Humulus lupulus L., also known as hops, is a vine whose flowers are a major component in brewing. It delivers flavor, bitterness, and aroma to beer and also aids in foam stabilization. Furthermore, it plays an important role in beer conservation due to its antimicrobial and antioxidant properties, which have recently been studied for food preservation. Hops can also be found in the production of cosmetics and is considered healthy food. There are more than 250 cataloged varieties of hops, and among the main attributes that differ from each other are alpha-acids, beta-acids, and essential oils. Those components give the beer a unique combination of characteristics, and may even influence its category. There are many ways to identify the hop variety from its acids and essential oils using methods such as chromatography, mass spectrometry, capillary electrophoresis, and nuclear magnetic resonance. However, these methods demand expensive and complex equipment, inaccessible or unavailable to most beer producers. In this work, we present a database that includes 1592 images of hop leaves, from 12 popular hop varieties in southeastern Brazil. From these images, it is possible to explore methods of pattern recognition and machine learning to classify hop varieties.

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Specifications Table

| Subject                  | Agricultural Sciences |
|--------------------------|-----------------------|
| Specific subject area    | Plant variety classification |
| Type of data             | Figure, text annotation |
| How data were acquired   | Cellphone camera sensor |
|                           | Instruments: Motorola Moto G7, Samsung Galaxy A11 and Apple iPhone 11 |
| Data format              | JPG, XML (Pascal VOC XML Annotation Format for label and bounding box) |
| Parameters for data      | The only constraint imposed on data collection was to include at least one entire hop leaf. |
| collection               |                                    |
| Description of data      | Images were taken in a natural environment, with varying climate, light, focus, occlusion, resolution, distance, and angle. Samples contain adult and young leaves. There was no removal of outliers or low-quality images. No pre-processing was adopted either. |
| collection               |                                    |
| Data source location     | Institution: Atlântica Hops |
|                           | City/Town/Region: Juquiá, São Paulo / Litoral Sul Paulista |
|                           | Country: Brazil |
|                           | Institution: Hops Brasil |
|                           | City/Town/Region: Cedral, São Paulo / São José do Rio Preto |
|                           | Country: Brazil |
|                           | Institution: Brazuca Lúpulos |
|                           | City/Town/Region: Petrópolis, Rio de Janeiro / Serrana |
|                           | Country: Brazil |
| Data accessibility       | https://doi.org/10.6084/m9.figshare.14933178 |

Value of the Data

- Classify the hop variety is of paramount importance for brewers [1,2] and also other applications (cosmetic, medicinal) [3–5]. Current methods are expensive and complex [6–9]. Computer vision may be a viable path.
- The data can provide ground reference for testing and validating machine learning methods to support image classification of hop varieties. Brewers could apply these methods and try to improve the production process by better-controlling hop variety.
- This dataset is the first hop variety dataset publicly available.

1. Data Description

The UFOP Hop Varieties Dataset (UFOP-HVD) consists of 1592 images of hop leaves captured in 3 plant nurseries in Brazil. The leaf images were acquired by different people and different mobile devices (camera sensors) in order to increase the representativeness of the database. Images were taken in a natural environment, with varying climate, light, focus, occlusion, resolution, distance, and angle. Samples contain adult and young leaves. There was no removal of outliers or low-quality images. No pre-processing was adopted either. There are more than 250 cataloged varieties [10] of this plant and, among the main attributes that differ from each other, are the alpha-acids, beta-acids, and [11] essential oils. The present dataset focuses on 12 varieties popular in southeastern Brazil. Fig. 1 contains examples of each of the 12 varieties used in this dataset. Table 1 contains the number of images of each class as well as the image resolutions according to the devices (Motorola Moto G7, Samsung Galaxy A11, and Apple iPhone 11).

Each image may contain one or more leaves of a hop of the same variety. All leaves were marked with bounding boxes as shown in the examples in Fig. 2 and labeled by field specialists. The leaf with the largest area was labeled as main (bounding box red), while the others as extra leaves (in yellow). The bounding box annotations are provided with the dataset in the Pascal VOC XML format [12].
Table 1
Hop variety distribution per image resolution.

| Hop Variety          | 1040 × 520 | 1032 × 581 | 3391 × 2345 | 4096 × 2304 | 3683 × 3024 | 3024 × 4032 | 4032 × 3024 | 3072 × 4096 | 4096 × 3072 |
|----------------------|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Cascade              | 51         | 9          | 0           | 0           | 1           | 3           | 46          | 0           | 0           |
| Centennial           | 0          | 0          | 0           | 0           | 0           | 0           | 0           | 83          | 42          |
| Cluster              | 30         | 0          | 0           | 23          | 0           | 0           | 50          | 0           | 0           |
| Comet                | 55         | 10         | 0           | 0           | 0           | 3           | 47          | 12          | 44          |
| Hallertau Mittelfruh | 0          | 0          | 0           | 0           | 0           | 0           | 0           | 67          | 74          |
| Nugget               | 0          | 8          | 0           | 58          | 0           | 2           | 48          | 0           | 0           |
| Saaz                 | 0          | 7          | 1           | 0           | 0           | 1           | 48          | 39          | 76          |
| Sorachi Ace          | 0          | 8          | 0           | 0           | 0           | 0           | 50          | 76          | 59          |
| Tahoma               | 0          | 8          | 0           | 0           | 0           | 3           | 47          | 31          | 30          |
| Triple Pearl         | 60         | 8          | 0           | 0           | 0           | 1           | 49          | 0           | 0           |
| Triumph              | 0          | 9          | 0           | 42          | 0           | 5           | 45          | 0           | 0           |
| Zeus                 | 0          | 8          | 0           | 0           | 0           | 8           | 42          | 63          | 2           |
| **Total**            | **196**    | **75**     | **1**       | **123**     | **1**       | **26**      | **472**     | **371**     | **327**     |
Fig. 1. Examples of the 12 Hops varieties contained in this data set: (a) Cascade; (b) Nugget; (c) Cluster; (d) Triple Pearl; (e) Hallertau Mittelfruh; (f) Centennia; (g) Saaz; (h) Sorachi Ace; (i) Tahoma; (j) Comet; (k) Triumph; (l) Zeus.

Fig. 2. Labeling methodology: leaf with the largest area was labeled as main (red bounding box), while the others as extra leaves (yellow).
See below an example of an XML file available with the dataset:

```
<annotation>
  <folder>cascade</folder>
  <filename>cascade_l1_13.jpg</filename>
  <path>../validation/cascade/cascade_l1_13.jpg</path>
  <source>
    <database>UFOP-HVD</database>
  </source>
  <size>
    <width>520</width>
    <height>1040</height>
    <depth>3</depth>
  </size>
  <segmented>0</segmented>
  <object>
    <name>cascade</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>225</xmin>
      <ymin>2</ymin>
      <xmax>475</xmax>
      <ymax>235</ymax>
    </bndbox>
  </object>
  <object>
    <name>cascade</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>1</xmin>
      <ymin>2</ymin>
      <xmax>238</xmax>
      <ymax>257</ymax>
    </bndbox>
  </object>
  <object>
    <name>cascade</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>102</xmin>
      <ymin>325</ymin>
      <xmax>391</xmax>
      <ymax>622</ymax>
    </bndbox>
  </object>
  <object>
    <name>cascade</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>291</xmin>
      <ymin>580</ymin>
      <xmax>428</xmax>
      <ymax>702</ymax>
    </bndbox>
  </object>
  <object>
    <name>cascade</name>
    <pose>Unspecified</pose>
    <truncated>0</truncated>
    <difficult>0</difficult>
    <bndbox>
      <xmin>318</xmin>
      <ymin>717</ymin>
      <xmax>472</xmax>
      <ymax>890</ymax>
    </bndbox>
  </object>
</annotation>
```
We emphasize that each XML refers to an acquired image and that it can contain more than one leaf and consequently more than one bounding box annotation. The XML presented corresponds to the left image of Fig. 2.

From the original dataset, a new one was generated containing all the leaves cut by the bounding boxes. This other set of data is called Cropped Dataset. The number of leaves per class in this database and the average of extracted leaves per image are displayed in Table 2.

| Hop Variety                      | Number average extracted leaf / image | Number total leaf / variety |
|----------------------------------|--------------------------------------|-----------------------------|
| Cascade                          | 3.76                                 | 414                         |
| Centennial                       | 1.62                                 | 202                         |
| Cluster                          | 4.36                                 | 449                         |
| Comet                            | 1.88                                 | 321                         |
| Hallertau Mittelfrueh             | 1.65                                 | 232                         |
| Nugget                           | 3.81                                 | 442                         |
| Saaz                             | 2.05                                 | 353                         |
| Sorachi Ace                      | 2.02                                 | 390                         |
| Tahoma                           | 2.30                                 | 274                         |
| Triple Pearl                     | 3.53                                 | 417                         |
| Triumph                          | 3.77                                 | 381                         |
| Zeus                             | 2.31                                 | 284                         |
| **Total**                        | **2.61**                             | **4159**                    |

2. Experimental Design, Materials and Methods

The database is divided into three sets of data (70% for training, 15% for validation and 15% for test) in order to standardize the evaluation of machine learning methods. The division can be seen in Tables 3 and 4.

| Hop Variety                      | # Train | # Validation | # Test | Total  |
|----------------------------------|---------|--------------|--------|--------|
| Cascade                          | 78      | 16           | 16     | 110    |
| Centennial                       | 89      | 18           | 18     | 125    |
| Cluster                          | 73      | 15           | 15     | 103    |
| Comet                            | 121     | 25           | 25     | 171    |
| Hallertau Mittelfrueh             | 99      | 21           | 21     | 141    |
| Nugget                           | 82      | 17           | 17     | 116    |
| Saaz                             | 122     | 25           | 25     | 172    |
| Sorachi Ace                      | 137     | 28           | 28     | 193    |
| Tahoma                           | 85      | 17           | 17     | 119    |
| Triple Pearl                     | 84      | 17           | 17     | 118    |
| Triumph                          | 71      | 15           | 15     | 101    |
| Zeus                             | 87      | 18           | 18     | 123    |
| **Total**                        | 1128    | 232          | 232    | 1592   |

Since the database is unbalanced in terms of images per class, results must be reported using recall, precision and F1-score per class.
Table 4  
Number of leaves of each class for each of the partitions (train, validation, test), in Cropped Dataset.

| Hop Variety               | # Train | # Validation | # Test | Total |
|---------------------------|---------|--------------|--------|-------|
| Cascade                   | 318     | 39           | 57     | 414   |
| Centennial                | 158     | 23           | 21     | 202   |
| Cluster                   | 316     | 58           | 75     | 449   |
| Comet                     | 212     | 52           | 57     | 321   |
| Hallertau Mittelfruhe     | 165     | 30           | 37     | 232   |
| Nugget                    | 301     | 74           | 67     | 442   |
| Saaz                      | 265     | 40           | 48     | 353   |
| Sorachi Ace               | 286     | 43           | 61     | 390   |
| Tahoma                    | 203     | 32           | 39     | 274   |
| Triple Pearl              | 299     | 56           | 62     | 417   |
| Triumph                   | 260     | 56           | 65     | 381   |
| Zeus                      | 196     | 48           | 40     | 284   |
| **Total**                 | **2979**| **551**      | **629**| **4159**|

Ethics Statement

Not applicable.

CRediT Author Statement

**Pedro Castro**: Conceptualization, Data curation, Writing–original draft; **Eduardo Luz**: Conceptualization, Experimental Design, Writing-Reviewing and editing; **Gladston Moreira**: Conceptualization, Writing-Reviewing and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Data Availability

UFOP Hop Varieties Dataset (UFOP-HVD) (Original data) (figshare).

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