CLAIMS

What is claimed is:

1. A method of controlling building service systems associated with a building for optimizing a plurality of building performance parameters in providing an environment with respect to a region of the building, using at least one processor, the building service systems comprising an air-conditioning and/or heating system, a lighting system and a shading system, the method comprising:

predicting, based on a shading and lighting prediction model, a visual comfort condition and a lighting condition with respect to the region of the building;

optimizing, based on a first multi-component cost function including a plurality of components relating to a plurality of lighting or thermal performance parameters with respect to the region of the building, one or more first control parameters for controlling the lighting system and the shading system based on the predicted visual comfort condition and the predicted lighting condition;

predicting, based on a building dynamics model, a plurality of building response parameters based on the predicted visual comfort condition and the predicted lighting condition associated with the region of the building;

optimizing, based on a second multi-component cost function including a plurality of components relating to the plurality of building performance parameters, one or more second control parameters for controlling the air-conditioning and/or heating system based on the predicted plurality of building response parameters,

wherein the shading and lighting prediction model comprises:

a daylight penetration model configured to estimate a transmitted daylight illuminance associated with the shading system with respect to the region of the building;

a visual comfort model configured to predict the visual comfort condition based on the estimated transmitted daylight illuminance; and

a lighting power model configured to predict the lighting condition based on the estimated transmitted daylight illuminance, and

wherein the plurality of building performance parameters include a building energy efficiency parameter, a human thermal comfort parameter and a human visual comfort parameter.

2. The method according to claim 1, wherein the visual comfort model and the lighting power model are each based on a data-driven model, and the daylight penetration model is based on a non-data-driven model.

3. The method according to claim 1 or 2, wherein the daylight penetration model is configured to estimate the transmitted daylight based on an incident solar irradiance on one or more windows associated with the shading system.

4. The method according to claim 3, wherein the incident solar irradiance comprises a diffuse irradiance component, a direct irradiance component and a ground-reflected irradiance component.

5. The method according to any one of claims 1 to 4, wherein the visual comfort condition comprises a maximum illuminance at a work plane in the region of the building, and the visual comfort model is trained based on measured data for predicting the maximum illuminance at the work plane based on the estimated transmitted daylight illuminance.

6. The method according to any one of claims 1 to 5, wherein the lighting condition comprises a lighting power in the region of the building, and the lighting power model is trained based on measured data for predicting the lighting power based on the estimated transmitted daylight illuminance.

~~7. The method according to any one of claims 1 to 6, wherein the plurality of building performance parameters include a building energy efficiency parameter, a human thermal comfort parameter, and a human visual comfort parameter.~~

~~8~~7. The method according to any one of claims 1 to ~~7~~6, wherein the plurality of components of the second multi-component cost function comprises a first component relating to a cooling energy, a second component relating to a thermal comfort, a third component relating to a cooling power change rate, and a fourth component relating to soft constraints.

~~9~~8. The method according to claim ~~8~~7, wherein said optimizing, based on the second multi-component cost function, is based on ~~a minimization function with respect to~~ minimizing a consumption of the cooling energy, a predicted mean vote (PMV) variation from thermo-neutral, the cooling power change rate, and constraints violation.

~~10~~9. The method according to any one of claims 1 to ~~9~~8, wherein the plurality of components of the first multi-component cost function comprises a first component relating to a lighting power, a second component relating to a cooling power associated with heat flux gain from lighting associated with the lighting system, and a third component relating to a cool power associated with heat flux gain from one or more windows associated with the shading system.

~~11~~10. The method according to claim ~~10~~9, wherein said optimizing, based on the first multi-component cost function, is based on minimizing electricity power of the lighting associated with the lighting system and the cooling power due to the heat flux gain from the lighting associated with the lighting system and the heat flux gain from the one or more windows associated with the shading system.

~~12~~11. The method according to any one of claims 1 to ~~11~~10, wherein said optimizing, based on the first multi-component cost function, and said optimizing, based on the second multi-component cost function, are based on model predictive control.

~~13~~12. A control system for controlling building service systems associated with a building for optimizing a plurality of building performance parameters in providing an environment with respect to a region of the building, the building service systems comprising an air-conditioning and/or heating system, a lighting system and a shading system, the control system comprising:

a memory; and

at least one processor communicatively coupled to the memory and configured to:

predict, based on a shading and lighting prediction model, a visual comfort condition and a lighting condition with respect to the region of the building;

optimize, based on a first multi-component cost function including a plurality of components relating to a plurality of lighting or thermal performance parameters with respect to the region of the building, one or more first control parameters for controlling the lighting system and the shading system based on the predicted visual comfort condition and the predicted lighting condition;

predict, based on a building dynamics model, a plurality of building response parameters based on the predicted visual comfort condition and the predicted lighting condition associated with the region of the building; and

optimize, based on a second multi-component cost function including a plurality of components relating to the plurality of building performance parameters, one or more second control parameters for controlling the air-conditioning and/or heating system based on the predicted plurality of building response parameters,

wherein the shading and lighting prediction model comprises:

a daylight penetration model configured to estimate a transmitted daylight illuminance associated with the shading system with respect to the region of the building;

a visual comfort model configured to predict the visual comfort condition based on the estimated transmitted daylight illuminance; and

a lighting power model configured to predict the lighting condition based on the estimated transmitted daylight illuminance, and

wherein the plurality of building performance parameters include a building energy efficiency parameter, a human thermal comfort parameter and a human visual comfort parameter.

~~14~~13. The control system according to claim ~~13~~12, wherein the visual comfort model and the lighting power model are each based on a data-driven model, and the daylight penetration model is based on a non-data-driven model.

~~15~~14. The control system according to claim ~~13~~12 or ~~14~~13, wherein the daylight penetration model is configured to estimate the transmitted daylight based on an incident solar irradiance on one or more windows associated with the shading system.

~~16~~15. The control system according to claim ~~15~~14, wherein the incident solar irradiance comprises a diffuse irradiance component, a direct irradiance component and a ground-reflected irradiance component.

~~17~~16. The control system according to any one of claims ~~13~~12 to ~~16~~15, wherein the visual comfort condition comprises a maximum illuminance at a work plane in the region of the building, and the visual comfort model is trained based on measured data for predicting the maximum illuminance at the work plane based on the estimated transmitted daylight illuminance.

~~18~~17. The control system according to any one of claims ~~13~~12 to ~~17~~16, wherein the lighting condition comprises a lighting power in the region of the building, and the lighting power model is trained based on measured data for predicting the lighting power based on the estimated transmitted daylight illuminance.

~~19. The control system according to any one of claims 13 to 18, wherein the plurality of building performance parameters include a building energy efficiency parameter, a human thermal comfort parameter, and a human visual comfort parameter.~~

~~20~~18. The control system according to any one of claims ~~13~~12 to ~~19~~17, wherein the plurality of components of the second multi-component cost function comprises a first component relating to a cooling energy, a second component relating to a thermal comfort, a third component relating to a cooling power change rate, and a fourth component relating to soft constraints.

~~21~~19. The control system according to claim ~~20~~18, wherein said optimize, based on the second multi-component cost function, is based on ~~a minimization function with respect to~~minimizing a consumption of the cooling energy, a predicted mean vote (PMV) variation from thermo-neutral, the cooling power change rate, and constraints violation.

~~22~~20. The control system according to any one of claims ~~13~~12 to ~~21~~19, wherein the plurality of components of the first multi-component cost function comprises a first component relating to a lighting power, a second component relating to a cooling power associated with heat flux gain from lighting associated with the lighting system, and a third component relating to a cool power associated with heat flux gain from one or more windows associated with the shading system.

~~23~~21. The control system according to claim ~~22~~20, wherein said optimize, based on the first multi-component cost function, is based on minimizing the lighting power of the lighting associated with the lighting system, the cooling power due to the heat flux gain from the lighting associated with the lighting system and the heat flux gain from the one or more windows associated with the shading system.

2422. The control system according to any one of claims 1312 to 2321, wherein said optimize, based on the first multi-component cost function, and said optimize, based on the second multi-component cost function, are based on model predictive control.

2523. A computer program product, embodied in one or more non-transitory computer-readable storage mediums, comprising instructions executable by at least one processor to perform a method of controlling building service systems associated with a building for optimizing a plurality of building performance parameters in providing an environment with respect to a region of the building, using at least one processor, the building service systems comprising an air-conditioning and/or heating system, a lighting system and a shading system, the method comprising:

predicting, based on a shading and lighting prediction model, a visual comfort condition and a lighting condition with respect to the region of the building;

optimizing, based on a first multi-component cost function including a plurality of components relating to a plurality of lighting or thermal performance parameters with respect to the region of the building, one or more first control parameters for controlling the lighting system and the shading system based on the predicted visual comfort condition and the predicted lighting condition;

predicting, based on a building dynamics model, a plurality of building response parameters based on the predicted visual comfort condition and the predicted lighting condition associated with the region of the building; and

optimizing, based on a second multi-component cost function including a plurality of components relating to the plurality of building performance parameters, one or more second control parameters for controlling the air-conditioning and/or heating system based on the predicted plurality of building response parameters,

wherein the shading and lighting prediction model comprises:

a daylight penetration model configured to estimate a transmitted daylight illuminance associated with the shading system with respect to the region of the building;

a visual comfort model configured to predict the visual comfort condition based on the estimated transmitted daylight illuminance; and

a lighting power model configured to predict the lighting condition based on the estimated transmitted daylight illuminance, and

wherein the plurality of building performance parameters include a building energy efficiency parameter, a human thermal comfort parameter and a human visual comfort parameter.