Laboratoire Interdisciplinaire sur l'Organisation Nanométrique et Supramoléculaire

Using TANGO for controlling a microfluidic system with automatic image analysis and droplet detection

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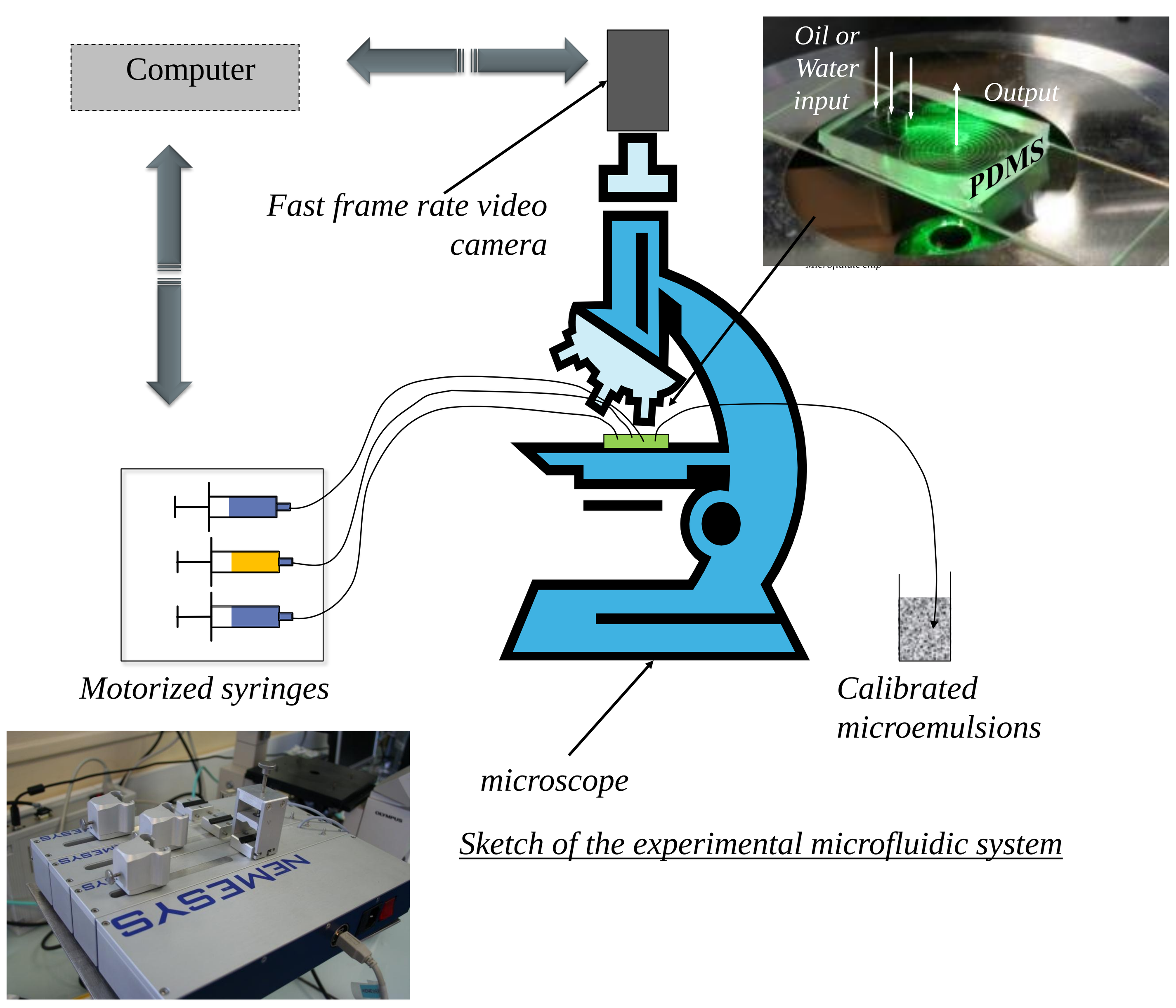
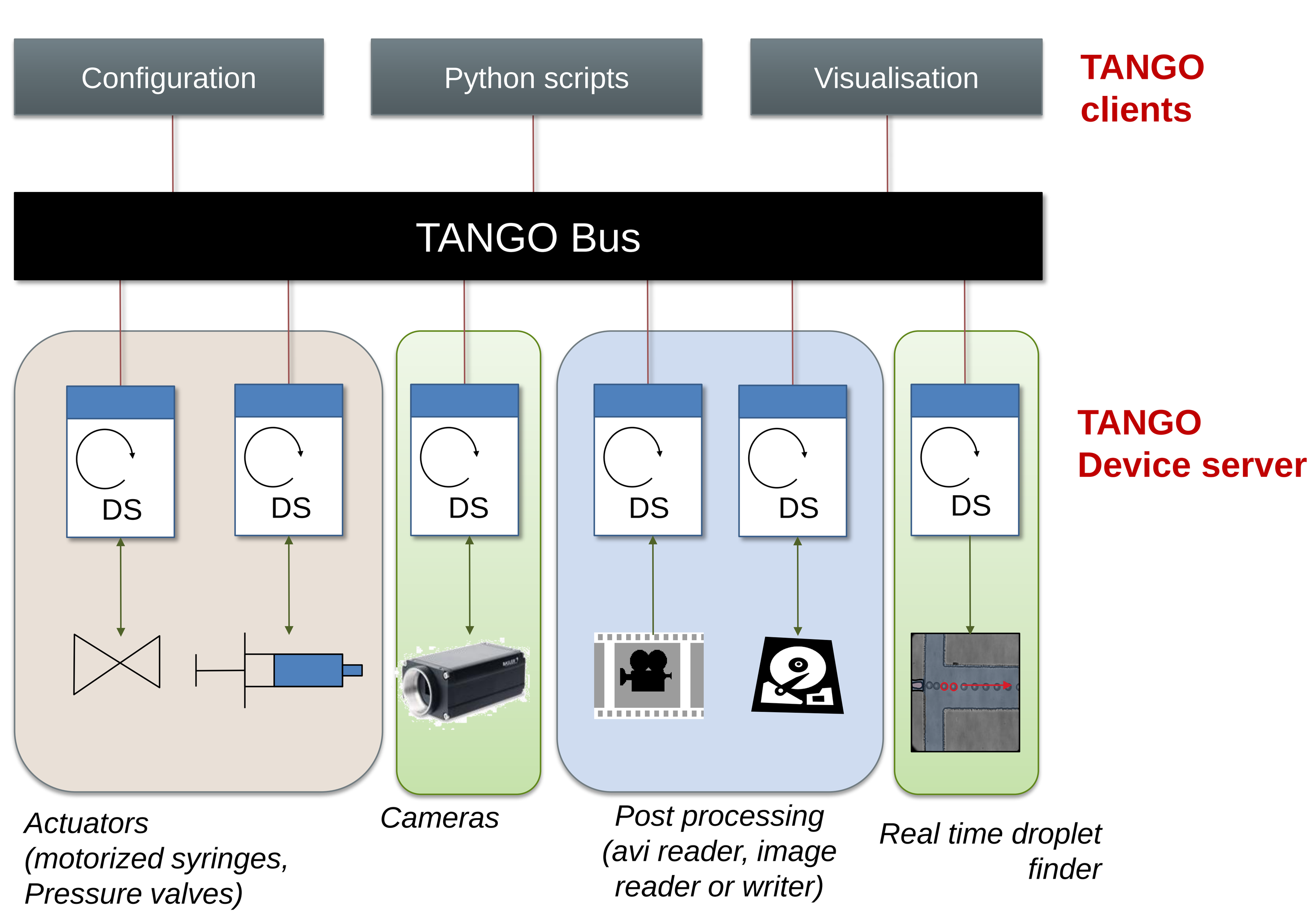
Abstract :
The microfluidics is the science and technology of systems that process or manipulate small amounts of fluids, using channels with dimensions of tens to hundreds of micrometers. Since a decade microfluidics has become a powerful tool for fundamental and applied researches. Microfluidics influence subject areas from chemical synthesis and biological analysis to optics and information technology. At CEA / LIONS, we integrate microfluidics technology in several research projects. The present work deals with the development of tools for the detection and the analysis of complex calibrated micro-drops.
Although this technique uses small volume of chemicals, it requires the use of numbers of accurate electronic equipments such as motorized syringes, valve, pressure sensors and video cameras with fast frame rate coupled to microscopes.
We use a TANGO* control system for all these heterogeneous equipments in microfluidics experiments and video acquisition. We have developed a set of device servers which allow image acquisition and droplets detection (size, number, velocity) almost in real time.
Using TANGO, we are able to provide feedback to actuators, in order to adjust the size and the rate of the droplet formation.
* A.Götz and al,"A CORBA-based Control System", ICALEPCS 2003



Sketch of the experimental microfluidic system

TANGO Device servers
The Phantom video camera is interfaced with a C++ device server based on PhCon (control libraries for the Phantom high speed cameras given by Vision Research). For testing, we also use TANGO devices that can publish previously recorded images or video on image attributes.

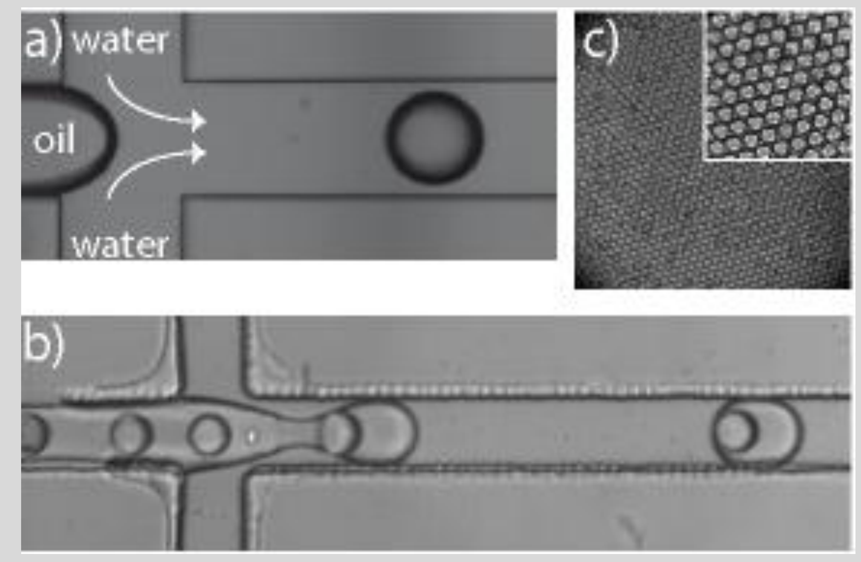
Droplet detection
The "droplets finder" application developed in the present work can connect to all these devices and process the image to find drops. The software is developed in C++, for providing fast results, and is based on the OpenCV (Open Source Computer Vision) libraries, which give programming functions for real time computer vision.
From these libraries, we are using the cvHoughCircle function. which implements a Hough* algorithm and can find circles on a grayscale image. Some parameters have to be specified: maximal radii of circles, minimal distance between circles, and two method (Hough) specific parameters. The function returns a list of circles with their centres coordinates and radii. A post processing (for brightness and contrast) is made on the image for improving the results.
* Yuen, H. K.and al,"Comparative study of Hough transform methods for circle finding", Image Vision Comput., Butterworth-Heinemann, **8**, 1990, 71-77



http://iramis.cea.fr/sis2m/lions

Microfluidic principles :
This technology is based on the manipulation of continuous liquid flow through microfabricated channels. In the lab we use rapid prototyping of polymer (polydimethylsiloxane-pdms) casting [1] and we designed original microfluidic chips for droplet formation.
The basic principle is the following. Two immiscible fluids (oil and water for instance) meet at a cross junction. Due to the viscous shear the liquid/liquid interface is deformed until a drop is created. In this particular case the local shear is well controlled leading to a very reproducible process [2]. The straightforward consequence is the formation of a monodisperse emulsion where a droplet crystal is shown.

[1] McDonald, J.C. *et al*. "Fabrication of microfluidic systems in poly(dimethylsiloxane)". *Electrophoresis*, **21**, 27-40 (2000).
[2] Garstecki P, Stone H A and Whitesides G M 2005 *Phys. Rev. Lett.* **94** 164501



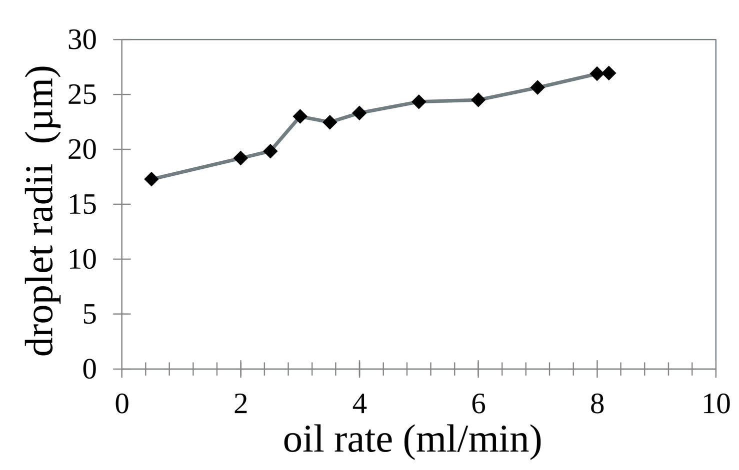
a- Droplet formation at a cross junction

b- Complex droplet formation at a cross junction (double emulsion).

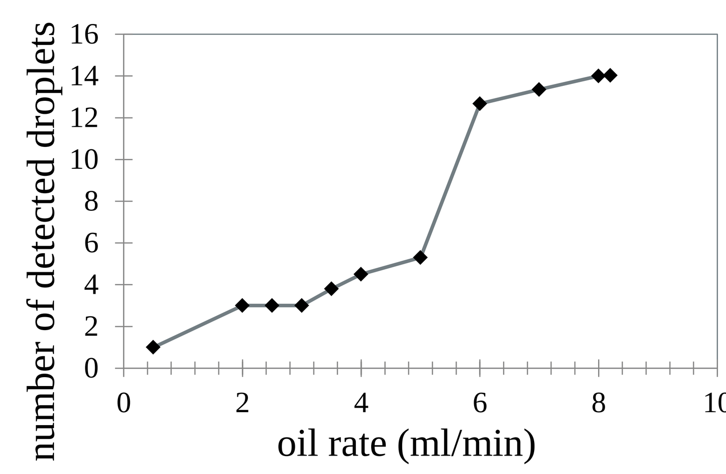
c- Crystal of droplets

Droplet detection
The droplet detection device server is compiled with Microsoft Visual C++ 2008 express version, in "debug" mode, and "release" mode, with the corresponding TANGO and OpenCV libraries. Execution times of the droplet detection (see Table 1) are given by the software, and have been obtained on a simple laptop computer with the following configuration: Intel Core 2 Duo P8600 @2.40 GHz and 4 Go ram.

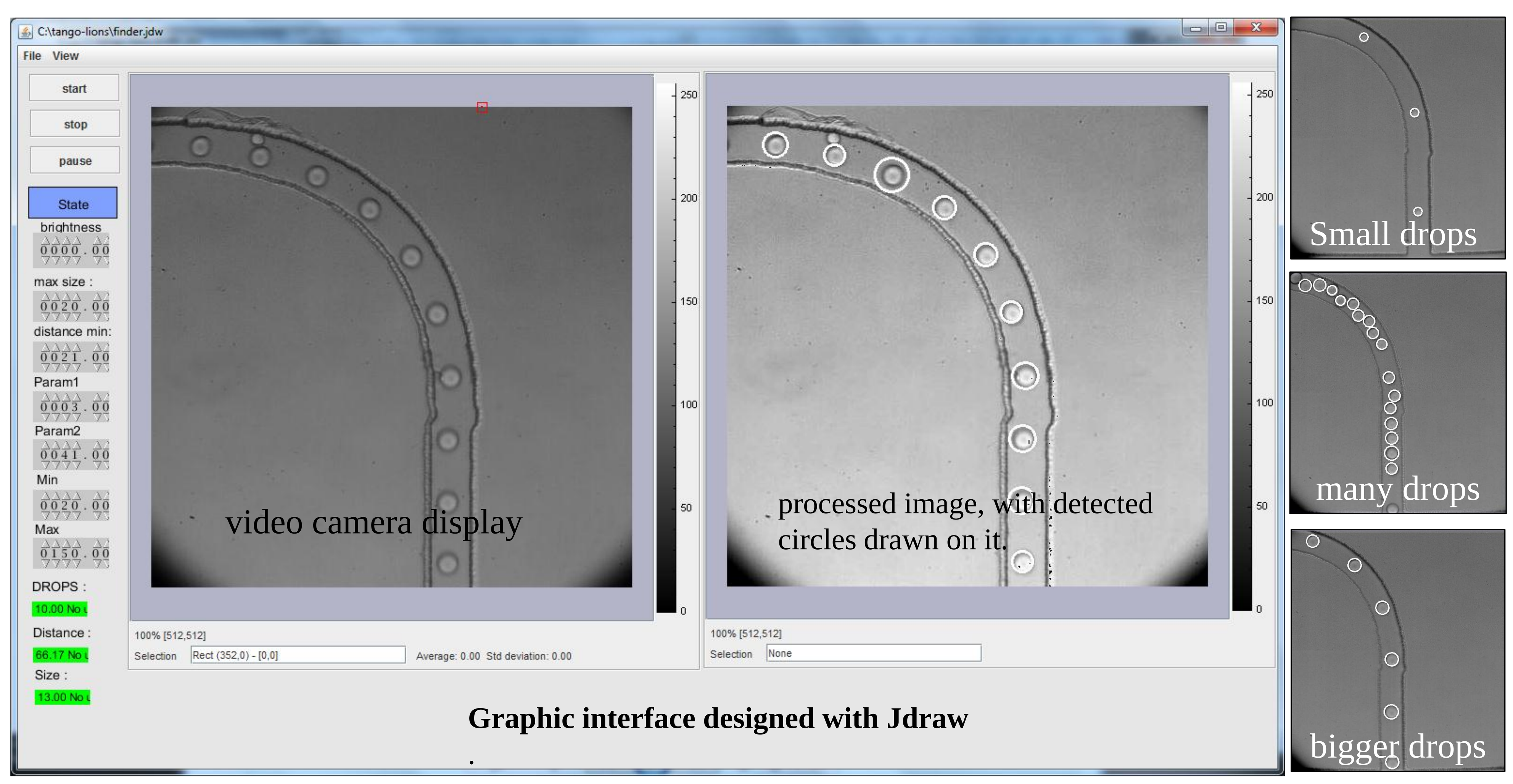
Number of detected circles	Detection time	Complete processing time
6 (debug mode)	170ms	240ms
6 (release mode)	80ms	120ms
17 (debug mode)	430ms	500ms
17 (released mode)	200ms	240ms



Measured droplet radii obtained by detection when oil rate is varying. The water rate is constant (5µl/min and 80µl/min)



Number of detected droplets when the oil rate is varying. The water rate is constant (5µl/min and 80µl/min). The gap observed is due to real evolution of droplets, and not of detection errors.



Graphic interface designed with Jdraw

Discussion and future work
The droplet detection system is working and allows the records of droplets evolution. However for the moment only 80% of droplets are detected. Moreover, the size measured is not always correct. This is the reason why we decided to average the result over 10 images. One possibility to avoid such errors will be to upgrade the software, i.e. by adding a system of averaging on the past images.
Detection process could also be improved: for the moment we try to find circles but; it could be interesting to detect "joined lines", and make a selection by fitting circles or ellipses. OpenCV offer some functions to do that. We could also try to detect "blobs", regions in the image that are either brighter or darker than the surrounding.

Conclusion
We have developed an automatic image analysis software with droplet detection for microfluidic systems. Microfluidic is a technic where electronic equipments are important. We demonstrate here that TANGO control command system, normally designed for synchrotron, is usable for more simple laboratory applications.
Our droplet detection is fully functional. Averaged radii and number of droplets are displayed almost in real time. This application can help researchers to control the micro fabrication parameters.
We thank Clélia Timsit, for the experiments preparation.