Super resolution for fundoscopy based on 3D image registration

Carlos Hernandez-Matas (1), Xenophon Zabulis (1)

1 Institute of Computer Science – FORTH

EMBC 2014, Chicago, USA

Super Resolution I

Produce images of **higher resolution** and **definition**

Super Resolution (SR) methods utilize **multiple images** of the **same scene** acquired from slightly **different viewpoints**

In retinal imaging, SR may be used to obtain more precise measurements, such as the needed **[Hubbard 1999]** for Arteriolar to Venular diameter Ratio (AVR).

Super Resolution II

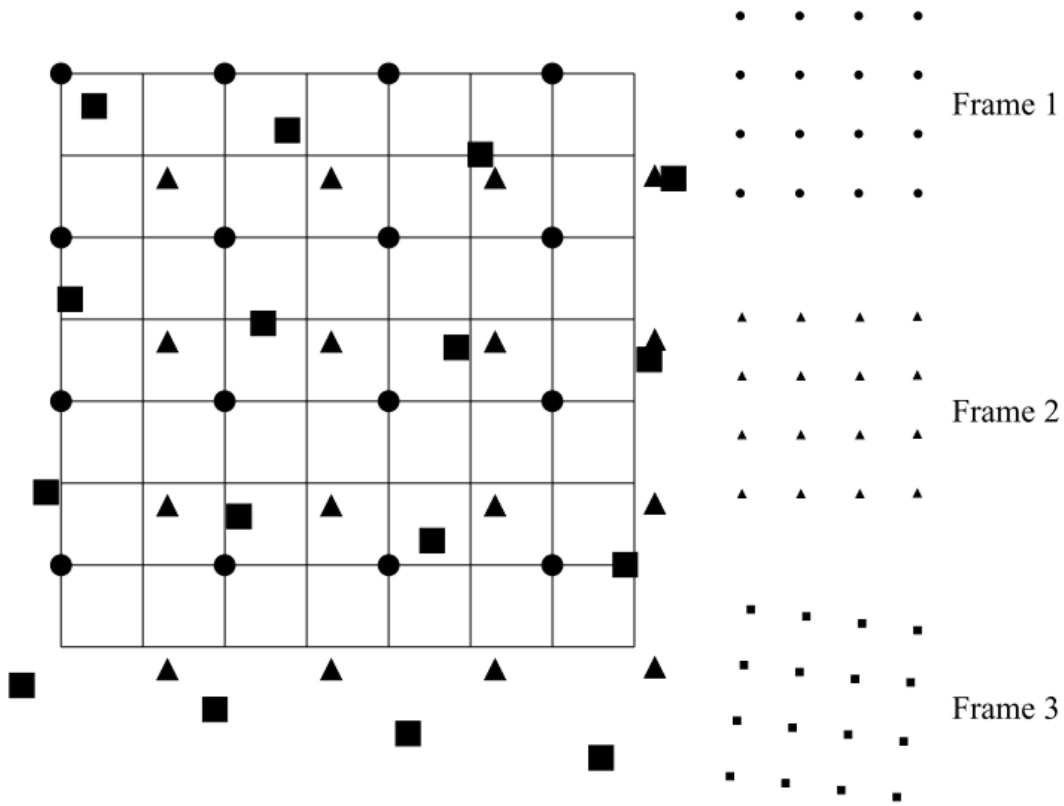


Figure from "Numerical Algorithms for Image Superresolution", Nguyen 2000

Retinal registration

Current SR methods for retinal imaging use 2D translation and rotation approaches for image registration **[Meitav 2011]**, **[Molodij 2014]**.

Nevertheless, 3D registration methods for retinal imaging exist and are more accurate than 2D registration, as they account for the 3D structure of the imaged surface **[Stewart 2003], [Tsai 2010], [Lin 2008], [Ryan 2001], [Chen 2010], [Perez-Rovira 2011], [Zheng 2011], [Bathina 2013]**. But they haven't been applied to SR, mostly for mosaicing.

<u>We will show:</u> that applying the **3D registration** paradigm in retinal images provides **better SR results**.

Retina is not a planar surface

The surface of the retina is **curved**.

Region of interest for computing metrics such as Arterio Venular Ratio is limited to 10-15 degrees of visual angle.

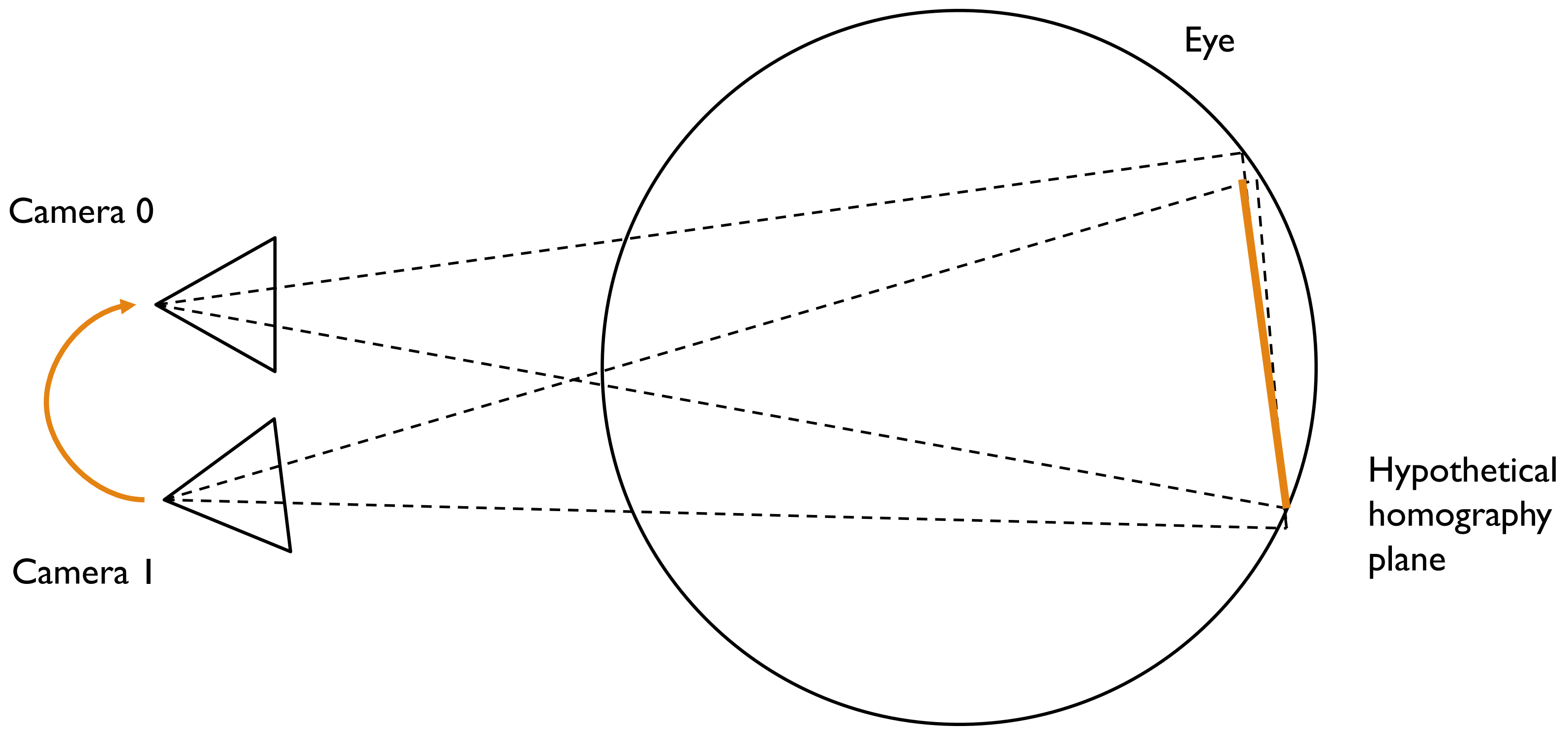
Planarity assumption is **sufficient**, as a first step.

This assumption allows us to calculate a homography between images.

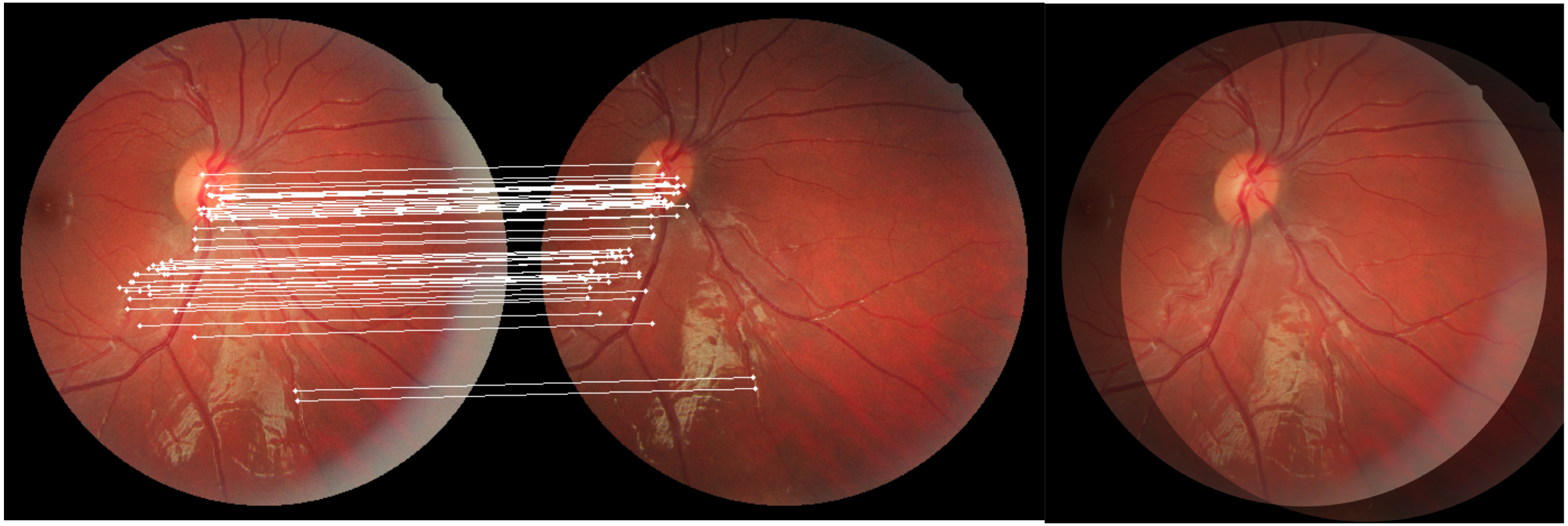
A better registration method (i.e. one that accounts for surface curvature) would only improve results.

Homography registration I

Transform different observations of the same planar surface to make them match



Homography registration II



- SURF features to detect keypoints.
- Establish correspondences via approximate nearest neighbors
- Homography estimation

Homography in super resolution for fundus images

- Super resolution in fundus images has been used with 2D registration methods
- **3D registration** methods provide **more accurate** results
- We revisit **Super Resolution** for retinal images using **3D** registration methods, to obtain **higher quality** images.

Experiments

Registration error I

Dataset 1 (81 points)	This work	Keren 1988	Lucchese 2000	Vandewalle 2006	Marcel 1997
Mean	0,4884	16,8608	447,9509	17,1637	15,2349
Std	0,2451	9,6545	384,3768	11,1891	7,7316

In retinal images, 3D registration provides better registration, which can be observed through a smaller registration error

Control points selected using SIFT features, to make them independent from the ones used in out method (SURF).

Registration error II

Dataset 2 (2621 points)	This work	Keren 1988	Lucchese 2000	Vandewalle 2006	Marcel 1997
Mean	0,5851	52,2144	319,3092	15,5748	6,4975
Std	0,2485	35,3212	347,2220	25,7937	4,0704

Dataset 3 (208 points)	This work	Keren 1988	Lucchese 2000	Vandewalle 2006	Marcel 1997
Mean	0,3875	5,2442	96,9436	7,2677	5,1491
Std	0,2362	2,8381	60,3513	3,2337	3,2980

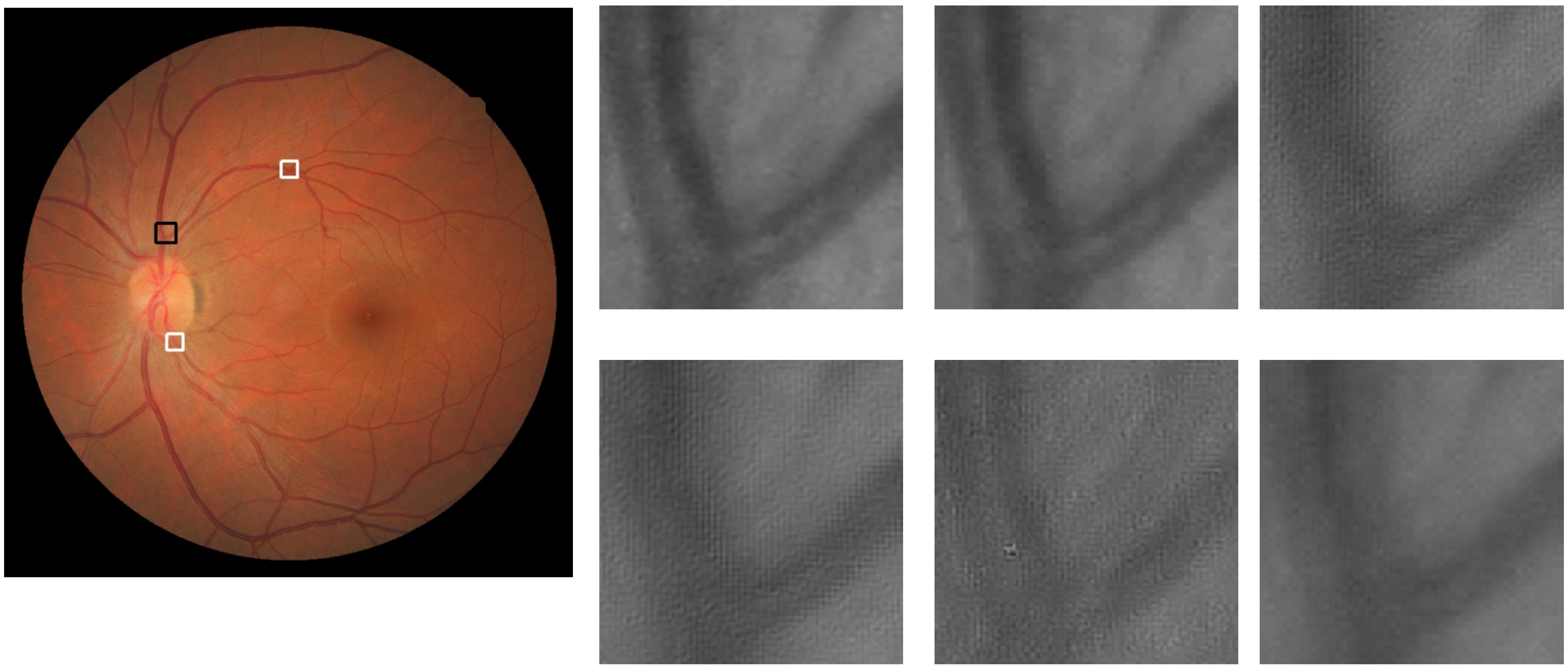
Registration error III

We calculated the SNR of the registration by:

- Selecting 4 images of each dataset
- Scaling them with a factor of 0.5
- Registering them using methods based on 2D rotation and translation.
- Producing a super resolved image the size of the original images
- Calculating the similarity between the SR image and the reference image via SNR for each of the registration methods.

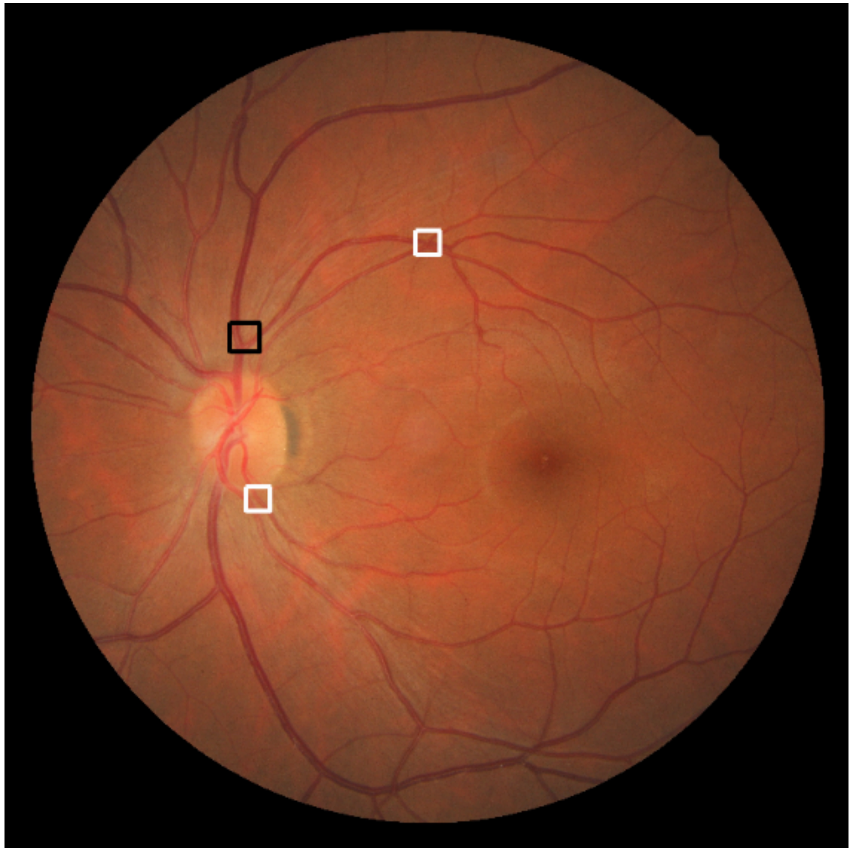
	This work	Keren 1988	Lucchese 2000	Vandewalle 2006	Marcel 1997
Dataset 1	11,6335	7,9317	0,5670	8,2380	9,1917
Dataset 2	9,5344	7,6581	5,9235	8,0751	7,3038
Dataset 3	17,0561	17,7945	11,3587	17,7945	17,7945

Registration comparative

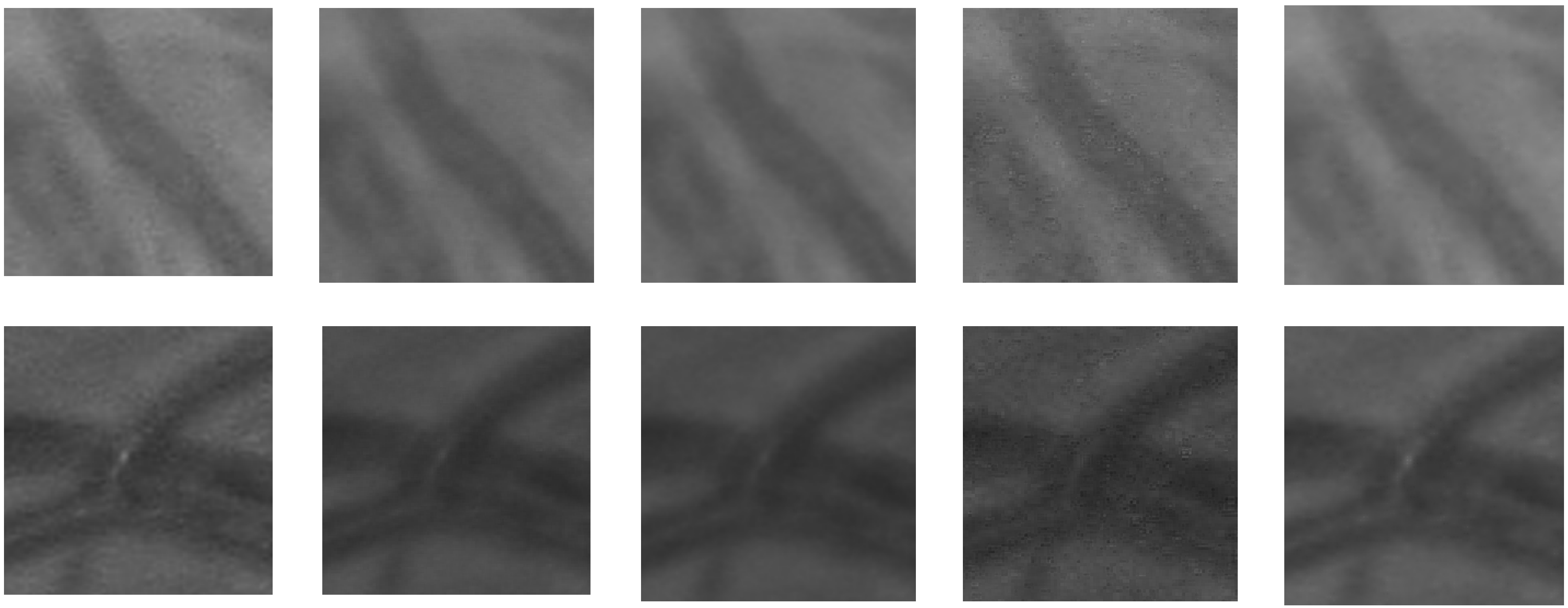


Original patch, proposed method, [Vandewalle 2006], [Keren 1988], [Lucchese 2000], [Marcel 1997], as implemented at lcav.epfl.ch/software/superresolution

SR: Dataset 1



- 9 images
- 2912x2912 pixels
- Scaling factor 3



Qualitative comparison of SR methods using the proposed registration for dataset 1,
in two 250 250 pixel SR image details. Showing the green channel to better show the results.
Left to right: bicubic interpolation, [Irani 1991], [Pham 2006], [Vandewalle 2006], and [Zomet 2001].

Computational time

	Bicubic interpolation	Irani 1991	Pham 2006	Vandewalle 2006	Zomet 2001
Time (s)	0,5	3252	18956	22265	6210

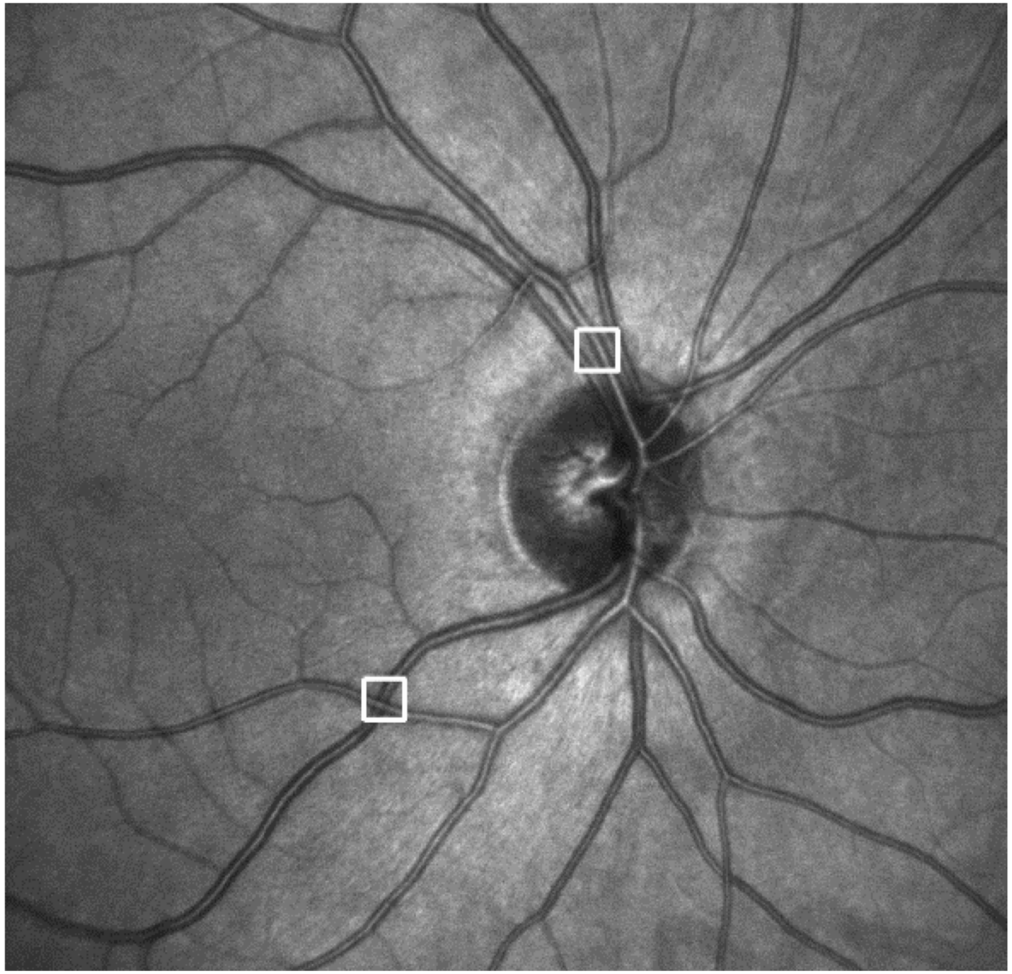
Image size: 2912 x 2912

Amount of images: 9 (1 in interpolation)

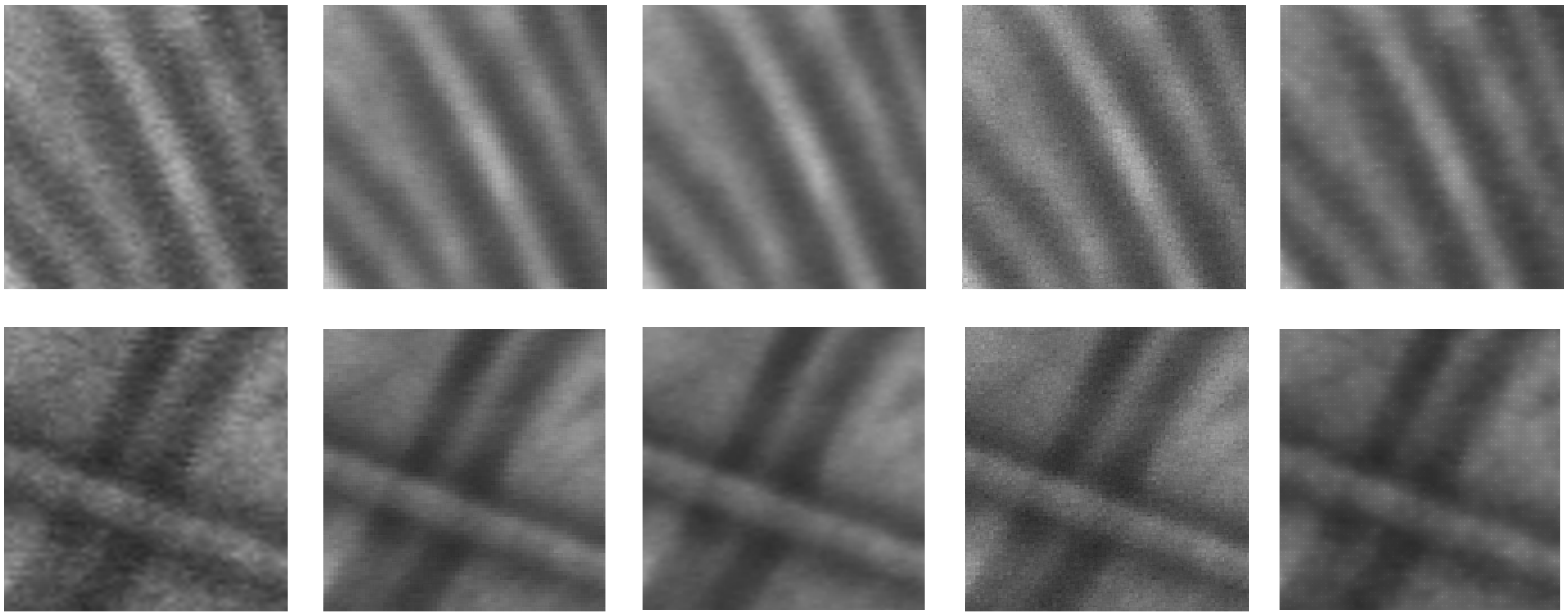
Scaling factor: 3

Conventional PC with an i7-4770 CPU, at 3.40 GHz and 16 GB of RAM

SR: Dataset 2

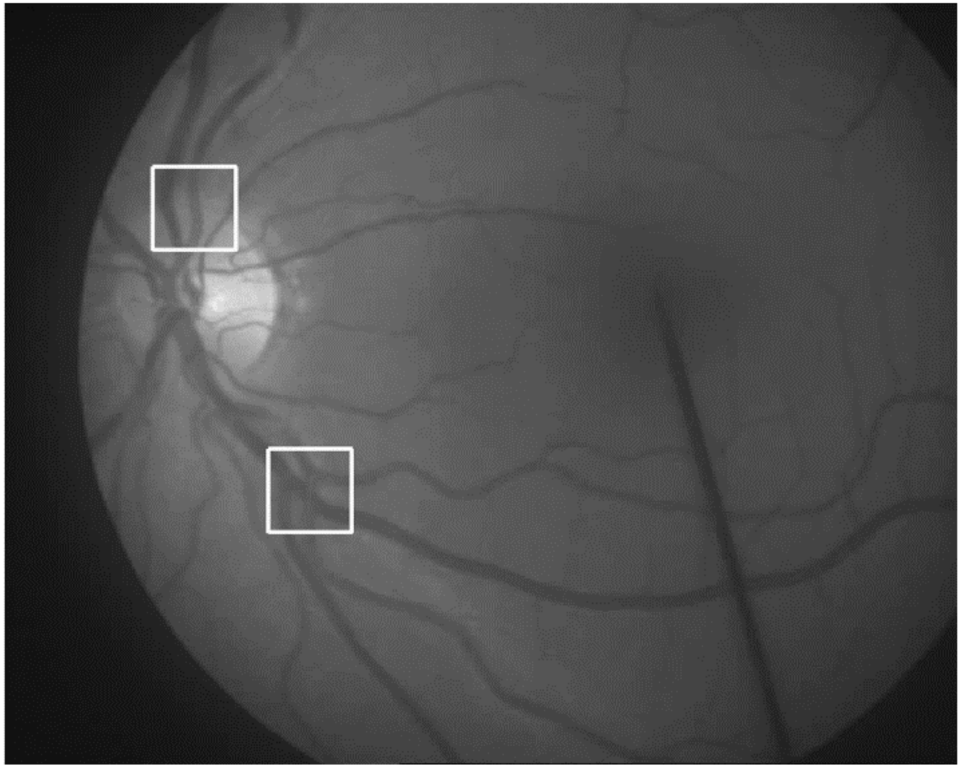


- 16 images
- 1536x1480 pixels
- Scaling factor 4

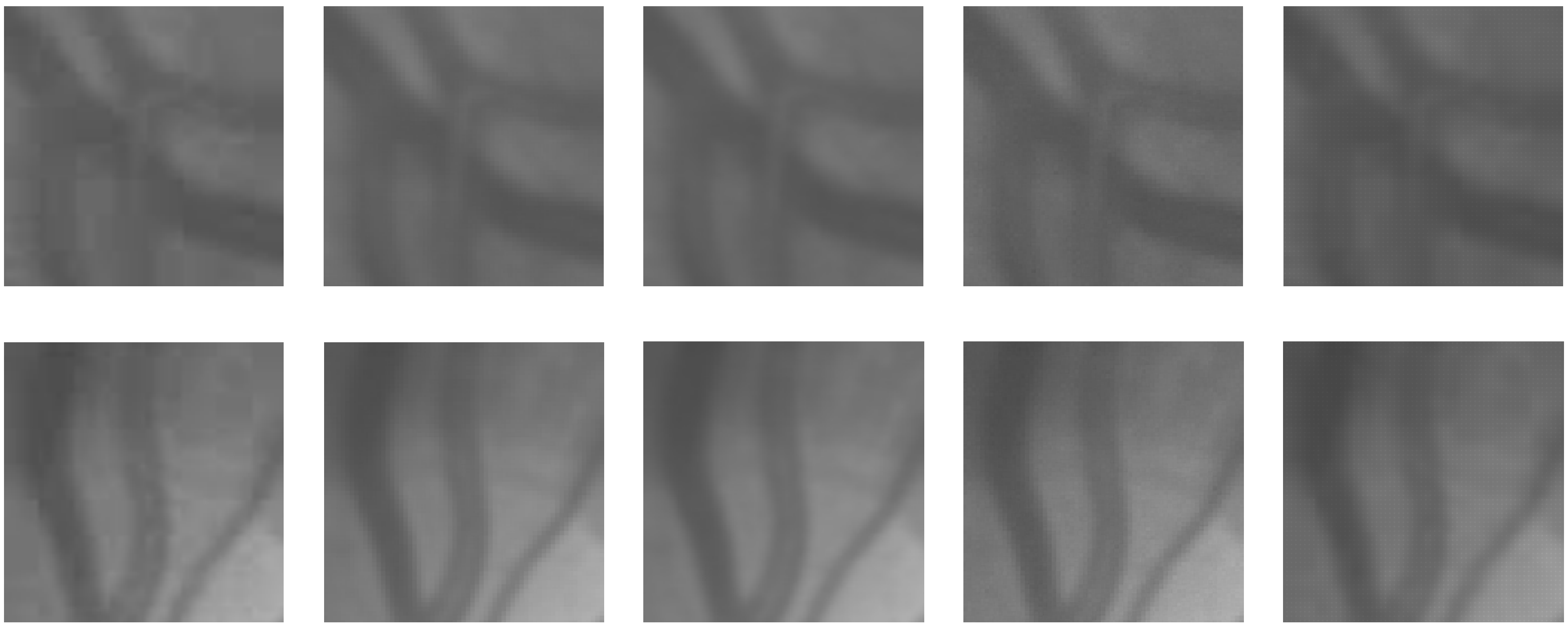


Qualitative comparison of SR methods using the proposed registration for dataset 2,
in two 250 250 pixel SR image details. Showing the green channel to better show the results.
Left to right: bicubic interpolation, [Irani 1991], [Pham 2006], [Vandewalle 2006], and [Zomet 2001].

SR: Dataset 3



- 16 images
- 720x576 pixels
- Scaling factor 4



Qualitative comparison of SR methods using the proposed registration for dataset 3,
in two 250 250 pixel SR image details. Showing the green channel to better show the results.
Left to right: bicubic interpolation, [Irani 1991], [Pham 2006], [Vandewalle 2006], and [Zomet 2001].

Conclusions

A method for SR in fundoscopy images has been proposed, which differs from existing approaches to retinal image SR by the fact that it considers the perspective differences between the combined images.

In the experiments, we show that the **proposed** image registration **method** (a) provides **subpixel accuracy** and is, thus, suitable for application in the generation of SR images and (b) provides **better image alignment than 2D registration** methods that are conventionally employed in this task and, consequently, improve the quality of the obtained SR results

The obtained results provide **better image resolution and definition** and, thus, could **potentially improve** vessel **segmentation** and **measurement** in retinal images.

Thank you!