CLAIMS

What is claimed is:

1. A method of predicting remaining useful life of a multi-component operational system, using at least one processor, the method comprising:

obtaining component remaining useful life information associated to a plurality of components of the operational system, the component remaining useful life information indicates a remaining useful life corresponding to each component of the plurality of components;

obtaining component relationships information in relation to the operational system, the component relationships information indicates a relationship between a component and one or more other components of the multi-component operational system; and

determining the remaining useful life of the operational system based on the component remaining useful life information associated to the plurality of components and the component relationships information,

wherein the method further comprises:

if the component relationships information is not available, creating the component relationships information, and

wherein the creating the component relationships information comprises:

collecting predefined KPIs (key performance indicators) of the operational system from a database system;

obtaining KPIs data of the operational system from sensors, wherein the KPIs data is operational data in relation to a plurality of system parameters associated to the plurality of components;

calculating correlation coefficients of the plurality of components based on the operational data; and

creating the component relationships information based on the correlation coefficients.

2. The method according to claim 1, wherein the component relationships information comprises, for each pair of correlated components of the plurality of

components, the correlation coefficients that represent the relationship between the pair of components.

3. The method according to claim 1 or 2, wherein said determining the remaining useful life of the operational system based on the component remaining useful life information associated to the plurality of components and the component relationships information further comprises:

determining, for each component of the plurality of components, a significance value associated to the component;

selecting a primary component from the plurality of components based on respective significance values of the plurality of components; and

determining the remaining useful life of the operational system based on the remaining useful life corresponding to the primary component selected and the remaining useful life corresponding to one or more components which are correlated to the primary component using a system remaining useful life estimation function.

4. The method according to claim 3, wherein the component relationships information comprises, for each pair of correlated components of the plurality of components, a first correlation coefficient indicating a degree to which a first component of the pair affects a second component of the pair, and a second correlation coefficient indicating a degree to which the second component of the pair affects the first component of the pair.

5. The method according to claim 4, wherein the component relationships information in relation to the plurality of components of the operational system further comprises, for each component of the plurality of components, an importance value associated to the component, the importance value indicating a degree to which the component contributes to a health condition of the operational system based on a correlation between the component and one or more other components.

6. The method according to claim 5, wherein the system remaining useful life estimation function comprises, for each component of the one or more components which are correlated to the primary component selected, a weight corresponding to an effect of the remaining useful life corresponding to the component, the weight being

based on the second correlation coefficient and the importance value associated to the component.

7. The method according to any one of claims 1 to 6, further comprising:

determining whether the remaining useful life of the operational system is below a threshold;

in response to determining that the remaining useful life of the operational system is below a threshold, determining an optimization result based on an objective function to minimize cost of repair of components, cost of replacement of components or system and/or downtime of the system; and

providing a recommendation based on the optimization result.

8. The method according to any one of claims 1 to 7:

further comprising obtaining the operational data in relation to the plurality of system parameters associated to the plurality of components of the operational system; and

wherein said obtaining remaining useful life information associated to a plurality of components of the operational system comprises determining, for each component of the plurality of components, the remaining useful life corresponding to the component with respect to the operational data based on a component remaining useful life function.

9. The method according to any one of claims 1 to 7 further comprising obtaining the operational data in relation to the plurality of system parameters associated to the plurality of components of the operational system; and wherein said obtaining component relationships information in relation to the operational system comprises determining the component relationship information with respect to the operational data based on the predefined KPIs.

10. The method according to any one of claims 1 to 9, wherein the operational system comprises a chiller system.

11. A system for remaining useful life prediction of a multi-component operational system, the system comprising:

a memory; and

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

obtain component remaining useful life information associated to a plurality of components of the operational system, the component remaining useful life information indicates a remaining useful life corresponding to each component of the plurality of components;

obtain component relationships information in relation to the operational system, the component relationships information indicates a relationship between a component and one or more other components of the multi-component operational system; and

determine the remaining useful life of the operational system based on the component remaining useful life information associated to the plurality of components and the component relationships information,

wherein the at least one processor is further configured to:

if the component relationships information is not available, create the component relationships information, and

wherein, to create the component relationships information, the at least one processor is configured to:

collect predefined KPIs (key performance indicators) of the operational system from a database system;

obtain KPIs data of the operational system from sensors, wherein the KPIs data is operational data in relation to a plurality of system parameters associated to the plurality of components;

calculate correlation coefficients of the plurality of components based on the operational data; and

create the component relationships information based on the correlation coefficients.

12. The system according to claim 11, wherein the component relationships information comprises, for each pair of correlated components of the plurality of components, the correlation coefficients that represent the relationship between the pair of components.

13. The system according to claim 11 or 12, wherein said determine the remaining useful life of the operational system based on the component remaining useful life information associated to a plurality of components and the component relationships information further comprises:

determining, for each component of the plurality of components, a significance value associated to the component;

selecting a primary component from the plurality of components based on respective significance value of the plurality of components; and

determining the remaining useful life of the operational system based on the remaining useful life corresponding to the primary component selected and the remaining useful life corresponding to one or more components which are correlated to the primary component using a system remaining useful life estimation function.

14. The system according to claim 13, wherein the component relationships information comprises, for each pair of correlated components of the plurality of components, comprises a first correlation coefficient indicating a degree to which a first component of the pair affects a second component of the pair, and a second correlation coefficient indicating a degree to which the second component of the pair affects the first component of the pair.

15. The system according to claim 14, wherein the component relationships information in relation to the plurality of components of the operational system further comprises, for each component of the plurality of components, an importance value associated to the component, the importance value indicating a degree to which the component contributes to a health condition of the operational system based on a correlation between the component and one or more other components.

16. The system according to claim 15, wherein the system remaining useful life estimation function comprises, for each component of the one or more components which are correlated to the primary component selected, a weight corresponding to an effect of the remaining useful life corresponding to the component, the weight being based on the second correlation coefficient and the importance value associated to the component.

17. The system according to any one of claims 11 to 16, wherein the at least one processor is further configured to:

determine whether the remaining useful life of the operational system is below a threshold;

in response to determining that the remaining useful life of the operational system is below a threshold, determine an optimization result based on an objective function to minimize cost of repair of components, cost of replacement of components or system and/or downtime of the system; and

provide a recommendation based on the optimization result.

18. The system according to any one of claims 11 to 17:

wherein the at least one processor is further configured to obtain the operational data in relation to the plurality of system parameters associated to the plurality of components of the operational system; and

wherein said obtain component remaining useful life information associated to a plurality of components of the operational system comprises determining, for each component of the plurality of components, the remaining useful life corresponding to the component with respect to the operational data based on a component remaining useful life function.

19. The system according to any one of claims 11 to 17, wherein the at least one processor is further configured to obtain the operational data in relation to the plurality of system parameters associated to the plurality of components of the operational system; and wherein said obtain component relationships information in relation to the plurality of components of the operational system comprises determining the component relationship information with respect to the operational data based on the predefined KPIs.

20. 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 predicting remaining useful life of a multi-component operational system according to any one of claims 1 to 10.