

FRONTAL AREAS OF THE Q400 AIRPLANE BASED ON IMAGEJ SOFTWARE

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Objective

As proposed by Dr. Arnold R. Miller [1], the purpose of this study is to accurately determine the frontal area of the Q400 airplane, based on the digital image found on the Bombardier Q400 website [2], using ImageJ software. ImageJ software is an open source, public domain software developed at the National Institutes of Health by an employee of the federal government [3].

Calibration of the Software

In order to determine the consistency of digital measurements across several applications, I created a square in Macromedia Fireworks graphics software whose sides measured 5.00 cm (roughly 142 px). After saving the image as "Calibrate_Square.png" (a portable network graphic file), I re-opened the file in IrfanView, an independent, open-source graphics program, and confirmed that IrfanView also measured the square at 5.00 cm (or 142 px). To confirm that the digital measurements would be consistent with physical measurements, I then printed the image directly from Fireworks and measured the square with a physical ruler, and confirmed that the sides of the square measured 5.00 cm on paper.

I repeated this same process with a circle that measured 14.11 cm in diameter (400x400 px) in Macromedia Fireworks. I then measured the circle on paper, and confirmed the diameter to be 14.11 cm. To calculate the area, I used $A = \pi r^2$, with π as 3.1459 and r as 7.055; thus, the area is 156.38 cm^2 .

I opened the digital image of the circle in file in ImageJ, and set the scale within the program according to the software instructions. This entailed drawing a line through the center of the circle (the diameter), with known length 14.11 cm, and setting the "Known distance" as "14.11" and the "Unit of length" as cm, checking the "Global" box, as per the instructions. With the scale set, and the software calibrated, I then outlined my image using the "circle selection," then selected

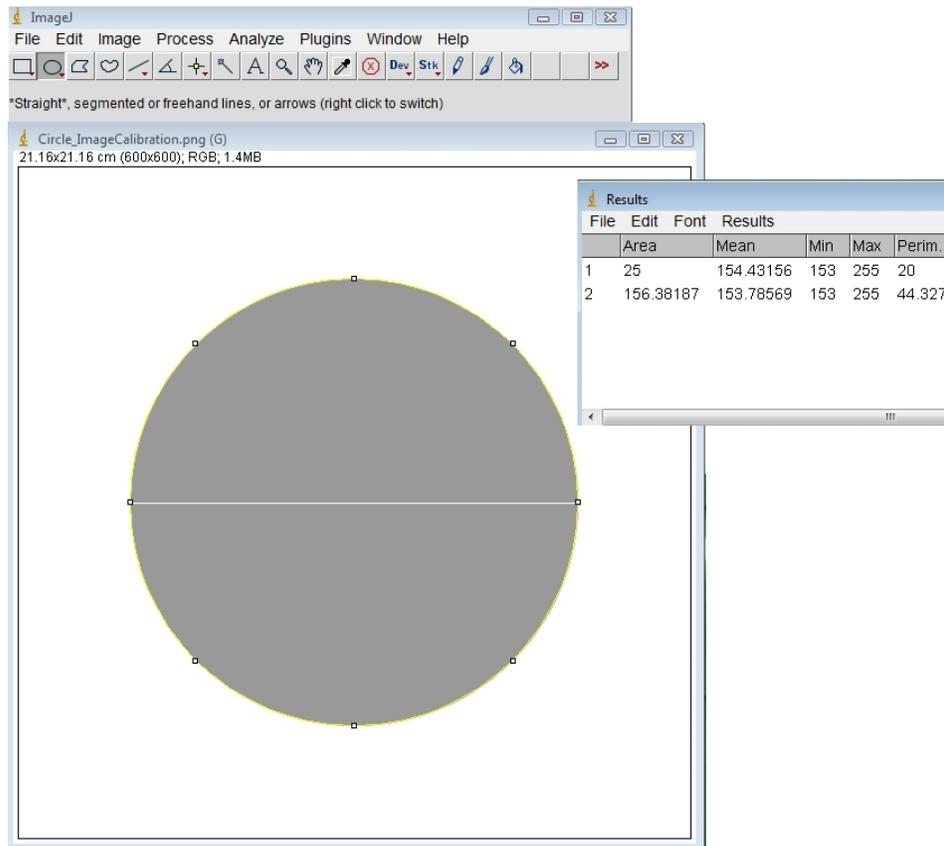


Fig.1 Circle in ImageJ. Showing the results of the measurement of the circle in ImageJ software.

"Measure" under the "Analyze" tab. ImageJ correctly calculated the area of my circle as 156.38 cm² (see Figure 1), which is in agreement with the physical measurement to five significant figures.

Measurement of the Q400

With the ImageJ software calibrated and tested, I then proceeded to measure the frontal areas of the Q400. In Fireworks, I imported the image of the airplane and drew a horizontal line through the center of the fuselage, which can be approximated as an ellipse. The length of the line measured 91 pixels, or 3.21028 cm. The "known area" in ImageJ can then be set to 3.21028 and the "units" set to "cm"; thus, the scale is 28.346 pixels/cm.

I calculated Section 1 (see Figure 2) by utilizing the "polygon selection" tool to first outline the wings, engines, and fuselage connector area of the airplane, which area is 20.6715 cm². I then calculated the area of Section 2 by laying an ellipse over the fuselage, which is 7.9928 cm². The area of Section 3 is similarly calculated by again using the polygon selection tool; the area of the tail section is 5.9417 cm².

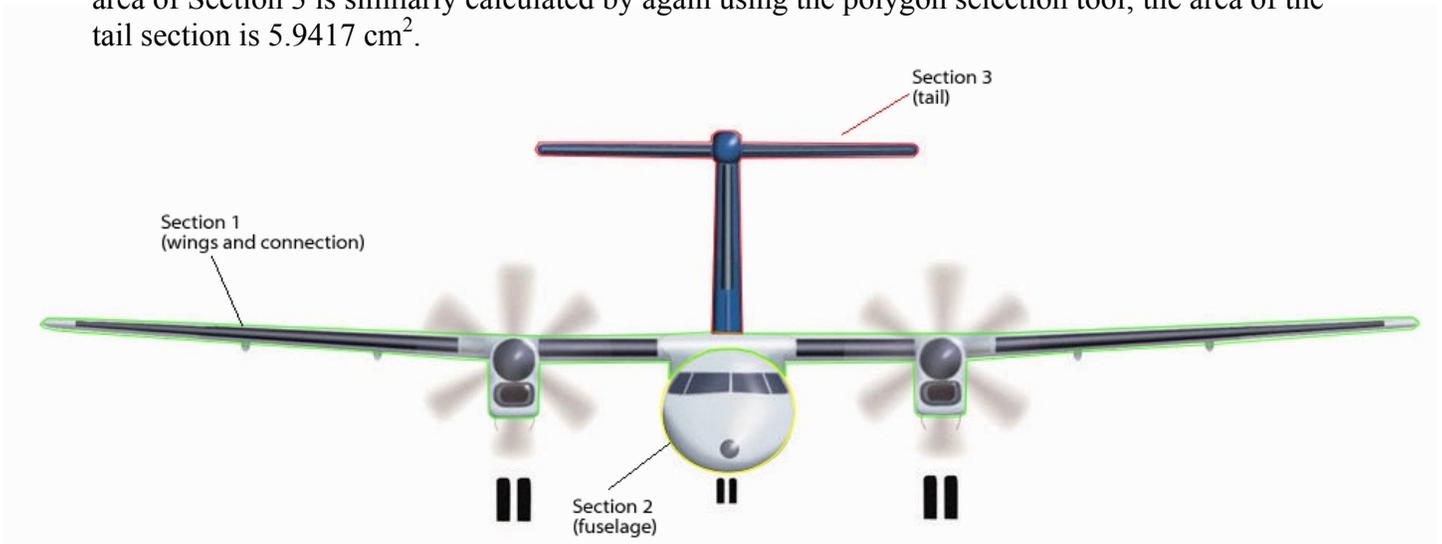


Fig.2 Bombardier Q400 in ImageJ. Showing the outlined sections of the frontal areas of the airplane in ImageJ.

Since it is known that the maximum diameter of the fuselage is 2.7 m [4], we can set up the following correspondences [1]:

$$3.21028 \text{ cm} \sim 2.7 \text{ m}$$

Thus, dividing both sides by 3.21028,

$$1 \text{ cm} \sim 0.841048 \text{ m}$$

We then square each side to get

$$1 \text{ cm}^2 \sim 0.70736 \text{ m}^2$$

This number, which we will call c_1 , corresponds to the cm scale, found by utilizing the maximum diameter of the fuselage.

Results

We can get the frontal area of the three sections, denoted A_1 , A_2 , and A_3 , respectively, of the Q400 airplane in m^2 by using the above formula, with c_1 as our scale, and plugging in the cm measurements of Sections 1, 2 and 3:

$$A_1 = 20.6715 \text{ cm}^2 \times 0.70736 \text{ m}^2/\text{cm}^2 = 14.6222 \text{ m}^2$$

$$A_2 = 7.9928 \text{ cm}^2 \times 0.70736 \text{ m}^2/\text{cm}^2 = 5.6538 \text{ m}^2$$

$$A_3 = 5.9417 \text{ cm}^2 \times 0.70736 \text{ m}^2/\text{cm}^2 = 4.2029 \text{ m}^2$$

Similarly, ImageJ can be used to find the approximate frontal areas of the airplane by drawing a horizontal line through the center of the fuselage, which measures 91 pixels, and setting the "known area" as 2.7 m. ImageJ automatically calculates the scale, which is 33.704 pixels/meter.

Sections 1, 2 and 3 can be measured again using the pixels/meter scale, and displays the following results:

$$A_1 = 14.6524 \text{ m}^2$$

$$A_2 = 5.66227 \text{ m}^2$$

$$A_3 = 4.22587 \text{ m}^2$$

With the scale set as 33.704 pixels/meter, we can test the accuracy of ImageJ by drawing a horizontal line from wingtip to wingtip. The Bombardier Q400 fact sheet states that the wingspan of the Q400 is 28.4 m, while the horizontal line measures 955 pixels in length. Using our scale we can calculate:

$955 \text{ pixels (length of the wingspan in ImageJ)} / 33.704 \text{ pixels (the number of pixels per meter)} = 28.3349 \text{ m}$, a number almost identical to the measurement of the full-scale airplane.

Thus, Section 1 (wings and connector) is approximately 14.6222 m^2 , Section 2 (fuselage) is approximately 5.6538 m^2 , and Section 3 (tail) is approximately 4.2029 m^2 . Each of these measurements can then be added for the total frontal area of the full-scale Q400, approximately 24.4790 m^2 . Therefore, the ratio of the frontal area of the fuselage to the total frontal area of the airplane is $A_2 / (A_1 + A_2 + A_3)$, or 0.23.

References

[1] Miller, A. Vehicle Projects LLC, email message to Kristen A. Johnson, 15 February 2011.

[2] Bombardier Q400. Website: http://www.q400.com/q400/en/multimedia_01.jsp. Downloaded image 28 August 2007.

[3] ImageJ Software. Website: <http://rsbweb.nih.gov/ij/index.html>.

[4] Bombardier Q400 Fact Sheet. Website:
http://q400nextgen.com/en/medias/gallery/literature/factsheetq400_en.pdf