CLAIMS

1. A building control method to control an environment of a zone, the building control method comprising:

acquiring real-time measurements related to the zone, the real-time measurements including at least two types of measurements;

providing a linearized building dynamics model; and

for a control interval, predictively determining an optimized output from optimizing a cost function based on the linearized building dynamics model, wherein the cost function is configured to simultaneously optimize two or more objectives, each of the objectives being determined by different types of the measurements ; and

using the optimized output to control at least one actuator operable in the zone, wherein the optimized output is one of a time series of optimized outputs determined based on the linearized building dynamics model, and wherein the optimized output corresponds to a combination of manipulated variables, each of the manipulated variables being configured to control a different one of the at least one actuator~~.~~;

~~2. The building control method according to claim 1, further comprising:~~

for a model adaptation interval, using one or both of the real-time measurements and historical measurements to adapt a non-linear machine learning-based building dynamics model to obtain an adapted non-linear building dynamics model; and

for each adapted non-linear building dynamics model obtained, applying linearization with feedback to linearize the adapted non-linear building dynamics model to obtain the linearized building dynamics model for use in optimizing the cost function at a subsequent control interval.

~~3.~~2. The building control method according to claim 1~~ or claim 2~~, further comprising:

at a selected control interval, using the real-time measurements to regenerate the linearized building dynamics model to obtain a regenerated linearized building dynamics model; and

at the control interval following the selected control interval, optimizing the cost

function using the regenerated linearized building dynamics model.

~~4.~~3. The building control method according to claim ~~3~~2, wherein the regenerated linearized building dynamics model is regenerated at successive control intervals.

~~5.~~4. The building control method according to ~~any one of~~ claim~~s~~ ~~2~~1 ~~to 4~~or claim 3, wherein the adapted non-linear building dynamics model obtained at the model adaptation interval is used to regenerate a plurality of the linearized building dynamics models, each of the plurality of the linearized building dynamics models corresponding to respectives ones of the successive control intervals.

~~6.~~5. The building control method according to any one of claims ~~2~~1 to ~~5~~4, further comprising:

after a first plurality of successive control intervals, performing a second adaptation of the adapted non-linear building dynamics model to obtain a second adapted non-linear building dynamics model; and

using the second adapted non-linear building dynamics model to regenerate the linearized building dynamics model at each of a second plurality of successive control intervals.

~~7.~~6. The building control method according to claim ~~2~~1, wherein the adapted non-linear building dynamics model is adapted at each of one or more model adaptation intervals, and wherein each of the one or more model adaptation intervals comprises a plurality of successive control intervals.

~~8.~~7. The building control method according to any one of claims 1 to ~~7~~6, wherein the non-linear building dynamics model is based on a recurrent neural network with a non-linear autoregressive exogenous structure.

~~9.~~8. The building control method according to any one of claims 1 to ~~8~~7, wherein the linearized building dynamics model is obtained by performing a Taylor's expansion for a given state vector.

~~10.~~9. The building control method according to any one of claims 1 to ~~9~~8, wherein a process of linearizing to provide the linearized building dynamics model is characterized by an average processing time that is shorter than the control interval, and wherein the average processing time includes time for linearizing to obtain the linearized building dynamics model and for determining the optimized output.

~~11.~~10. The building control method according to claim ~~10~~9, wherein the control interval is three orders of magnitude larger than the processing time.

~~12.~~11. A building control system for controlling an environment of a zone, the building control system comprising:

at least one model predictive control system configured to:

acquire real-time measurements related to the zone, the real-time measurements including at least two types of measurements;

provide a linearized building dynamics model; and

for a control interval, predictively determine an optimized output from optimizing a cost function based on the linearized building dynamics model, wherein the cost function is configured to simultaneously optimize two or more objectives, each of the objectives being determined by different types of the measurements; and

using the optimized output to control at least one actuator operable in the zone, wherein the optimized output is one of a time series of optimized outputs determined based on the linearized building dynamics model, and wherein the optimized output corresponds to a combination of manipulated variables, each of the manipulated variables being configured to control one of the at least one actuator~~.~~

~~13. The building control system according to claim 12~~, wherein the model predictive system is further configured to:

for a model adaptation interval, use one or both of the real-time measurements and historical measurements to adapt a non-linear machine learning-based building dynamics model to obtain an adapted non-linear building dynamics model; and

for each adapted non-linear building dynamics model obtained, apply linearization with feedback to linearize the adapted non-linear building dynamics model to obtain the linearized building dynamics model for use in optimizing the cost function at a subsequent control interval.

~~14.~~12. The building control system according to ~~claim 12 or~~ claim ~~13~~11, wherein the model predictive system is further configured to:

at a selected control interval, use the real-time measurements to regenerate the linearized building dynamics model to obtain a regenerated linearized building dynamics model; and

at the control interval following the selected control interval, optimize the cost function using the regenerated linearized building dynamics model.

~~15.~~13. The building control system according to claim ~~14~~12, wherein the regenerated linearized building dynamics model is regenerated at successive control intervals.

~~16.~~14. The building control system according to any one of claims ~~13~~11 to ~~15~~13, wherein the adapted non-linear building dynamics model obtained at the first model adaptation interval is used to regenerate a plurality of the linearized building dynamics models, each of the plurality of the linearized building dynamics models corresponding to respective ones of the successive control intervals.

~~17.~~15. The building control system according to any one of claims ~~13~~11 to ~~16~~14, wherein the model predictive control system is further configured to:

after a first plurality of successive control intervals, perform a second adaptation of the adapted non-linear building dynamics model to obtain a second adapted non-linear building dynamics model; and

use the second adapted non-linear building dynamics model to regenerate the linearized building dynamics model at each of a second plurality of successive control intervals.

~~18.~~16. The building control system according to claim ~~13~~11, wherein the non-linear building dynamics model is adapted at each of one or more model adaptation intervals, and wherein each of the one or more model adaptation intervals comprises a plurality of successive control intervals.

~~19.~~17. The building control system according to any one of claims ~~12~~11 to ~~18~~16, wherein the non-linear building dynamics model is based on a recurrent neural network with a non-linear autoregressive exogenous structure.

~~20.~~18. The building control system according to any one of claims ~~12~~11 to ~~19~~17, wherein the linearized building dynamics model is obtained by performing a Taylor's expansion for a given state vector.

~~21.~~19. The building control system according to any one of claims ~~12~~11 to ~~20~~18, wherein the linearized building dynamics model is characterized by an average processing time that is shorter than the control interval, and wherein the average processing time includes time for linearizing to obtain the linearized building dynamics model and for determining the optimized output.

~~22.~~20. The building control system according to claim ~~21~~19, wherein the control interval is three orders of magnitude larger than the processing time.

~~23.~~21. A building comprising:

two or more building services sub-systems operable in one or more zones of the building, at least one of the two or more building services sub-systems being configurable by at least one actuator;

at least one sensor disposed in the one or more zones;

a machine learning-based model predictive control system is configured to:

acquire real-time measurements from the at least one sensor, the real-time measurements including at least two types of measurements related to the one or more zones;

provide a linearized building dynamics model; and

for a control interval, predictively determine an optimized output from optimizing a cost function based on the linearized building dynamics model, wherein the cost function is configured to simultaneously optimize two or more objectives, each of the objectives being determined by different types of the measurements; and

use the optimized output to control the at least one actuator, wherein the optimized output is one of a time series of optimized outputs determined based on the linearized building dynamics model, and wherein the optimized output corresponds to a combination of manipulated variables, each of the manipulated variables being configured to control a different one of the at least one actuator~~.~~

~~24. The building of claim 23~~, wherein the model predictive system is further configured to:

for a model adaptation interval, use one or both of the real-time measurements and historical measurements to adapt a non-linear machine learning-based building dynamics model; and

at each control interval:

perform linearization of the non-linear building dynamics model; and

optimize the cost function to obtain the optimized output, wherein the model adaptation interval comprises a plurality of the control intervals.

~~25.~~22. The building of claim ~~24~~21, wherein adaptation of the non-linear machine learning-based building dynamics model is responsive to a change in a configuration of the one or more zones.

~~26.~~23. The building of claim ~~25~~22, wherein the adaptation is performed not more than once every 24 hours, and wherein the linearization is performed at each control interval multiple times a day.