Model-based Shading and Lighting Controls Considering Visual Comfort and Lighting Energy Use

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Abstract

Fenestration properties and controls affect energy use and comfort conditions in building perimeter zones. Dynamic façades with high performance glazing and automated shading have the potential to balance daylighting needs, comfort and energy use, when integrated with lighting and thermal systems controls. Recent efforts on developing efficient shading control strategies mainly focused on either providing more daylight to reduce lighting energy use, preventing glare, or controlling solar gains to reduce cooling requirements. Usually, this requires different sensors and control systems for shading, lighting and air-conditioning operation.

This Thesis presents the development and implementation of a model-based control algorithm for automated shading and lighting operation, aiming at minimizing energy use while reducing the risk of glare. A detailed lighting model is used to compute real-time interior lighting conditions, energy use and daylight glare probability, based on the readings of two sensors on every building façade. The model, validated with full-scale experiments, is able to predict the performance of dynamic façades with complex fenestration systems and employs a hybrid ray tracing and radiosity method for lighting simulation and a detailed daylight glare module based on DGP. The model-based operation ensures optimal shade position and light dimming levels that minimize energy use while satisfying glare constraints at each time step. The developed algorithm is demonstrated in a full-scale office space, controlling shades and electric lighting through the real-time model-based optimizer, using simple sensor readings as inputs. The results show the performance of the optimized controls in terms of energy use, visual comfort and daylight provision, leading to integrated, smart façade controls for perimeter building zones.