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An Application to Count Yeast Cells Using Novel Lab-On-a-Chip Solution for the Wine Value Chain

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Summary:
Lab-on-a-chip solutions have emerged as a viable cost-effective portable solution to bring laboratory capabilities elsewhere. This kind of technologies enable to speed up decision-making process in several industry value chains. In this work, we present an application to count yeast cells along the wine production value chain. Our solution is based upon a microscope-on-a-chip device designed with out-of-the-shelf components. The solution also relies on top of state-of-the-art computer vision solutions and we demonstrate it operates to the same standards as optical microscopy.

Keywords: Lab-on-a-chip, holography, microfluidics, computer vision, wine quality.

Introduction

In recent years, lab-on-a-chip solutions have emerged as *in situ* solutions to traditional sample analysis for several biomedical essays. Despite this, several proposals need the fabrication of expensive custom components. In this work, we present a cost-effective solution aimed to automate a problem presented in the wine industry: certain types of wines as sparkling wines require a strict yeast count at specific stages of their production. The wine industry is one of the industries with more impact in Western Europe. According to the annual report State of the Work vine and wine sector (2022), four Western-European countries (Spain, France, Italy and Portugal) are present in the top ten countries for vineyard surface area of the globe, netting a total 36,9% of the vineyard surface area of the Earth [1].

Proposal

Here, we present an approach to use out-of-the-shelf components to create a laboratory setup to solve this problem, which consists of a lensless holographic microscope built on top of commercial components, like a lensless camera (37U Series, The Imaging Source) and an LED micro-display (JBD013 Series, Jade Bird Display), alongside with custom 3D-printed parts and common laboratory disposables. We have previously introduced similar experiences using these kind of microscope-on-a-chip technologies applied to other fields [2].

This set-up is connected to a novel application, developed using Python programming language and the QT desktop application framework. Such application can capture real-time images from the wine samples. Later, the user can execute several steps of a computer vision pipeline to post-process the images and count the cells. A typical pipeline consists of: normalization, feature extraction, image composition (to increase both resolution and scanning area), holographic reconstruction and particle count. Our application implements state-of-the-art computer vision and machine learning algorithms to extract the features of the images in the first place to create composite images to increase the sensing range of the microscope, for example the well-known SIFT method [5]; also regarding the particle count, for example, the Hough transform [3] or the YOLO neural network [4].

Results

A series of experiments were designed to test the viability of our setup as an alternative to confocal imaging in order to measure cells of *Saccharomyces cerevisiae* in white wine samples.

Here, we present a few of these results. For example, as a qualitative result, Fig. 1 shows, in a visual inspection, how the microscopy technique is able to recover cells images from the holographic reconstructions of the captured images. Moreover, this figure –extracted from our graphical framework interface– shows the automatic count of cells using the Hough transform method. For this sample, a total 80 cells were retrieved, which implies a $9.70 \cdot 10^6$ cells/mL count in the wine sample. As it can be seen in the image, the resolution of the reconstructed image is around 2-3 µm, half the size of a typical *Saccharomyces cerevisiae* cell.

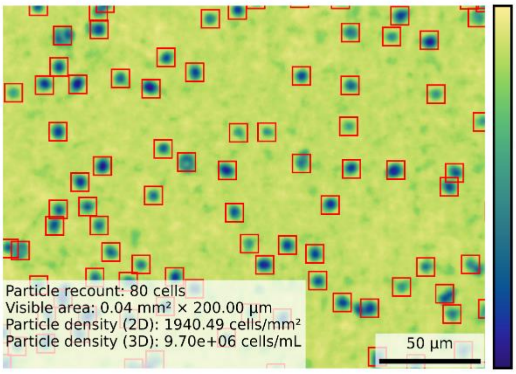

Fig. 1. A capture from our microscope-on-a-chip setup. The capture is the result of applying a reconstruction algorithm that consists on: normalization, feature extraction, image composition (from a 5x5 mosaic to a single image), holographic reconstruction and particle count.

Finally, we compared our lab-on-a-chip measurements with ones from the optical microscopy. We created a culture of *Saccharomyces cerevisiae* and diluted it to lower concentrations exposing the samples the both devices. Fig. 2 shows the calibration comparison between both sets of measurements.

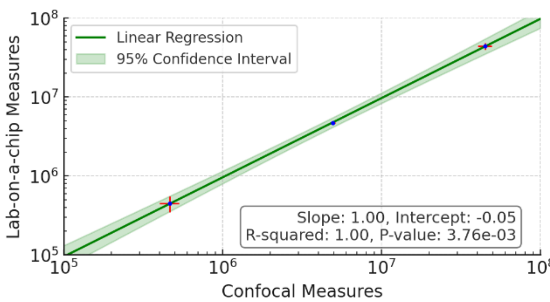

Fig. 2. The calibration measurements of our lab-on-a-chip setup for cell counting.

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