Use of greyscale voxel values in continuous DLP printing

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ABSTRACT

Digital light processing (DLP) stereolithography is a technique for 3D printing using a DLP ultraviolet (UV) projector for curing photopolymer. The printed geometry is specified by a data volume that is sliced and projected layer-by-layer into a vat of liquid photoreactive resin. This produces objects of good precision, but each voxel value is conventionally either fully lit (1) or unlit (0). The printed objects therefore suffer from aliasing (staircase artifacts). Recently, systems have emerged that enable continuous 3D printing [1-3]. Although such systems may give rise to superior surface finishes as the staircase effect is greatly reduced or even removed (Figure 1, right), the discrete quantization artifact of the projector is still present. In other recent work [4], employing layered DLP printing, it was possible to control the growth of each voxel using greyscale values in the projector output (Figure 1, left). In this work, we adapt the use of greyscale voxel values to continuous DLP systems in order to create an artifact-free process. This enables 3D printing of geometries that resemble injection moulded parts. While the surface appearance of 3D printed objects is conventionally controlled in a post-processing step, we will explore development of innovative surface microstructure and appearance as an integrated part of the 3D printing process.
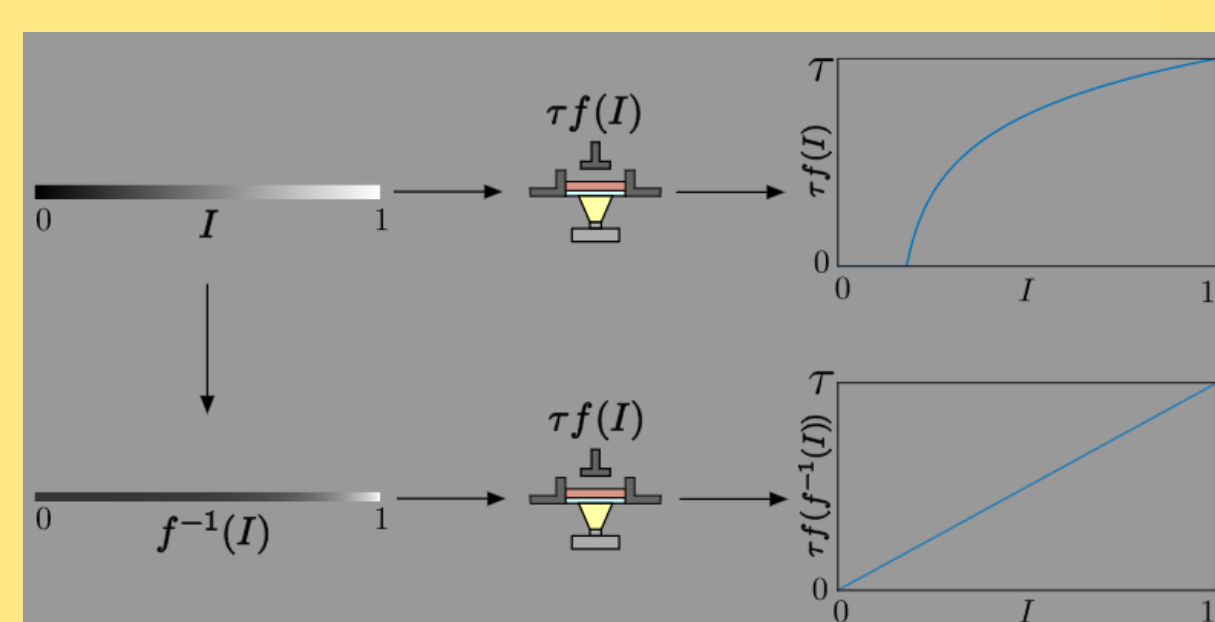
GREYSCALE VALUES
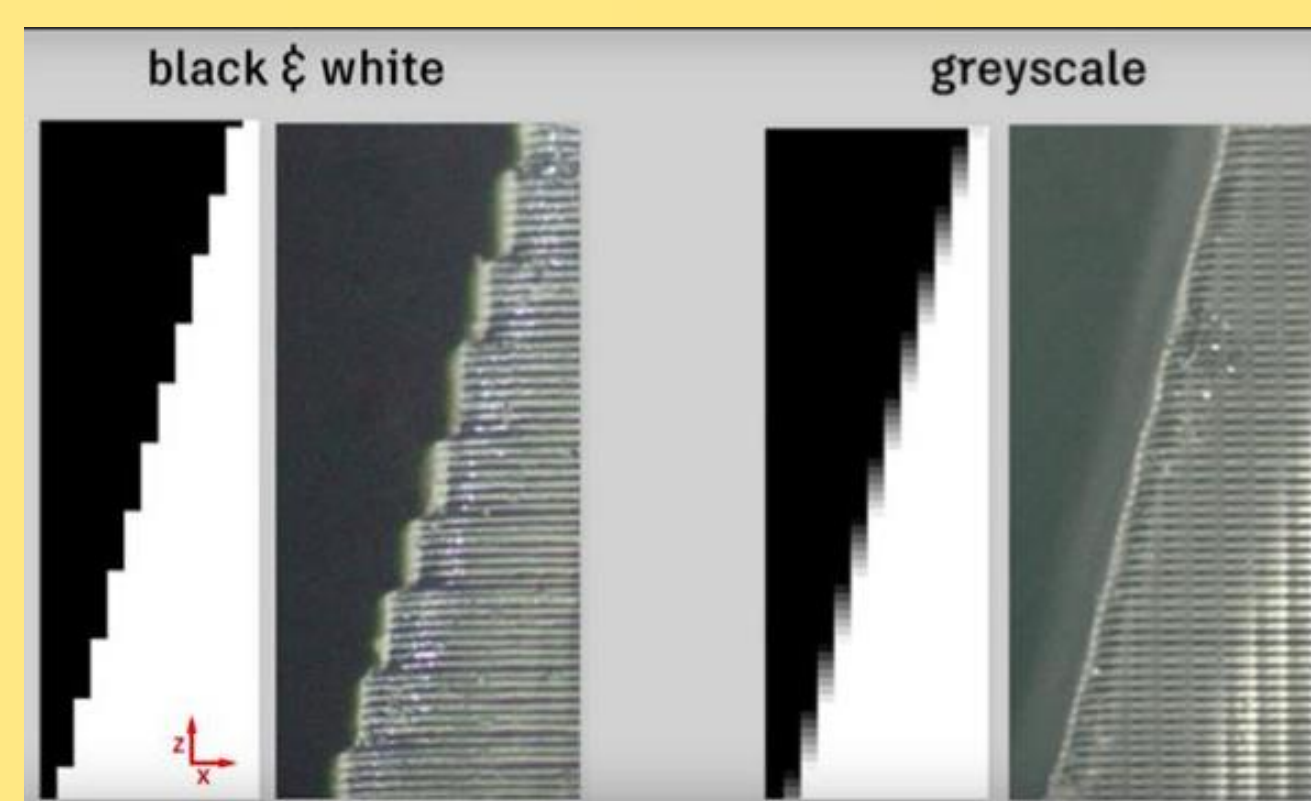
Effect of Grayscale (Fig.1):

- Subvoxel resolution;
- Subvoxel offset;
- Antialising

How to apply it:

Relationship between curing process and UVs intensity is not linear (Fig.2):

- print linear pattern with all grayscale values
- measure the surface height with the projector resolution
- find a fit and estimate the parameters α, β and γ
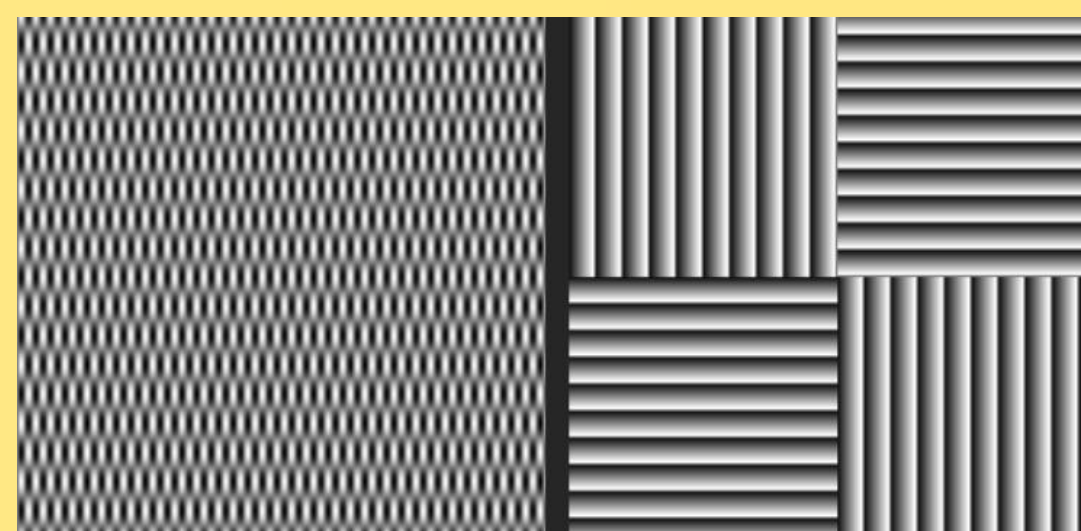- The relationship has become linear and can be used to apply grayscale

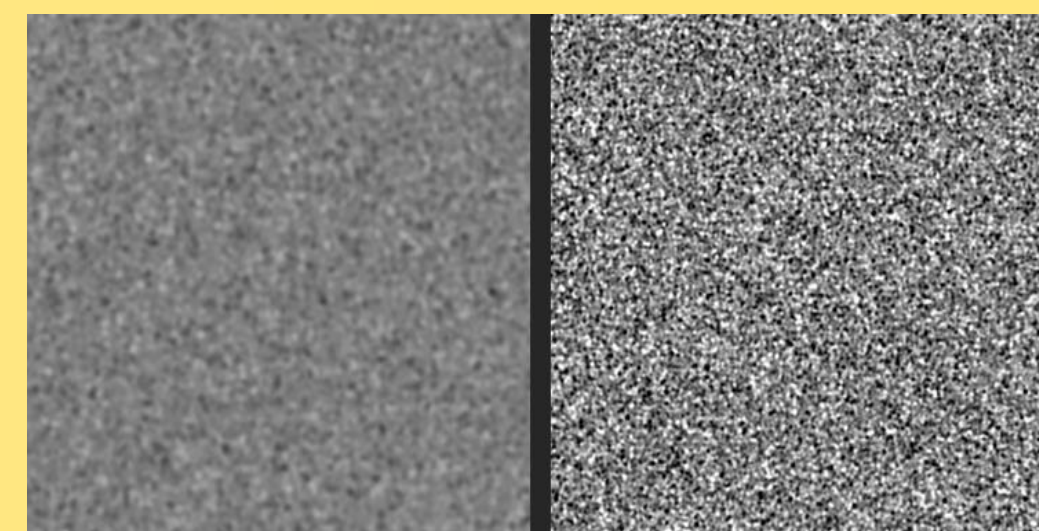**Supersampling or multisampling during slicing (Fig.3)**
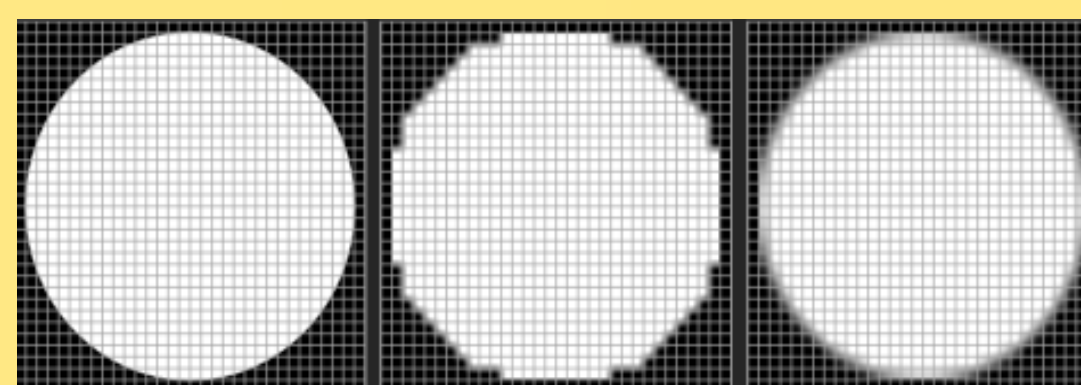
2D sinusoid (Fig.4)
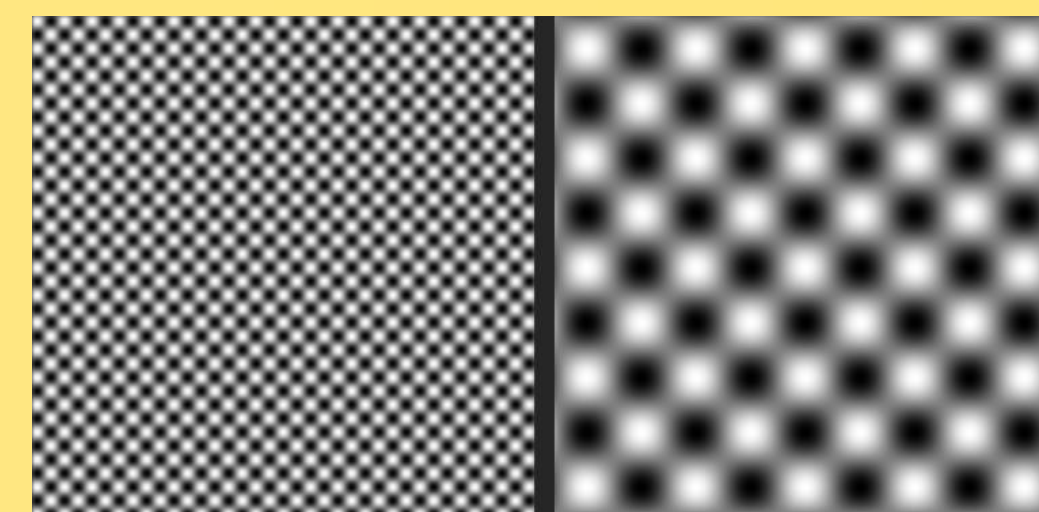
Ridged structure and 2D sinusoid to control anysotropy (Fig.5)
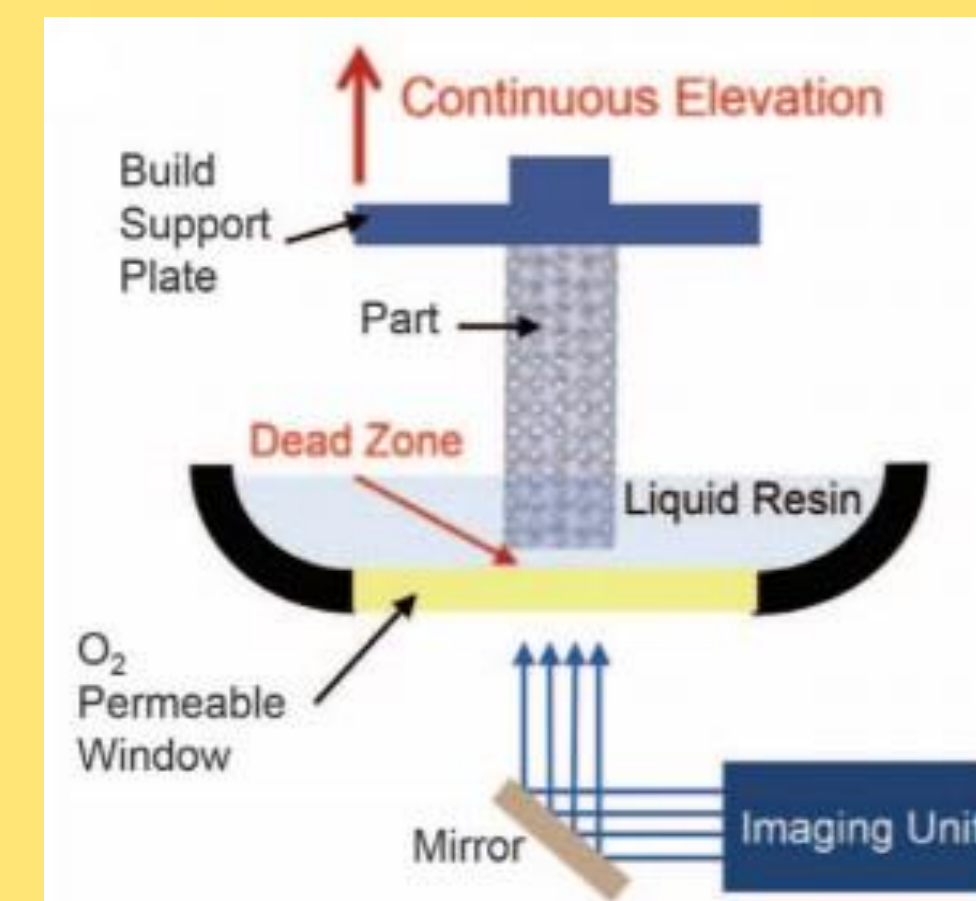

Solid sparse convolution noise (Fig.6)
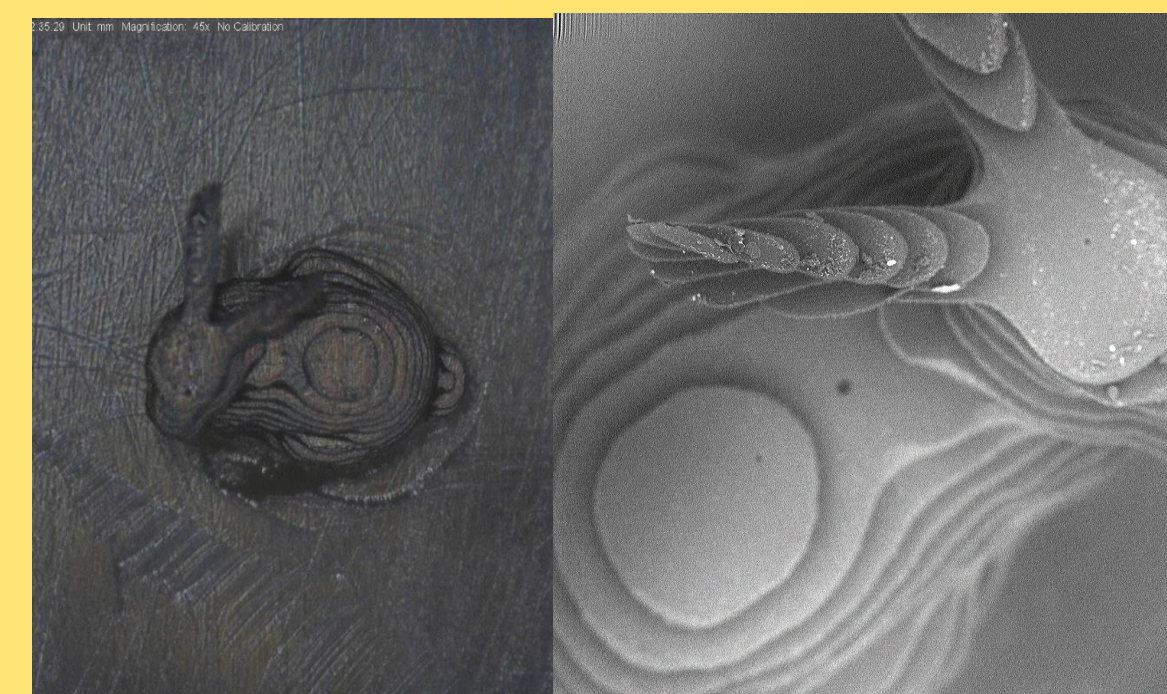

Examples of grayscale applications (Fig.7)
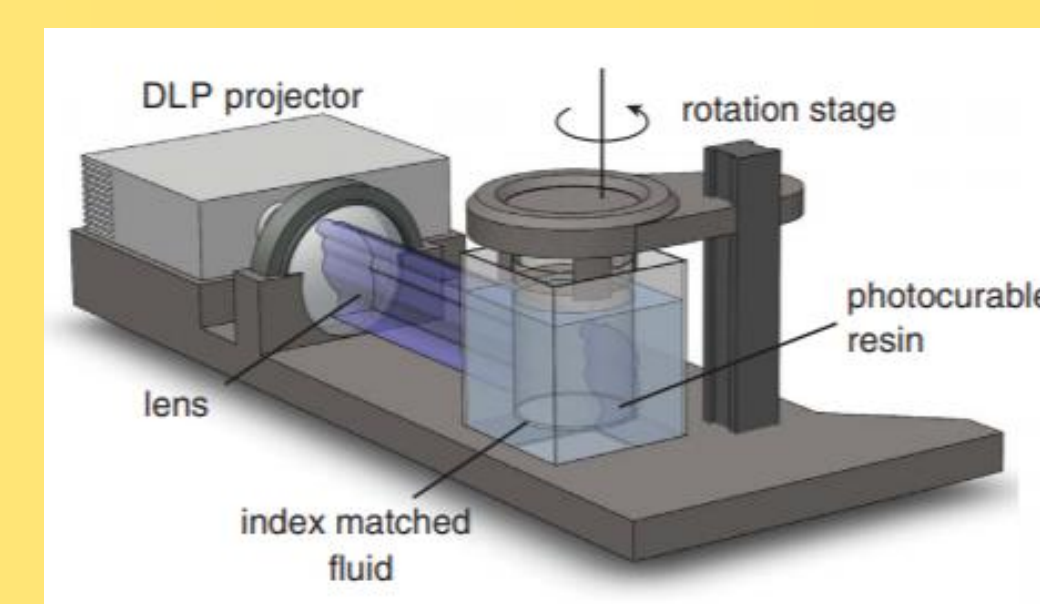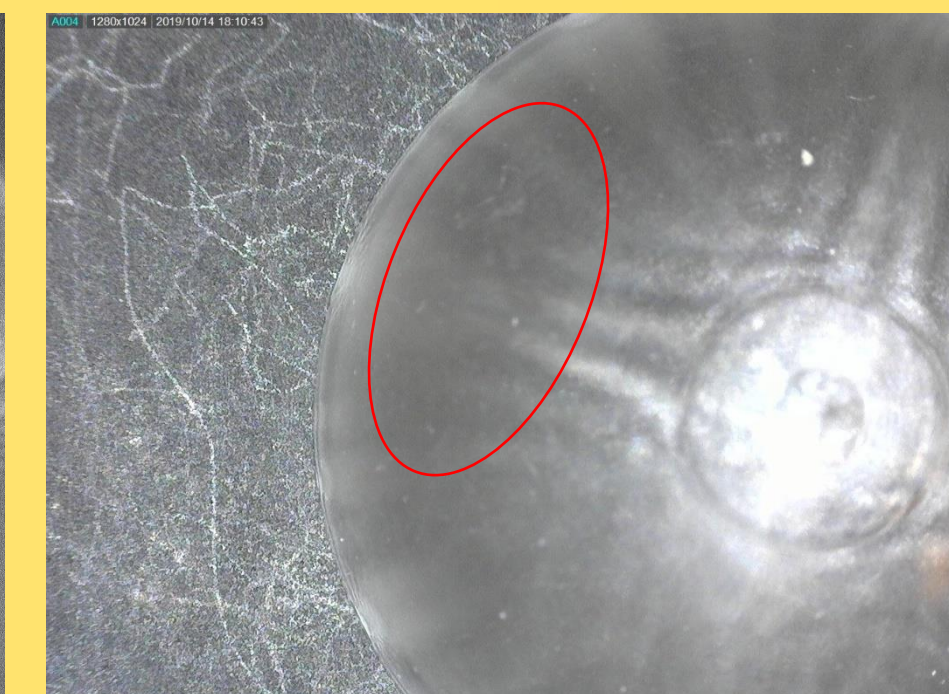
CONTINUOUS PRINTING

Continuous liquid interface production of 3D objects (Fig.8)
- The part is produced continuously by simultaneously elevating the build support plate while changing the 2D cross-sectional UV images from the imaging unit.
- Increasing the speed, the resolution decreases
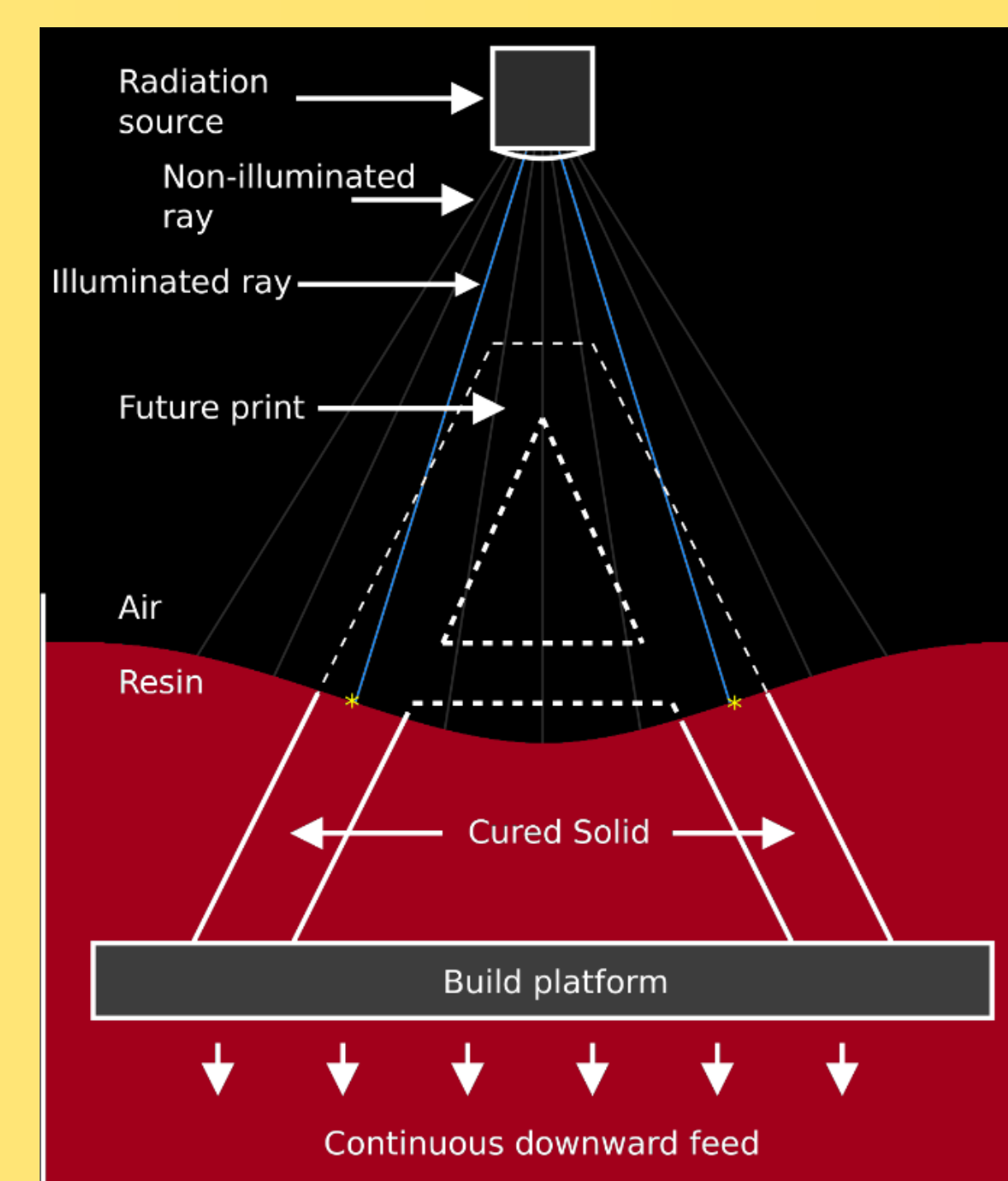
Traditional layered printing (Fig.9)   **Continuous printing (Fig.10)**

Computed axial lithography (Fig.11)
- Scalable to larger print volumes and is several orders of magnitude faster.
- Light energy to material volume as set of 2D images that cross-link the photopolymer from different angles

Additive Manufacturing Apparatus (Fig.12)
A deformation of the resin surface affects the print quality.
- Dynamic slicing algorithm that works on a ray by ray basis given any resin topography. This solution compensates any surface deformation in the resin.

Examples of continuous printing (Fig.13)
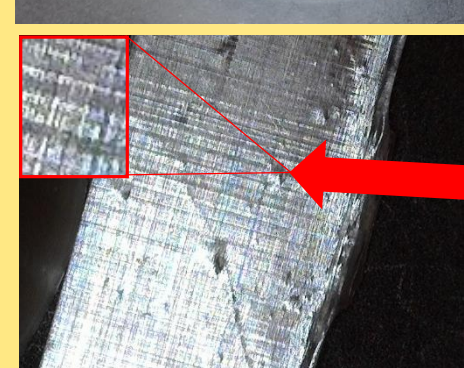
COMBINATION AND FUTURE DEVELOPMENT

The aim is to adapt the use of greyscale values to continuous systems in order to improve precision, resolution of the printing. The challenges are multiple:
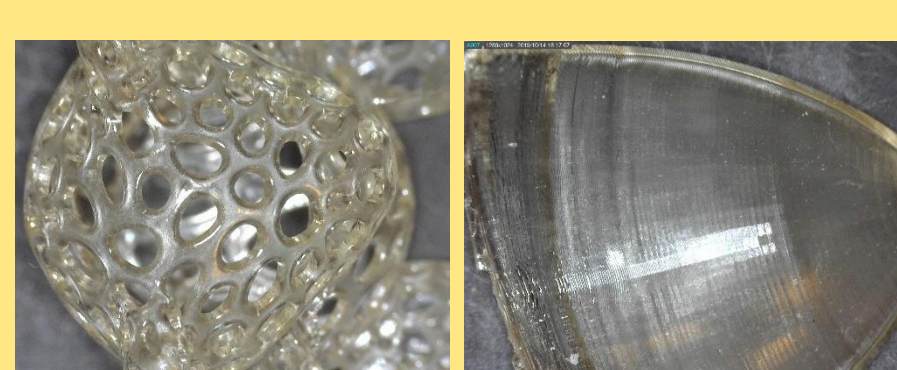
- To obtain a layerless printing without artifact case (Fig.14)

- To avoid aliasing (Fig.15)

- To reduce the pixelization due to the voxel solidification (Fig.16)

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Fig.8: Tumbleston, J. R., Shirvanyants, D., Ermoshkin, N., Janusziewicz, R., Johnson, A. R., Kelly, D., Cehn, K., Pinschmidt, R., Rolland, J. P., Ermoshkin, A., Samulski, E. T., and DeSimone, J. M. (2015). Continuous liquid interface production of 3D objects.

Fig.11: Kelly, B. E., Bhattacharya, I., Heidari, H., Shusteff, M., Spadaccini, C. M., and Taylor, H. K. (2019). Volumetric additive manufacturing via tomographic reconstruction.

Fig.12: Eiriksson, E. R. (2017). Computer Vision for Additive Manufacturing. PhD thesis, Department of Applied Mathematics and Computer Science, Technical University of Denmark.