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Quadratic Tracking Control of Photopolymerization for Additive Manufacturing

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1 Background

Rapid prototyping has flourished over the past decade and quickly matured into industrialized additive manufacturing (AM), also know as 3-D printing. AM through photopolymerization is a prominent technique in which a photopolymer is selectively solidified towards a near net shape part, often in a layer-wise process. The technique of photopolymerization comprises the processes where liquid photopolymers are selectively cured by delivering some type of light, typically ultraviolet (UV).

2 Problem

Although photopolymerization-based AM is increasingly being used in the manufacturing industry, several challenges are still faced in order to improve repeatable product quality. It is commonly recognized that an in-depth understanding and monitoring of the curing process and the control thereof has a great potential to lead to end products of better quality [1]. This motivates the research on closed-loop control of the curing process and the build-up of material properties. A roadmap to improve repeatable product quality is depicted in Figure 1 [2]. This work mainly focuses on the 0-D SISO case in which the system boundary is drawn at (sub-)voxel scale. There is little consensus about strategies to achieve beneficial material properties to improve product quality. In order to move to a higher dimensional problem and to cope with varying control objectives, a flexible control architecture is desired.

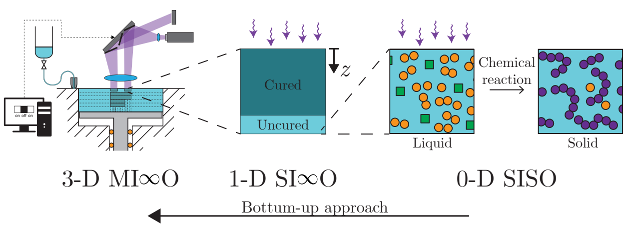

Figure 1: Roadmap to improve product quality [2].

3 Approach

This work mainly focuses on tracking control of the curing degree, p, which is a measure for the progress of the polymerization reaction. The time-evolution is typically described by a nonlinear first order differential equation. An extension to the quadratic tracking framework is introduced to anticipatively control this nonlinear system. For this purpose, an updating strategy is proposed based on sequential linearization of the nonlinear model. First, the controlled system is validated by means of simulation and subsequently the controlled system is experimentally validated on the setup described in [3].

4 Results and Outlook

The experimentally obtained closed-loop tracking response of a sigmoid-shaped reference signal is depicted in Figure 2. The work can be considered as a twofold proof of principle. Firstly, the potential of model-based control of the material property evolution is demonstrated. Secondly, the extension to the quadratic tracking framework is validated. Two extensions are proposed in [4]. The domain can be extended to 1-D SI∞O and a control-oriented model is proposed that includes temperature, strain and stress evolution.

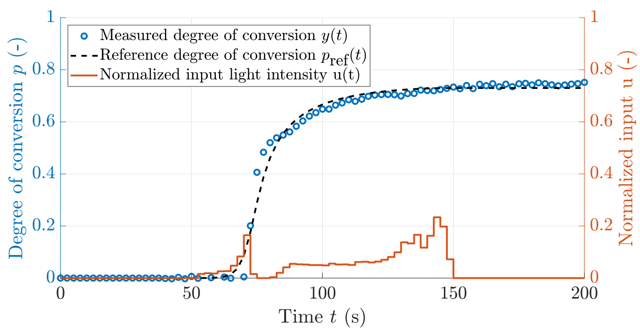

Figure 2: Experimental closed-loop curing response.

References

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