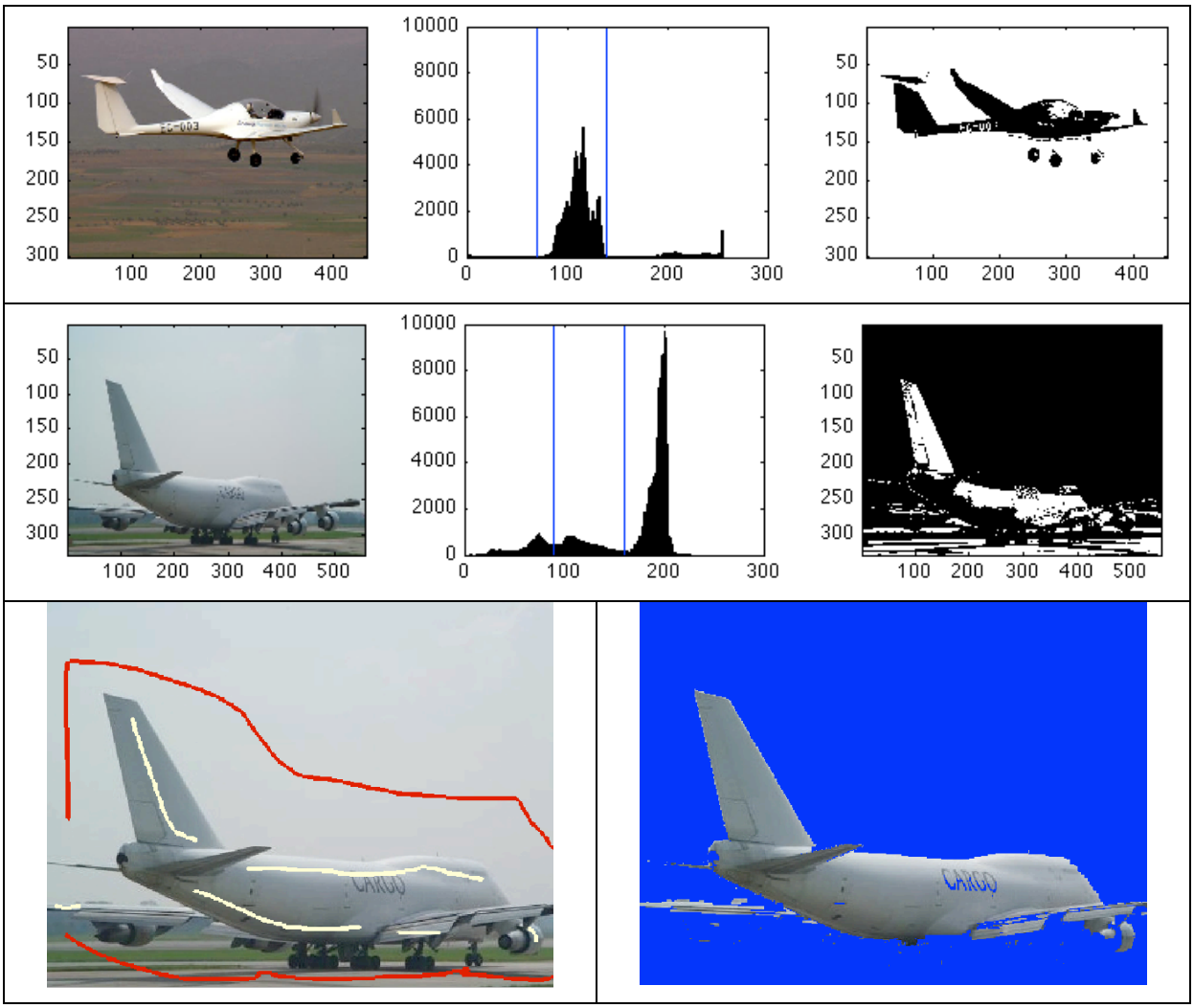
**Introduction to Computer Vision**

**P. Fua**

1.5 hours, no documents allowed.

1) Answer each one of the three main questions on a **separate** sheet of paper. You are encouraged to provide short answers with illustrative diagrams.
2) Write your name clearly on all the sheets you hand in.
3) The three main questions are almost completely independent from each other. If you cannot find the answer to one, skip to the next one.
4) The exam is designed to be long. Do not panic if you cannot finish everything.
5) If you mention an algorithm by name in your responses, for example the *Canny Edge Detection algorithm*, explain what it does and why it is appropriate.
6) Vous pouvez répondre en Français si vous êtes plus à l'aise.

## I Images and Graphs




1) The graph in the middle of the top row is the histogram of the image on its left after gray-level conversion. Explain what this means.
2) In the image to the right of the top row, all pixels whose gray level values are between 50 and 140 are shown in white, the others in black. Propose a simple histogram-based algorithm that would extract most of the airplane's fuselage as a single connected region.
3) The second row depicts another plane. In this case, the pixels that appear in white on the right-most image are those whose gray levels are between 90 and 160. What would the algorithm described above probably do on the fuselage? How do you explain the difference in behavior?
4) Propose a supervised graph-based algorithm that takes as input both the image of the second plane and the user-supplied points depicted on the left side of the third row to produce the foreground region shown on the right side. The algorithm can assume the yellow points to be within the fuselage and the red ones without. Explain how such an algorithm works and why it can achieve such a result.
5) Similar graph-based algorithms can be used to compute disparities in image stereo-pairs. Explain. Why is this useful?

**II Shape from X**

**Figure a**

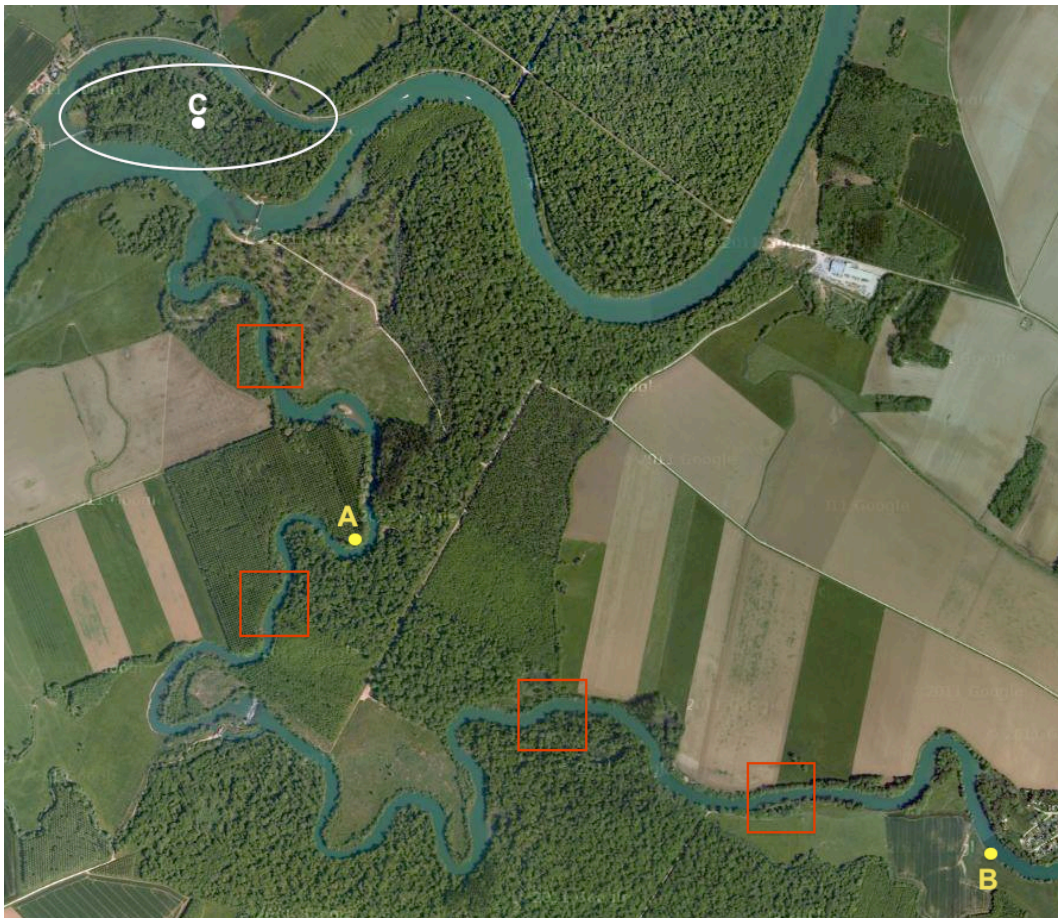
**Figure b**

1) The lunar landscape on the left can be interpreted as bumps and the one on the right as craters. However, the two figures depict the same image with the one on the right flipped upside down. Explain this phenomenon.

2) Say that we want to design a shape-from-shading algorithm to extract 3D shape information from image. Describe such an algorithm and comment on the required assumptions with respect to
    a. Light source,
    b. Albedo,
    c. Specularities,
    d. Shadows,
    e. Surface smoothness,
    f. Boundary conditions.
3) Describe the algorithm you would you use if you had additional images taken from exactly the same position but at different time of day? Which of the above assumptions could be relaxed?

4) Similarly, if you had an additional camera that you could place wherever you choose, how would you use it to retrieve 3d shape information more reliably than by using a single image? Describe the algorithmic steps and discuss which assumptions of part 2) could be relaxed?

## III Delineation




The above figure is a satellite image of a river in France. We are interested in detecting the boundaries of this river network and the roads appearing in between the fields.

1) Design an image-based measure that can be used to distinguish the boundary pixels from the ones that are inside the river. Define it explicitly in terms of pixel intensities and give the relevant formulas.
2) Given the two points A and B shown in the figure, propose an algorithm to compute a path that follows the river boundary between these points.
3) Suppose that we are given a group of rectangular patches such as the red boxes, which contain only horizontal or vertical river segments. Propose an **efficient** algorithm that can delineate at least one of the river boundaries within the patch. Can you use this algorithm to delineate both boundaries? Hint: You may assume that a vertical (horizontal) border crosses each patch row (column) exactly once.
4) The roads between the fields appear mostly as linear structures. Propose an algorithm to detect all of them.
5) The boundaries of the island at the top-left corner can be represented by a closed contour consisting of a number of points. Given the white ellipse centered at the point C as the initialization, propose an algorithm to find its contour. It should rely on the image-based measure of part 1. You should also introduce and describe an appropriate geometric regularization term.