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Improved Bridging in FFF

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Title: Improved Bridging

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Abstract: This publication relates to a printing strategy that increases the visual quality and dimensional accuracy of “bridges” in 3D printed objects.

A bridge is a fully horizontal part in a 3D print that connects two pillars, without having a support structure under it. In present the slicing software, bridging areas are detected and for the bottom part (one, or several layers) of the bridges, settings are adjusted specifically for that area.

In the slicing engine Simplify3D 4.0 such bridge settings are named: Bridging extrusion multiplier, Bridging speed multiplier, and Fixed bridging infill angle. Depending on the length of a bridge, and the value of the print settings, a bridge may be printed correctly or incorrectly.

Figure 1 shows to test prints for testing bridging parameters. As can be seen in Figure 1, the bridging in the top image of Figure 1 is of a much higher quality compared to the bridging in the bottom picture. But it is not always evident what exactly makes a bridge fail or succeed.

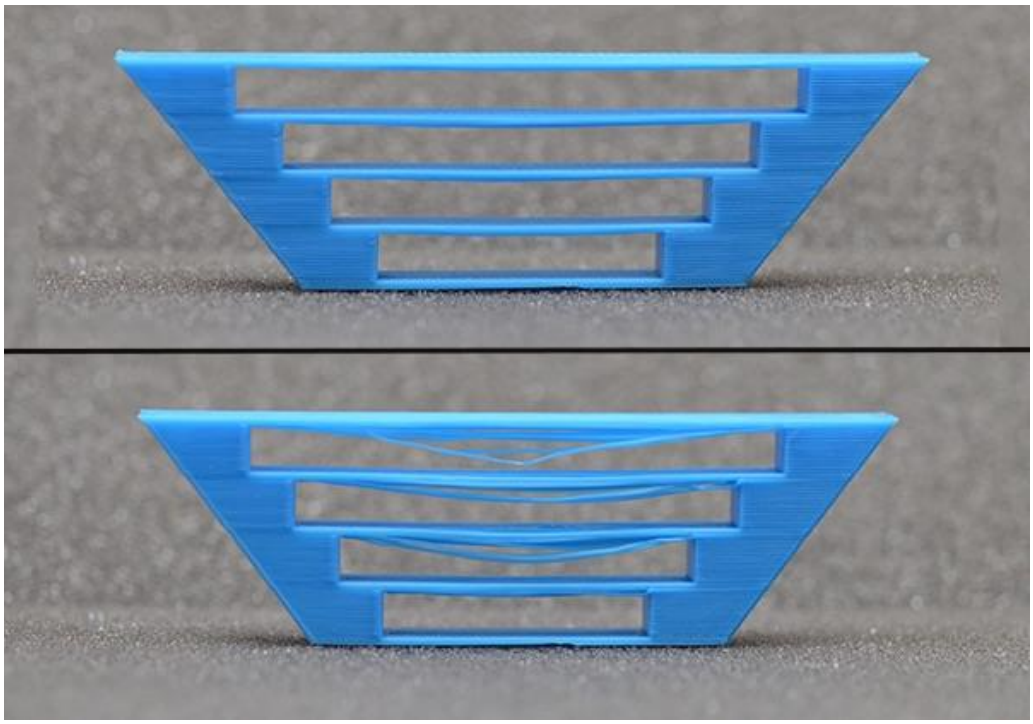


Fig. 1 Two test prints for testing bridging parameters
(source: simplify 3D website: https://www.simplify3d.com/software/release-notes/version-4-0-0/)

In the slicing software Ultimaker® Cura 4.13, the bridge settings also include the new settings called “bridge skin density”, which can be set for three bottom layers (skins) of a bridge, see also Figure 2 below.

Fig. 2 Example of bridging settings in Ultimaker Cura 4.13

By closely monitoring the printing process, we discovered that when printing a bridge area, the printing thread and the trace next to it, can coalesce. Figure 3 shows a video still of printing threads during printing of a bridge.

Fig. 3 Video still of printing threads during printing of a bridge

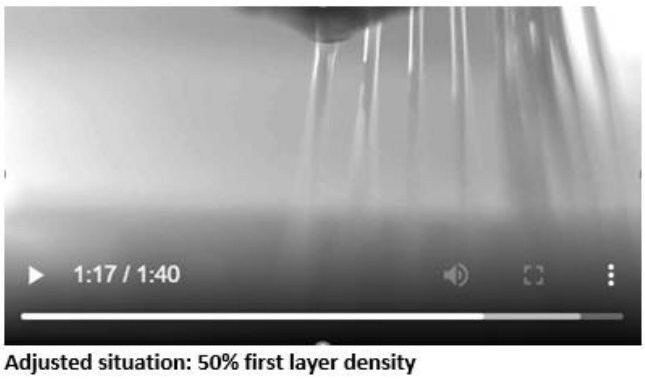
The image of Figure 4 is taken just before a thread and a trace coalesce, while in the bottom image, the thread has just coalesced with the previous trace next to it.

Fig. 4 Video still of printing a bridge with coalescence thread/traces

In our research we noticed that when such coalescence happens, the combined thread/trace is heavier and will sag more, resulting in worse bridge quality. Also the resulting bottom structure is more irregular and less visual appealing.

In the newly proposed strategy, the distance between the traces is increased (by lowering the skin density settings, see also Figure 2) in such a way that coalescence will not occur. In the picture below you can see the difference: when the distance between the traces is increased, there is no coalescence of the thread and the previous trace, while in the original situation there is.

Normal situation: 100% first layer density



Adjusted situation: 50% first layer density

Fig. 5 Video still of printing a bridge with 100% density (top) and 50% density (bottom)

The current default in the Ultimaker® CURA slicer is to use a standard skin layer for bridging. The skin infill pull the sides inwards resulting in an ugly and sagging bottom surface.

The new bridge settings in Ultimaker® CURA prevent the skin infill to be printed. Instead straight lines are pulled, which act as a net on top of which the remainder of the skin layers can be safely printed. The quality of this 'net' can be further improved by increasing the distance between the lines (= reducing the density). Other ways to control the sagging and robustness of the net is to improve cooling and reduce the print speed and flow. Special care needs to be taken to prevent the threads from breaking at the supporting edge.

The pictures below show the resulting improvement in the bridge quality in a printed part.

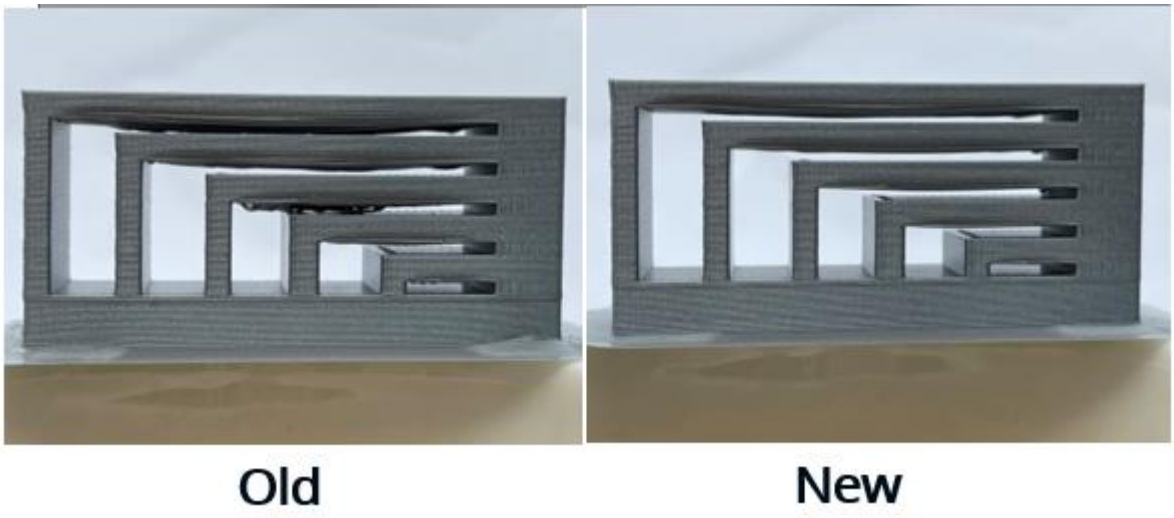


Fig. 6 Printed test object using the old settings (left) and the new settings (right)

Please note that the left image of Figure 6 is not the 100% density version. It is printed using the current default which does not use the new bridge settings and prints a standard skin layer.

It can be concluded that by using the correct bridging settings an increased visual quality of a printed object can be achieved and also an increased dimensional accuracy for the bridges.
As a result, more 3D models can be properly printed without the need of support at these areas, which results in higher productivity (i.e. shorter print time).