FreeCAD tutorial for building the falling seed geometry

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1 Prerequisites

This is a tutorial to help you build a parametric model for the falling seed that you will study in the 3D printing module. To go through this tutorial you should have FreeCAD installed on your computer and you should have got familiar with FreeCAD through the **Getting started with FreeCAD** tutorial.

2 Building the model

2.1 Goal and architecture of the project

The goal of this tutorial is to get you to build an idealized CAD model for a falling seed and a parameters summary spreadsheet, similar to what is shown in Fig. 1. For this we will build a seed wing using a base profile and the sweep utility, make a symmetric copy of it to get two wings, apply some position offset and other parameters to give us the possibility to break the symmetry of the model, add the core of the seed and finally make it hollow. All design parameters will be set in an **Input** spreadsheet to let you easily design several versions of the seed and evaluate the influence of design parameters on the fluid mechanics of the seed flight.

To get started:

- Create a new project.
- Go to the **Spreadsheet** workbench, and click on **Create a new speadsheet**. Rename the spreadsheet as **Input**.
- Save one first time the project as **falling_seed** in the **.fcstd** format. In all the following it is important that you save regularly your work each time you think you succeeded with a new significant step.

2.2 Build the first wing

- Go to the **Part Design** workbench and use the **Create a new sketch** button to start a new sketch in the XY plane.

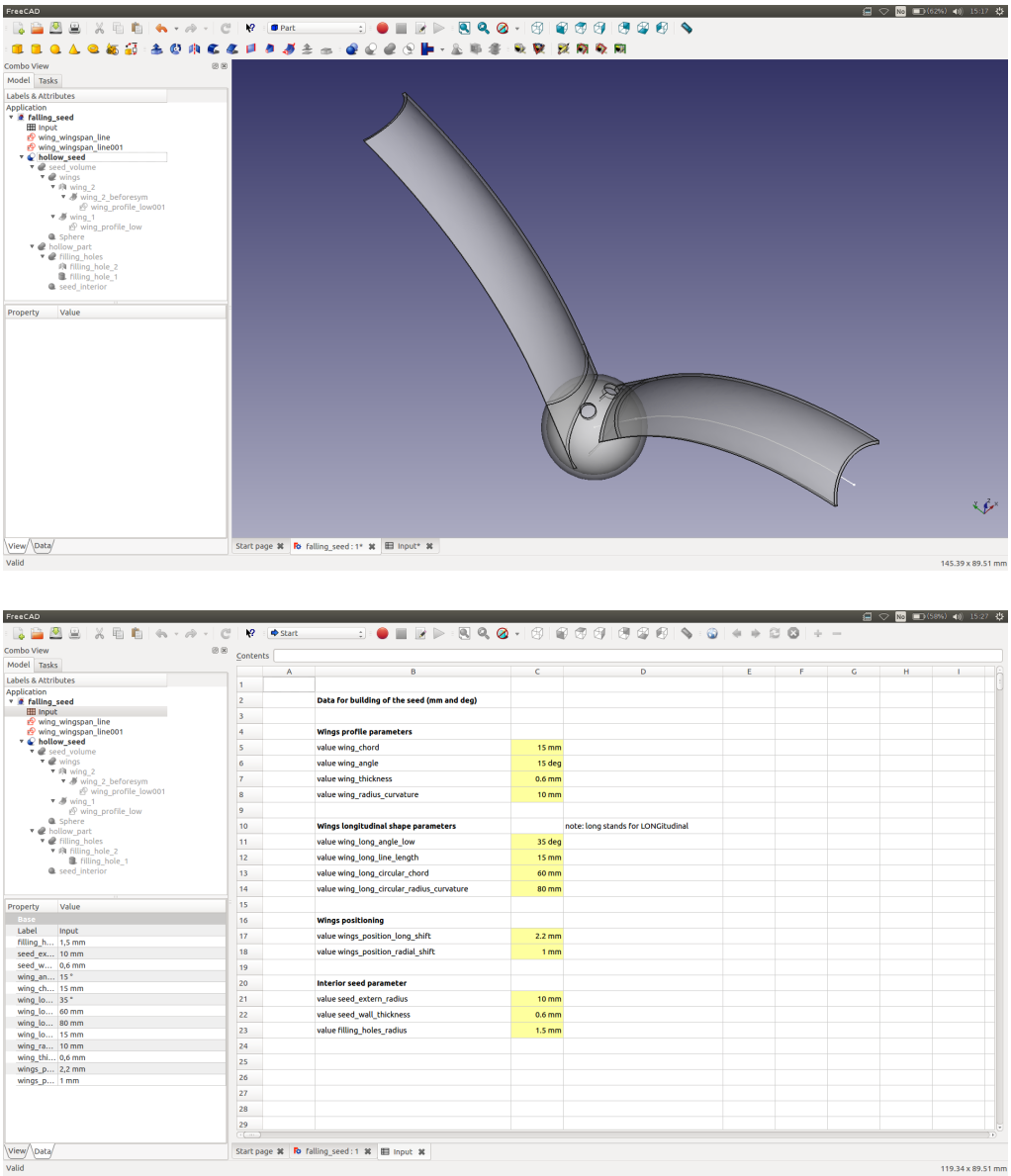

Figure 1: The final CAD model result you should get to and the corresponding control spreadsheet. Note the tree structure of the project.

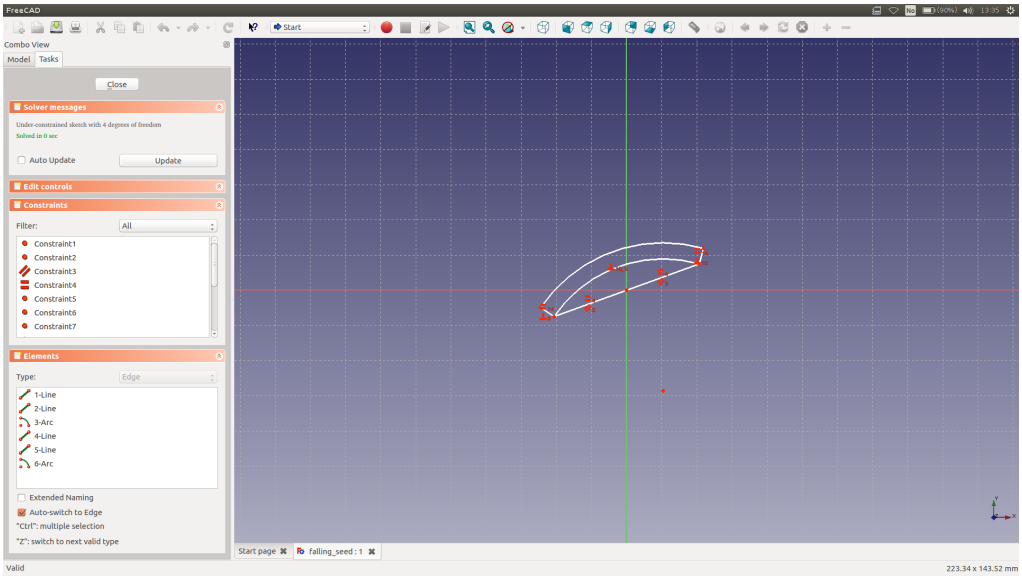

Figure 2

- Create two **lines** from the origin. Select both lines using the ctrl key and selecting one after the other and use the **Create a Parallel constraint** and the **Create an equality constraint** tools to get the origin of the referential to be in the middle of the two lines.

- Use the **Create an arc** tool to create an arc of circle joining the two external points of the segments you created before.

- Add two segments on the extremities of the arc of circle. Use the **Create a perpendicular constraint** tool to make both segments perpendicular to the arc of circle. Create a second arc of circle , with the same center as the previous one, and joining the free extremities of both segments. Add an equality constraint between the length of the two small segments. Your sketch should now look like Fig 2.

- It is now time to add constraints. Set the radius of the smaller arc of circle to 10 mm. Set the length of one of the small segments to 0.6 mm. Set the distance between the exterior points of the first two segments you created to 15 mm. Set the angle between one of the initial segments you created and the X axis to 15 degrees. If you did it right, your wing profile should now be fully constrained. Later on we will use this sketch as the base profile for the seed wing.

- The two initial segments were only construction segments and should not be used to create a volume, so use the **Toggle the toolbar or selected geometry to/from construction mode** to take them out of the sketch that will be used for the 3D extension. Your sketch should now look like Fig. 3. Close the sketch editor, and rename the sketch as **wing__profile__low**.

- We now need to build the wingspan line, along which the wing will be built. Start a new sketch in the YZ plane. Build a sketch similar to the one in Fig. 4. Use a tangential constraint between the segment and the arc of circle. Toogle out of the construction mode the construction line on which the circle is built. Close the sketch, and rename it to **wing__wingspan__line**.

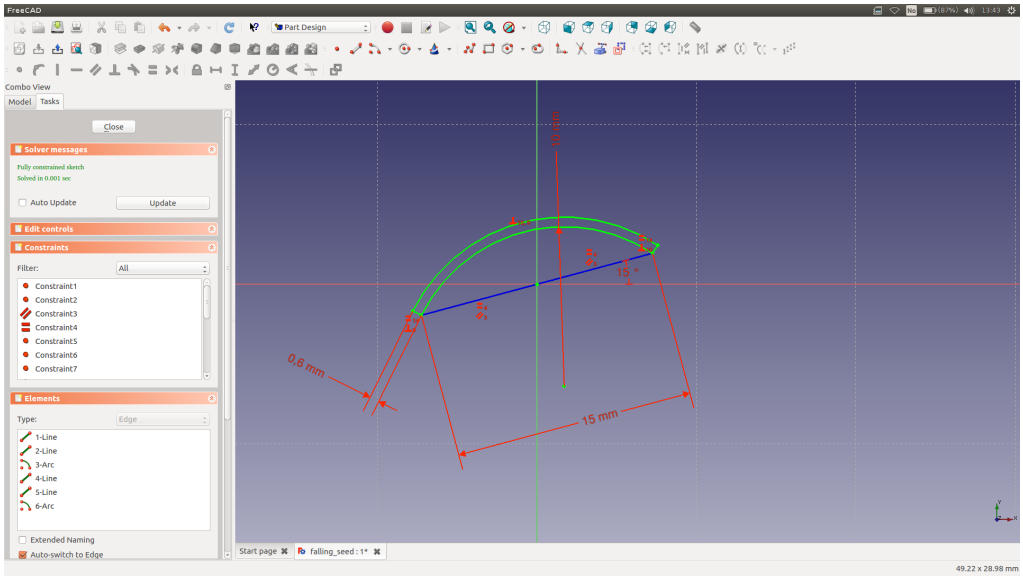

Figure 3

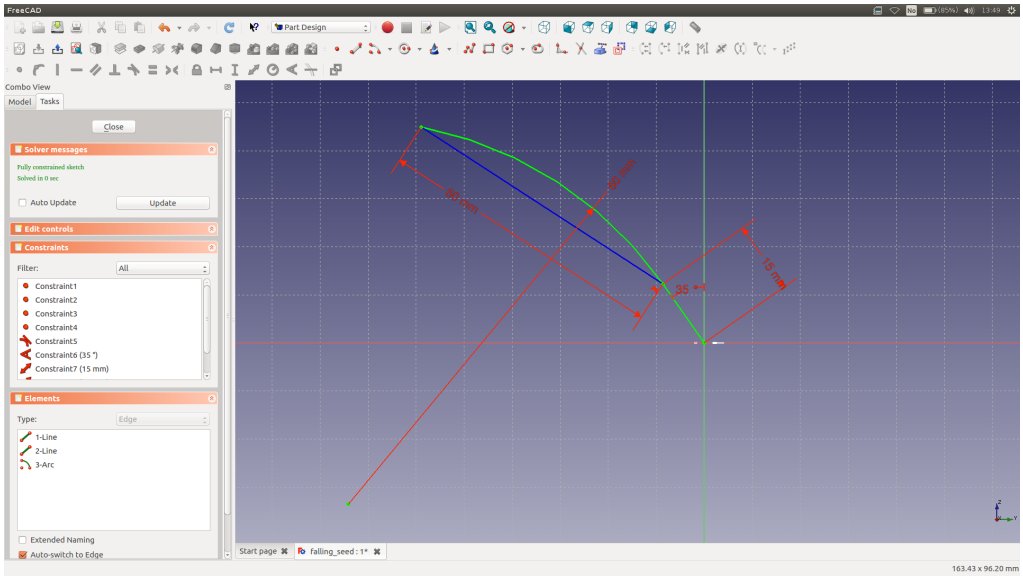

Figure 4

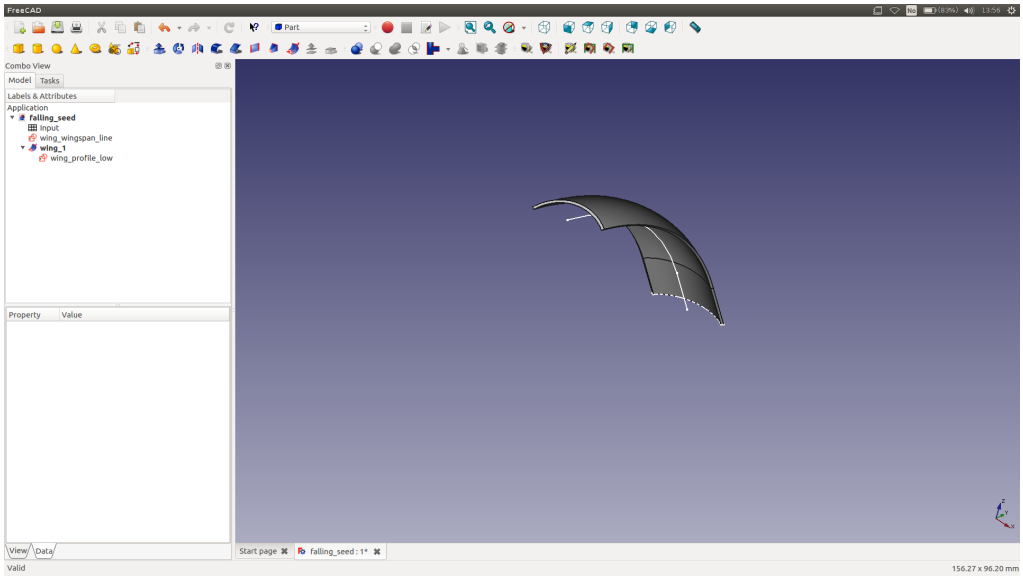

Figure 5

- We will now build a 3D wing from the wing base and the wingspan line. Go to the **Part** workbench. Click on the **Utility to sweep**. Set the **wing__profile__low** as the sketch to sweep using the arrow pointing to the right. Click the **Sweep Path** button and select both the line and arc of circle you created in the **wing__wingspan__line** sketch, then click **Done**, and **Ok**. This will create an empty shell. To turn this into a volume, click on the **sweep** object that was created in the **Labels & Attributes** tab, and in **Data** set **Solid** to **True** and **Fresnet** to **False**. You should now have a wing similar to Fig. 5. Rename the sweep object as **wing__1**.

2.3 Copy and build the symmetric wing, and apply offsets

- Copy and Paste the **wing__1**. Answer **yes** to copying also the underlying objects. Rename the copy you obtain as **wing__2__beforesym**.
- Use the **Mirroring a selected shape** tool to create a symmetric of **wing__2__beforesym** relative to the XZ plane. Rename the object you obtained as **wing__2**.
- Select both **wing__1** and **wing__2** using the ctrl key and use the **Make a union of several shapes** tool. Rename the object as **wings**. Your project should now look like Fig. 6. Remember that you can toogle on / off visibility of each part with the **space** key or in the **View** menu.
- Now we should write all the properties of the wings we built in the **Input** speadsheet to make it easy to adapt the model. Move to the **spreadsheet** workbench, and open the **Input** speadsheet. Fill it until it looks like the first two sections of Fig. 1. Set aliases corresponding to each dimensional value (**Tips**: name each alias as **<name>**, where the label of the cell on the left is **value <name>**). Replace numerical values in all your sketches by formula using the aliases in the sketches you defined. It should be obvious which alias goes to which constraint value if you followed me so far. (**Tips**: To break the symmetry in a realistic way, you should use **wing__angle** for the wing 1 and **-wing__angle** for the wing 2).

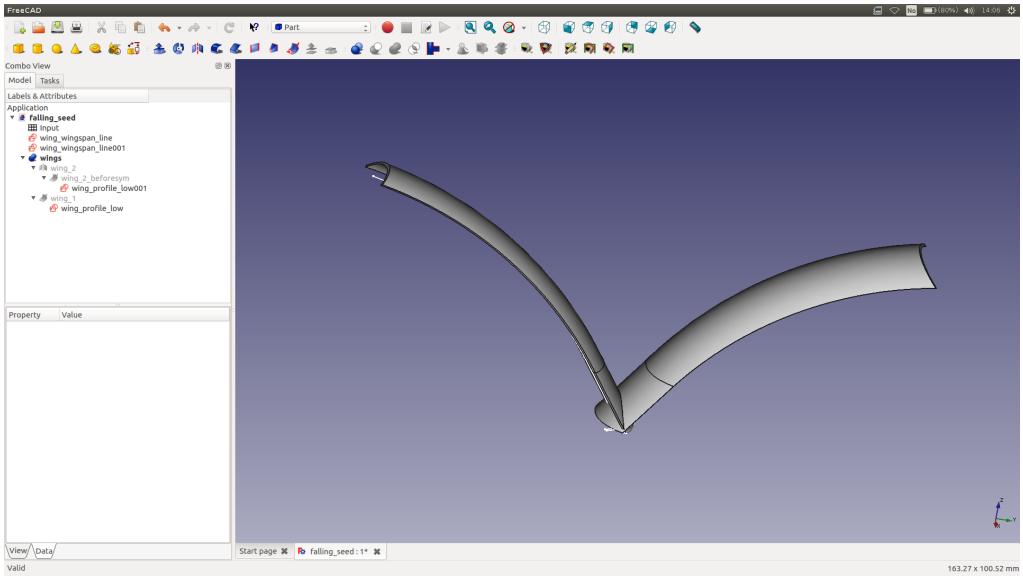

Figure 6

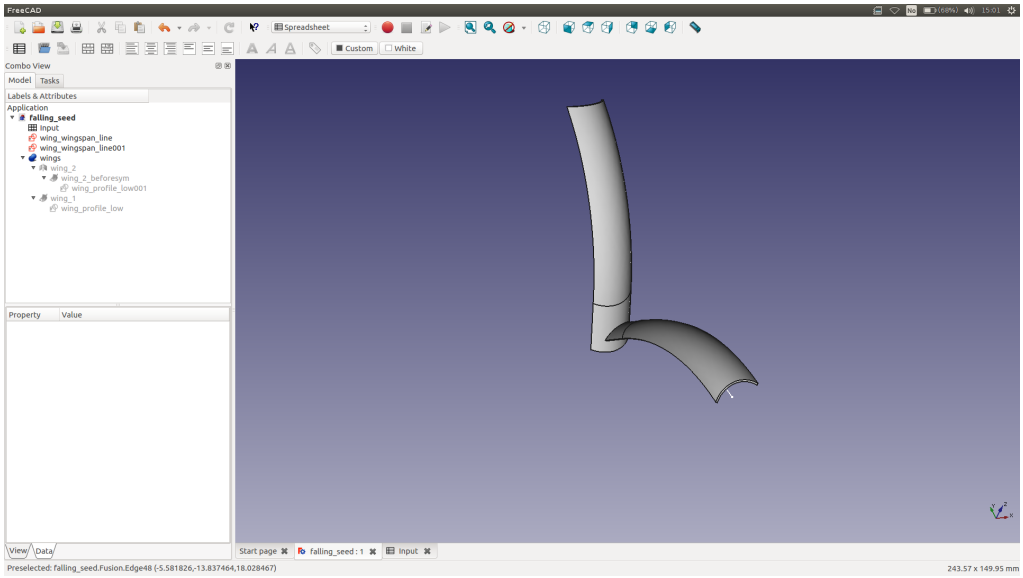

Figure 7

- An additional way to break the symmetry in the seed geometry is to add a position offset on the wings. Create two additional fields in the speadsheet, **wings_position_long_shift** and **wings_position_radial_shift** under a **Wings positioning** title. Use them to change the **Placement** field (in the **Data** tab) of both **wing_1** and **wing_2**. The longitudinal field can be used to shift position in the X direction, the radial shift in the Y direction. Put opposite signs between the wings, otherwise you will not break the symmetry but only tranlsate the wings. Put small values (typically 2.2 and 0.5 mm for example). (**Tips**: for being able to set a translation of the position of an object, select the object, go to the **Data** tab, and expand the **Placement > Position** menu. You can then enter formula as usual). Your pair of wings should now look like Fig. 7.

2.4 Add the core of the seed and make it hollow

The seed is nearly ready now. We just need to add its core and make it hollow. For this:

- Go to the **Part** workbench. Click **Create a sphere solid**. Set its radius to 10 mm and call it **seed_exterior**. Do a union of **wings** and **seed_exterior**, and rename it **seed_volume**.
- Create a new sphere, set its radius to 9 mm and call it **seed_interior**. Create a cylinder, set its radius to 1.5 mm and heigth to 15 mm. Rotate it 20 degrees around the Y axis using the **Placement** tool in the **Data** tab and rename it to **filling_hole_1**. Take the symmetry of it relatively to the YZ plane, and rename it **filling_hole_2**. Take the union of **filling_hole_1** and **filling_hole_2**, and rename it **filling_holes**. Take the union of **filling_holes** and **seed_interior**, and call it **hollow_part**. Take the difference between **seed_volume** and **hollow_part** and rename it **hollow_seed**. In the **View > Transparency** box, set 50. Explore your shape by moving it in 3D to check that it looks good. It should be similar to Fig. 1.
- In your speadsheet, create an **Interior seed parameter** section with fields named **seed_external_readius**, **seed_wall_thickness**, and **filling_holes_radius**. Create corresponding aliases and update the set value fields of your seed as a consequence.

3 Finished with CAD!

Congratulations, you are now finished with building a CAD model for a falling seed. In the 3D printing project you will print several versions of such seed, varying one or more parameters design, and perform experiments to assess the effect of the design parameters on the seed flight properties and the underlying fluid mechanics involved.