Multiphysics modeling and machine learning to determine light irradiation pattern in grayscale digital light processing (DLP) 3D printing

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Additive manufacturing (AM) is a rapidly growing field that continues to find new applications and reach new heights of structure fabrication as the technology continues to improve. Digital light processing (DLP) is one of the most promising AM technologies due to its fast build speed, high accuracy, and material versatility. In this approach, a light pattern is shone onto a build platform submerged in a vat of photopolymerizable resin. The resin is cured in the shape of the light pattern, and then the platform sinks further into the resin so that a new layer can be cured on top of the previous one. In this way, parts can be built very rapidly in a layer-by-layer manner. Moreover, the brightness of each pixel can be tuned within each layer, which allows the final modulus of the printed structures to vary throughout the part. This is known as grayscale DLP (g-DLP). While this is a very powerful fabrication method, there are still several factors that can limit the quality of the prints. The light used to cure each new layer of resin will also penetrate previous layers, which causes the curing reaction to continue. This can cause errors in the final properties of regions designed to be softer (lower degree of cure). There can also be property errors within each layer, known as over-curing, which is mainly caused by overlapping Gaussian light distributions from each pixel and the diffusion of free radicals generated during the curing process. This work presents a platform that integrates multiphysics modeling with machine learning to determine correct light irradiation dose to overcome overdose issues. First, a model that couples light propagation in resin, chemical reaction kinetics, and diffusion of chemical species is developed. This tool can be used to optimize the individual pixel intensities along property boundaries in order to sharpen the transition between regions. Separately, a neural network is used to determine the sequence of light intensities that will most-accurately produce the desired property pattern in the printing direction. This work not only provides a better understanding of the curing kinetics of DLP printing, but also provides a path toward unlocking the full potential of the g-DLP method.