extensions of DL formalisms exist, which make it possible to represent exceptions, and which would therefore be, at least in principle, suitable for representing non-classical concepts (Lieto & Pozzato, 2019). Nevertheless, such approaches pose various theoretical and practical difficulties, and are scarcely used in practice (Frixione & Lieto, 2012).

[6] For a proposal to adopt conceptual spaces for wine representation in a rather different context, see work by Paradis (2015).

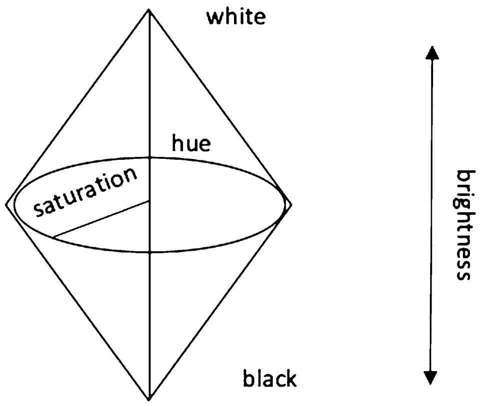

Fig. 3. Color spindle.

that is relevant for the description of the domain in question. In some cases, such dimensions can be directly related to perceptual information (i.e., information that can be directly measured by some kind of sensor): examples can be temperature, weight, brightness, or pitch. In other cases, dimensions can be more abstract in nature. To each quality dimension, a geometrical (topological or metrical) structure is associated. A point in a CS represents an epistemologically primitive entity at the level of analysis considered. For example, in the case of visual perception, a point in a CS corresponds to a perceptual primitive (e.g., an atomic shape) and is obtained from the measurements of the external environment performed, such as by a camera, through the subsequent processing of low-level vision algorithms.

As a simple illustrative example, let us consider a CS for color (Gärdenfors, 2000). In so-called HSL color space – a standard way of representing colors especially used by computer graphics – it is possible to describe colors by fixing three parameters: hue, saturation, and brightness (or luminosity). Such parameters can be viewed as the dimensions of a chromatic CS: hues can be arranged in a circle, on which complementary colors (e.g., red and green) lie opposite each other; saturation (i.e., color intensity) ranges from gray to full intensity, and therefore it is isomorphic to an interval of the real line; and brightness varies from white to black, so it can be represented as a linear dimension with two end points. As a result, a possible CS for colors is a tridimensional space with the structure of the familiar color spindle (see Fig. 3).

An important aspect of the theory is the definition of metric functions on CSs: the distance between two points in a CS can be calculated according to some appropriate metric function (e.g., usual Euclidean distance) and corresponds to the measure of the perceived similarity between the two corresponding entities.

In CSs, concepts are represented as regions of space: an individual I falls under a concept C if and only if the point representing I lies inside the region of the space corresponding to C (see Fig. 4). Convex sets of points have a special status in conceptualization. In convex sets of points, for every pair of points belonging to a set (and therefore sharing some features), all the points between them belong to the same set, and they share, in turn, the same features. In such a scenario, typicality effects in conceptualization have a natural geometrical interpretation. Given concepts that correspond to convex regions in some CSs, prototypes correspond to the geometrical centroids of the regions themselves. Then, given a certain concept, a degree of centrality can be associated with each point that falls within the corresponding region. This level of centrality may be interpreted as a measure of its typicality. Hence, one of the main features of CSs consists of the fact that they provide a natural way of explaining typicality. Their

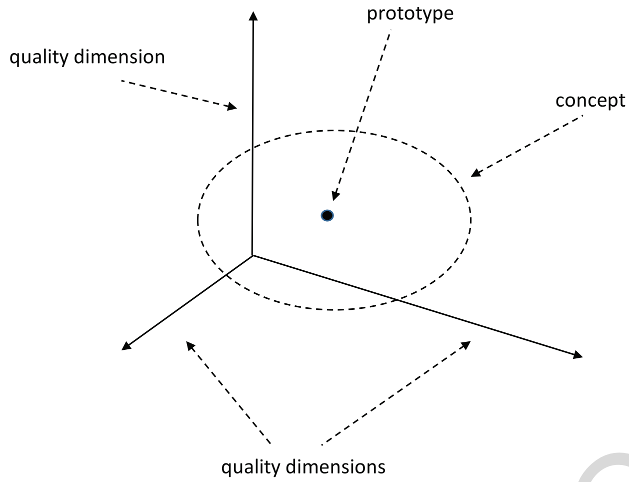

Fig. 4. A general three-dimensional conceptual space.

geometrical structure allows a natural way of calculating the semantic similarity among concepts and exemplars by using classical topological or metrical techniques.

In complex CSs, quality dimensions can be grouped into different *domains*. In other words, a CS can consist of a set of domains, each formed by a set of quality dimensions. As a simple example, let us consider a hypothetical CS for the representation of fruits. It could be formed, among others, by such domains as *shape*, *color*, and *taste*. Each domain in its turn has various dimensions, such as sweetness, acidity, bitterness, and saltiness for *taste*, or brightness, hue, and saturation for *color* (in this example, the *color* domain could have the same structure as the color CS of Fig. 4 above). A fruit concept, say ORANGE, is then represented as a set of regions, one for each domain. If we want to represent wine concepts through CSs, then a pivotal preliminary step would be that of determining the relevant domains and quality dimensions.

4. Wines in conceptual spaces: Looking for quality dimensions

In order to determine the quality dimensions of a CS aiming at representing wine concepts, we use the terminology developed by the AIS (2013) to describe the look, smell, and taste of wines (see Table 1). The AIS's wine tasting terminology can in fact be particularly useful to our case, as most descriptors are translatable in quantitative terms and thus measurable; this is a key aspect, as it allows us to regard these descriptors as quality dimensions in a CS.[7] So, let us analyze them to understand if, and how, they can be translated in quantitative terms and measured, thus becoming relevant quality dimensions.

Let us start by considering the potential look-related quality dimensions. In this case, the AIS's descriptors used to perform the visual examination of wines are three in number: 1) limpidity, 2) color, and 3) consistency or effervescence, depending on whether the wine is still or sparkling.

[7]To be clear, this choice may ignore some important characteristics of wine, such as its aesthetic properties, that many authors believe to be discoverable only through first-person experience (Borghini & Piazza, 2019). Moreover, wine vocabulary may be enormously richer; for a philosophical discussion, see, e.g., work by Lehrer (2007).

Table 1
A simplified version of the AIS's wine tasting terminology

Visual examination	Olfactory examination	Taste-olfactory examination		
Limpidity	Intensity	Sweetness	Acidity	Equilibrium
Color	Complexity	Pseudo warm (alcohol)	Tannicity	Intensity
Consistency	Quality	Softness	Saltiness	Persistence
Effervescence	Description	Structure or body		Quality

To begin with, limpidity is defined by the AIS (2013, p. 41) as the absence of suspended particulates, as even the presence of a few suspended particulates forbids one from evaluating a wine as limpid. Limpidity can easily be translated in quantitative terms and measured using a nephelometer. A nephelometer is an instrument that employs a light beam and a light detector, generally set at 90° from the source beam, to measure the concentration of suspended particulates in a liquid; limpidity is then a function of the light reflected into the detector from the suspended particulates. As such, limpidity can be regarded as a suitable quality dimension for wine representation.

Color is another characteristic that is easily translatable in quantitative terms and then measured. As we have seen above, in the HSL color space three variables are considered, and each can correspond to a relevant quality dimension: hue, saturation, and brightness. To repeat, hue is directly linked to the color's wavelength and so refers to the actual color (focusing on wines, red, pink, or yellow); saturation, indicating the amount of gray in a color, is a measure of its purity or how sharp or dull the color appears; and brightness, indicating the amount of black or white in a color, is a measure of its shade (darkness) or tint (lightness). For instance, a ruby red wine can be represented in the HSL color space by three numbers: 354 (hue), 80 (saturation), and 34 (brightness).

Consistency, or viscosity, is evaluated for still wines only. It is defined as the resistance of a fluid to flow, and it mostly depends on the presence in wines of alcohols, but also poly-alcohols, polyphenols, monosaccharides, polysaccharides, and other substances. Consistency is also affected by the wine temperature, so a standard value should be fixed, or – perhaps better – different standard values for each wine typology, depending on the suggested serving temperature (e.g., following the AIS's indications, 9° for young white wines and rosé wines, 11° for mature white wines and white dessert wines, 13° for young and delicate red wines, 15° for red wines with a medium body and tannicity and red dessert wines, and 17° for aged and evolved red wines). That being said, consistency can be determined by a rheometer, an instrument able to measure the way in which a liquid flows in response to applied forces, and thus translated in quantitative terms. For example, at the temperature of 25°C, the consistency of a wine with an alcohol content of 12% would be about 1.4 mPa.s, while pure water is 0.89 mPa.s.

Finally, effervescence is evaluated for lightly sparkling and sparkling wines only, as it is produced by the presence of carbon dioxide (CO_2). Three aspects of the development of bubbles of CO_2 flowing up to the surface are to be considered in assessing effervescence: the size of the bubbles, their quantity, and the persistence of the groups of bubbles. These three features can actually vary a lot depending on the glass that is used – for instance, on its form (Beaumont, Cilindre, Abdi, Maman, & Polidori, 2019) or on the presence of soap. Still, assuming fixing such a variable (e.g., using an ISO tasting glass, whose measures are officially regulated by the International Standard Organization, always washed in the same way) as well as the number of minutes to wait after the pouring process, they can be measured and used as relevant quality dimensions.

To sum up, look-related quality dimensions would be 5 or 7, depending on whether the wine is still or sparkling, grouped into three domains (see Table 2).

Table 2
Look-related quality dimensions

STILL WINE		SPARKLING WINE	
Look-related quality dimensions	Look-related domains	Look-related quality dimension	Look-related domains
Limpidity	Limpidity	Limpidity	Limpidity
Hue	Color	Hue	Color
Saturation		Saturation	
Brightness		Brightness	
Consistency	Consistency	Bubble size	Effervescence
		Bubble number	
		Bubble persistence	

Moving to potential smell-related quality dimensions, the AIS's wine tasting terminology indicates four descriptors to accomplish the olfactory examination of wines: 1) olfactory intensity, 2) olfactory complexity, 3) scent description, and 4) olfactory quality. In this case, determining the quality dimensions is more complicated for two main reasons. On the one hand, olfactory complexity and scent description presuppose the recognition of a great variety of odorous sensations; on the other hand, olfactory quality is hardly translatable in quantitative terms, and as such, cannot be measured. Let us see it better starting from the latter descriptor.

According to the AIS, olfactory quality is a subjective characteristic of wines, as it also depends on the evaluation of the wine's frankness and typicality, which is based on the taster's acquaintance with the kind of wine at issue and his or her previous tasting experiences. Even if the subjective character of olfactory quality is tied to the taster's knowledge and memories, not to his or her personal preferences, the taster is still asked to express an opinion, not to simply describe some intrinsic feature of the wine. That being said, we prefer not to regard olfactory quality as a relevant quality dimension in representing wines.[8]

Moving to olfactory intensity, it is made of all the aroma notes perceived at the same time, independently of their number or varieties. This characteristic can easily be measured by most sensory techniques, which are able to determine the total odor concentration in an investigated odor sample and thus its overall olfactory intensity.

Quite differently, olfactory complexity is regarded as the variety of odorous sensations, or families of scents, perceived. Thus, it is strictly related to scent description. Using the AIS terminology, a wine bouquet can be described by 10 different families of scents:[9] *aromatic* (mostly associated with aromatic grape varieties, such as malvasia or gewürztraminer), *vinous* (usually found in young red wines), *floral* (white or red flowers in young white or red wines, respectively; withered or dried flowers in more mature wines), *fruity* (white or yellow pulp fruit in young white wines; red or blackberry fruit in young red wines; preserved, very ripe, and dried fruit in more mature wines), *grassy* (green vegetal essences typical of particular grape varieties, such as sauvignon or lagrein), *mineral* (mineral and salty aroma typical of particular grape varieties, such as Rhineland riesling), *fragrant* (typical of sparkling wines

[8]Of course, the issue of the objectivity/subjectivity of the properties we value in wine is much debated, especially as far as complex properties, such as finesse (i.e., olfactory and taste-olfactory quality), balance and length, are addressed. For a discussion, see, e.g., work by Smith (2007) and Bender (2008).

[9]A different list of standardized wine aroma terminology is that of the Wine Aroma Wheel, originally developed by the Sensory Evaluation Sub-committee of the American Society for Enology and Viticulture (Noble et al., 1984; 1987). The list might also be interesting for our aim because terms were selected that were analytical and free of hedonic or value-judgment connotations.

obtained from refermentation in bottle), *spicy* (typical of wines aged in wooden barrels), *toasted* (typical of white and red wines after an evolution in barrel and in bottle), and *ethereal* (typical of more mature wines, such as Barolo or Brunello di Montalcino).

At present, both olfactory complexity and scent description can be determined by using instrumental analyses like gas chromatography (GC), mass spectrometry (MS), optical spectroscopy, or combined GC-MS. The main problem with these techniques for detecting odors, however, is that they simply separate out the different constituents of an odor sample rather than providing a measure of their relative olfactory intensity. More recently, an alternative technique has been introduced, the electronic nose (or E-nose), an electronic device that tries to imitate the human nose – as both of them are based on non-specific receptors (sensors vs. cells) and a posterior signal processing – and is able to recognize specific scents in investigated samples.

According to Gardner and Barlett (1994, p. 210), "An electronic nose is an instrument which comprises an array of electronic chemical sensors with partial sensitivity and an appropriate pattern recognition system capable of recognizing simple or complex odors." Very roughly,[10] an E-nose employs an array of n different non-selective chemical sensors (typically from 5 to 100); each sensor is sensitive to a broad range of different volatile molecules, not just one, but with a sensitivity that differs from that shown by the other sensors of the array. This means that the E-nose's responses, just like the ones from a human nose, are dependent on the whole range of volatile molecules contained in an odor sample. When in contact with volatile compounds, the sensors react – that is, they experience changes in electrical properties (e.g., current, voltage, resistance, electrical fields, and oscillation frequency). The outputs from all the individual sensors in the array are then processed so as to produce a specific response pattern reflecting the relative responses of each sensor to a given chemical compound. Finally, the identification and classification of odors are completed through comparison of the specific response pattern against previously learned patterns (of course, it is crucial to have an efficient technique for pattern recognition, using, for instance, artificial neural networks). Even if the performance of current E-noses is far from that of human noses, an E-nose combining 16 sensors was recently used to recognize 29 aromas usually present in white wines, grouped into different families – floral, fruity, microbiological, herbaceous, and chemical (Lozano, Santos, & Horrillo, 2005) – or to detect the main aromas usually present in red and white wines (Lozano et al., 2006; Santos et al., 2010). Moreover, it seems that the E-nose results correspond better than the predictions made by chromatography to the scores given by a panel of experts (Lozano, Santos, Gutiérrez, & Horrillo, 2007).

At any rate, using E-noses, it would be possible to translate wine aromas in quantitative terms and thus represent them as quality dimensions in a CS. More precisely, scent description can be expressed in a CS by n dimensions, depending on the number of sensors in the E-nose (e.g., 16); these n quality dimensions would be grouped in the description domain. Olfactory complexity can instead be regarded as a self-standing quality dimension, which can be established on the basis of the number of scents recognized by the E-nose.

To sum up, assuming, for instance, that the E-nose has 16 sensors, smell-related quality dimensions would number 18, grouped into three domains (see Table 3).

To conclude this section, let us examine potential taste-olfactory-related quality dimensions. In this case, the AIS terminology is particularly rich, as it indicates 10 or 11 descriptors (depending on whether the wine is white or red) to be used to complete the taste-olfactory examination of wines: 1) sweetness, 2) pseudo warmth or alcohol, 3) softness, 4) acidity, 5) tannicity (for red wines only), 6) saltiness, 7)

[10] For a more comprehensive explanation, see, e.g., work by Persaud (2016).

Table 3
Smell-related quality dimensions

Smell-related quality dimensions	Smell-related domains
Olfactory intensity	Olfactory intensity
Olfactory complexity	Olfactory complexity
N dimensions (depending on the number of sensors in the E-nose, e.g., 16 dimensions)	Scent description

structure or body, 8) taste-olfactory intensity, 9) taste-olfactory persistence (or length), 10) balance, and 11) taste-olfactory quality.

The latter two descriptors – balance and taste–olfactory quality – are, again, subjective characteristics of wines, as they both depend on the taster's acquaintance with the kind of wine at issue and his or her previous tasting experiences. As in the case of olfactory quality, the taster is once more asked to express an opinion, not to simply describe some intrinsic feature of the wine. We thus prefer not to regard balance and taste-olfactory quality as relevant quality dimensions in representing wine concepts. Let us examine the other descriptors.

To begin with, sweetness can be defined as the pleasurable sensation of roundedness especially experienced on the tip of the tongue; it is caused by the presence of sugars (glucose, fructose, and others) in wine, and thus can easily be determined by measuring the residual sugar concentration. For instance, according to the AIS terminology, a wine can be defined as dry when the residual sugar concentration is between 1 and 15 g/l, medium-dry between 15 and 30 g/l, medium-sweet between 30 and 50 g/l, sweet between 50 and 100 g/l, and excessively sweet more than 100 g/l. There are many techniques to measure residual sugar concentration, but an easy way to do that is to use test kits such as Clinitest®. Pseudo warmth can be described as a slight irritation in the mouth; it is a tactile sensation caused by alcohols present in wine, especially ethanol. With a good approximation, it can be roughly determined by measuring the alcoholic strength. Softness can be defined as a pleasant sensation of smoothness and velvetiness that involves the whole mouth; it is another tactile sensation caused prevalently by poly-alcohols (especially glycerol), but also colloidal substances (gum, mucilage, pectin), sugars, and other kinds of alcohol. Even if there is no direct way to measure softness, it can be roughly translated in quantitative terms by measuring the amount of glycerol, which is its most important determinant. The three descriptors above can be regarded as relevant quality dimensions and grouped into one domain: wine softness.

Acidity can be described as the sensation of crispness especially experienced under and along the sides of the tongue; it is determined by the presence of acids in wine (e.g., tartaric, malic, and lactic acids). This means that it can easily be translated in quantitative terms and measured by determining the pH (all wines lie on the acidic side of the pH spectrum, and most range from 2.5 to about 4.5 pH). Tannicity can be defined as the pleasant bitterish sensation of dryness and roughness perceived in the whole mouth; it is a tactile sensation caused by the presence of tannins and other polyphenols. It should be evaluated for red wines only, and it can be roughly translated in quantitative terms by measuring the total amount of polyphenols. Saltiness is the saline sensation especially experienced on the sides of the tongue and accompanied by an increase in salivation; it is determined by the presence of anions of organic and inorganic acids (e.g., phosphates, sulfates, chlorides), as well as of mineral salts (e.g., potassium, sodium, magnesium). Again, it can be translated in quantitative terms by measuring the total amount of those elements (in wines it is normally between 1 and 3 g/l), and the three descriptors above can be regarded as relevant quality dimensions and grouped into one domain: wine hardness.

Structure, or body, is the sensation that describes the thickness and fullness of wine in the mouth; it is determined by the total dry extract, which represents all that is solid in wine after taking away water,

Table 4
Smell-related quality dimensions

WHITE WINE		RED WINE	
Taste-related quality dimensions	Taste-related domains	Taste-related quality dimension	Taste-related domains
Sweetness Pseudo warmth Softness	Wine softness	Sweetness Pseudo warmth Softness	Wine softness
Acidity Saltiness	Wine hardness	Acidity Tannicity Saltiness	Wine hardness
Structure	Structure	Structure	Structure
Taste-olfactory intensity	Taste-olfactory intensity	Taste-olfactory intensity	Taste-olfactory intensity
Taste-olfactory persistence	Taste-olfactory persistence	Taste-olfactory persistence	Taste-olfactory persistence

ethanol, and other volatile substances. It can be translated in quantitative terms by measuring the total dry extract (normally between 16 and 22 g/l in white wines and 20 and 30 g/l in red wines). Taste-olfactory intensity is defined as the immediate impact of *all* substances giving taste to wine on the tongue and mouth mucous. With a certain approximation, it can be determined by measuring the total amount of those substances in wine. Finally, taste-olfactory persistence, or length, is the amount of time that the gustatory and aromatic sensations last in the mouth before tempering and disappearing; it is evaluated in seconds and thus translatable in quantitative terms. All three descriptors above can be considered relevant quality dimensions.

Some recent findings, obtained combining an E-nose and an E-tongue (an electronic device that tries to imitate the human tongue, with a similar structure to an E-nose), demonstrated that these two devices taken together are able not only to quantify sugar, acidity, pH, tartaric, malic and lactic acids, polyphenols, anthocyanins, and ions (e.g., Ca, Mg, and K) in wines, but also to be trained according to data given by panels of tasters (Di Natale et al., 2000; 2004).

To sum up, taste-related quality dimensions would be 8 or 9, depending on whether the wine is white or red, grouped into five domains (see Table 4).

If we put together all the quality dimensions described above, we can conclude that a CS aiming to represent wines should be composed of 31, 32, or 33 quality dimensions – depending on whether the wine is white, red, or sparkling – grouped into 11 related domains.

5. Provisional conclusions

Assuming that representing wines in terms of CSs is feasible, what are its main advantages? Describing wines according to their look, smell, and taste is important, especially at the commonsense and social level when, for instance, one has to decide which is the best wine to taste with a particular dish. As we have seen above, when wines are identified in this way, they clearly exhibit typicality effects that cannot be captured by DLs and other knowledge representation systems based on the classical theory of concepts. On the contrary, if we represent wines in terms of CSs, it would be easy to understand the prototype of a particular kind of wine (e.g., the prototype of BARBERA DEL MONFERRATO DOC) or what individual wines are its best exemplars or the most atypical ones (e.g., a still BARBERA DEL MONFERRATO DOC is a better exemplar of the category than a sparkling one, which is a rather atypical exemplar), and to measure the degree of similarity between different wines. Moreover, it would be easy to identify some possible overlapping between different kinds of wines and thus to account for the difficulty in discriminating between them.

That being said, what are the advantages of a hybrid approach over a purely non-classical one? Classifying wines according to their designations of origin, producers, vintage years, alcoholic strength, and grape varieties gives us critical information about them, which would be essential not to disregard. If we represent wines in terms of DL constructs, it would be possible to perform a series of relevant inferences, such as categorization (i.e., the process of attributing a specific wine as a member to a class, e.g., BARBERA DEL MONFERRATO DOC), classification (i.e., the process through which new class-subclass relations are inferred, e.g. BAROLO DOCG SARMASSA is a subclass of BAROLO DOCG, which is a subclass of DOCG GRAPE WINE, which is a subclass of GRAPE WINE WITH INDICATION OF ORIGIN), and consistency checking (i.e., the process of testing the logical coherence of a given ontology). The inferences above would be guaranteed by our hybrid approach, while they would be difficult to obtain with a purely non-classical representation of wine concepts.

To conclude, we believe that adopting a hybrid approach to the representation of wine concepts is highly advantageous. Thus, the next steps of our work will be: (i) specifying the wine knowledge base in terms of DL constructs starting from the Italian classification of wines; (ii) measuring the quality dimensions of a selected group of DOCG Italian wines; (iii) implementing the relevant CS; and (iv) combining the classical and non-classical representations of wine concepts. Moreover, we believe that a hybrid characterization can also be successfully applied to other relevant wine-related concepts, such as those of INDICATION OF ORIGIN and GRAPE PLANT. Given that some conflicts can easily arise between the classical and non-classical representations of these wine-related concepts (due, e.g., to climate change, which in the years to come might alter some features of a *terroir*[11] or a grape variety), our hybrid model, handling both kinds of information, would be able to perform important inferences about such possible discrepancies. For instance, as the characteristics of a specific land can be altered over time, being able to represent the prototype of a particular wine along with its best exemplars can be useful to possibly re-discuss the boundaries of a geographical indication or to determine the identity of a wine – in line with work by Borghini (2012).[12]

Acknowledgements

We wish to thank Andrea Borghini and Antonio Chella for their insightful comments and suggestions.

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[11] For an interesting discussion of the notion of *terroir*, see work by Scruton (2009).

[12] Although this paper was mutually conceived, discussed, and drafted, M. Cristina Amoretti should be considered responsible for Sections 2 and 4, while M. Frixione should be considered responsible for Section 3.

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