

SYSTEM, METHOD, AND COMPUTER PROGRAM PRODUCT FOR OPTIMIZING A MANUFACTURING PROCESS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/990,260, filed March 16, 2020, and Patent Application No. 17/175,785, filed February 15, 2021, the disclosures of which are hereby incorporated by reference in their entirety.

BACKGROUND

[0002] This disclosure relates generally to manufacturing processes and, in non-limiting embodiments, to systems, methods, and computer program products for optimizing a manufacturing process, such as a glass manufacturing process, and data processing techniques related thereto.

SUMMARY

[0002a] According to an aspect, the present disclosure refers to a computer-implemented method to optimize a manufacturing process, comprising: receiving, with at least one processor, manufacturing data associated with a manufacturing process for manufacturing a product, the manufacturing data comprising data from a plurality of data sources associated with a plurality of stages of the manufacturing process, the manufacturing data comprising values for a plurality of parameters including at least one process parameter value and at least one quality parameter value; generating, with at least one processor, a time-sequenced data structure comprising the manufacturing data, wherein each parameter of the plurality of parameters is associated with a time in the time-sequenced data structure; transforming, with at least one processor, the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages, wherein each parameter of the plurality of parameters is associated with at least one position; determining, with at least one processor, a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm; and optimizing the manufacturing process based on the new value.

[0002b] According to another aspect, the present disclosure refers to a system for optimizing a manufacturing process, comprising: at least one processor programmed or configured to: receive manufacturing data associated with a manufacturing process for manufacturing a product, the manufacturing data comprising data from a plurality of data sources associated with a plurality of stages of the manufacturing process, the manufacturing data comprising values for a plurality of parameters including at least one process parameter value and at least one quality parameter value; generate a time-sequenced data structure comprising the manufacturing data, wherein each parameter of the plurality of parameters is associated with a time in the time-sequenced data structure; transform the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages, wherein each parameter of the plurality of parameters is associated with at least one position; determine a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm; and optimize the manufacturing process based on the new value.

[0002c] According to another aspect, the present disclosure refers to a computer program product for optimizing a manufacturing process, comprising at least one non-transitory computer-readable medium including program instructions that, when executed by at least one processor, cause the at least one processor to: receive manufacturing data associated with a manufacturing process for manufacturing a product, the manufacturing data comprising data from a plurality of data sources associated with a plurality of stages of the manufacturing process, the manufacturing data comprising values for a plurality of parameters including at least one process parameter value and at least one quality parameter value; generate a time-sequenced data structure comprising the manufacturing data, wherein each parameter of the plurality of parameters is associated with a time in the time-sequenced data structure; transform the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages, wherein each parameter of the plurality of parameters is associated with at least one position; determine a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm; and optimize the manufacturing process based on the new value.

[0003] According to some non-limiting ~~embodiments or aspects~~examples, provided is a computer-implemented method to optimize a manufacturing process. The method may include receiving, with at least one processor, manufacturing data associated with a manufacturing process

for manufacturing a product. The manufacturing data may include data from a plurality of data sources associated with a plurality of stages of the manufacturing process. The manufacturing data may include values for a plurality of parameters including at least one process parameter value and at least one quality parameter value. The method may include generating, with at least one processor, a time-sequenced data structure including the manufacturing data. Each parameter of the plurality of parameters may be associated with a time in the time-sequenced data structure. The method may include transforming, with at least one processor, the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages. Each parameter of the plurality of parameters may be associated with at least one position. The method may include determining, with at least one processor, a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm. The method may include optimizing the manufacturing process based on the new value.

[0004] In some non-limiting ~~example embodiments or aspects~~, transforming the time-sequenced data structure to the positionally-dimensioned data structure may include: identifying, with at least one processor, a zone for each parameter of the plurality of parameters; determining, with at least one processor, for each parameter, a time delay factor based on a length of the zone for the parameter and a line speed of the zone; and generating, with at least one processor, the positionally-dimensioned data structure using a data matrix transformation based on the time-sequenced data structure, the zone for each parameter, and the time delay factor for each parameter.

[0005] In some non-limiting ~~example embodiments or aspects~~, the manufacturing process may be a glass manufacturing process and the product may include a coated glass product. The plurality of parameters may include: temperature, event time, electrical arcing, gas flow, voltage, current, power, pressure, or any combination thereof.

[0006] In some non-limiting ~~example embodiments or aspects~~, the method may include detecting, with at least one processor, at least one outlier parameter value in the time-sequenced data structure or the positionally-dimensioned data structure. The method may include removing, with at least one processor, the at least one outlier parameter value. The at least one algorithm may include a machine-learning algorithm configured to output the new value based on a model and at least one user input value.

[0007] In some non-limiting ~~example embodiments or aspects~~, the method may include identifying, with at least one processor, a set of empty data entries in the time-sequenced data structure or the positionally-dimensioned data structure. The method may include determining, with at least one processor, a proportion of missing data by comparing a size of the set of empty data entries to the size of the time-sequenced data structure or the positionally-dimensioned data structure. The method may include comparing, with at least one processor, the proportion of missing data to a predetermined tolerance threshold. The method may include, in response to the proportion of missing data not satisfying the predetermined tolerance threshold, deleting the set of empty data entries from the time-sequenced data structure or the positionally-dimensioned data structure. The method may include, in response to the proportion of missing data satisfying the predetermined tolerance threshold, imputing data into the set of empty data entries.

[0008] According to some non-limiting ~~example embodiments or aspects~~, provided is a system for optimizing a manufacturing process. The system may include at least one processor programmed or configured to receive manufacturing data associated with a manufacturing process for

manufacturing a product. The manufacturing data may include data from a plurality of data sources associated with a plurality of stages of the manufacturing process. The manufacturing data may include values for a plurality of parameters including at least one process parameter value and at least one quality parameter value. The at least one processor may be programmed or configured to generate a time-sequenced data structure including the manufacturing data. Each parameter of the plurality of parameters may be associated with a time in the time-sequenced data structure. The at least one processor may be programmed or configured to transform the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages. Each parameter of the plurality of parameters may be associated with at least one position. The at least one processor may be programmed or configured to determine a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm. The at least one processor may be programmed or configured to optimize the manufacturing process based on the new value.

[0009] In some non-limiting ~~example~~~~embodiments or aspects~~, transforming the time-sequenced data structure to the positionally-dimensioned data structure may include: identifying a zone for each parameter of the plurality of parameters; determining, for each parameter, a time delay factor based on a length of the zone for the parameter and a line speed of the zone; and generating the positionally-dimensioned data structure using a data matrix transformation based on the time-sequenced data structure, the zone for each parameter, and the time delay factor for each parameter.

[0010] In some non-limiting ~~example~~~~embodiments or aspects~~, the manufacturing process may include a glass manufacturing process and the product may include a coated glass product. The plurality of parameters may include: temperature, event time, electrical arcing, gas flow, voltage, current, power, pressure, or any combination thereof.

[0011] In some non-limiting ~~example~~~~embodiments or aspects~~, the at least one processor may be further programmed or configured to detect at least one outlier parameter value in the time-sequenced data structure or the positionally-dimensioned data structure. The at least one processor may be further programmed or configured to remove the at least one outlier parameter value. In some non-limiting ~~embodiments or aspects~~~~examples~~, the at least one algorithm may include a machine-learning algorithm configured to output the new value based on a model and at least one user input value.

[0012] According to non-limiting ~~example~~~~embodiments or aspects~~, provided is a computer program product for optimizing a manufacturing process. The computer program product may include at

least one non-transitory computer-readable medium including program instructions. The program instructions may, when executed by at least one processor, cause the at least one processor to receive manufacturing data associated with a manufacturing process for manufacturing a product. The manufacturing data may include data from a plurality of data sources associated with a plurality of stages of the manufacturing process. The manufacturing data may include values for a plurality of parameters including at least one process parameter value and at least one quality parameter value. The program instructions may cause the at least one processor to generate a time-sequenced data structure including the manufacturing data. Each parameter of the plurality of parameters may be associated with a time in the time-sequenced data structure. The program instructions may cause the at least one processor to transform the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages. Each parameter of the plurality of parameters may be associated with at least one position. The program instructions may cause the at least one processor to determine a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm. The program instructions may cause the at least one processor to optimize the manufacturing process based on the new value.

[0013] In some non-limiting ~~examples~~~~embodiments or aspects~~, transforming the time-sequenced data structure to the positionally-dimensioned data structure may include: identifying a zone for each parameter of the plurality of parameters; determining, for each parameter, a time delay factor based on a length of the zone for the parameter and a line speed of the zone; and generating the positionally-dimensioned data structure using a data matrix transformation based on the time-sequenced data structure, the zone for each parameter, and the time delay factor for each parameter.

[0014] In some non-limiting ~~examples~~~~embodiments or aspects~~, the manufacturing process may include a glass manufacturing process, the product may include a coated glass product, and the plurality of parameters may include: temperature, event time, electrical arcing, gas flow, voltage, current, power, pressure, or any combination thereof.

[0015] In some non-limiting ~~examples~~~~embodiments or aspects~~, the program instructions may further cause the at least one processor to detect at least one outlier parameter value in the time-sequenced data structure or the positionally-dimensioned data structure. The program instructions may cause the at least one processor to remove the at least one outlier parameter value. In some non-limiting

~~example embodiments or aspects~~, the at least one algorithm may include a machine-learning algorithm configured to output the new value based on a model and at least one user input value.

[0016] In some non-limiting ~~example embodiments or aspects~~, the manufacturing process may be a manufacturing process for a glass product. In some non-limiting ~~example embodiments or aspects~~, the manufacturing process may be a manufacturing process for a coated glass product. In some non-limiting ~~example embodiments or aspects~~, the manufacturing process may be for coating a glass product.

[0017] Further ~~examples embodiments or aspects~~ are set forth in the following numbered clauses:

[0018] Clause 1: A computer-implemented method to optimize a manufacturing process, comprising: receiving, with at least one processor, manufacturing data associated with a manufacturing process for manufacturing a product, the manufacturing data comprising data from a plurality of data sources associated with a plurality of stages of the manufacturing process, the manufacturing data comprising values for a plurality of parameters including at least one process parameter value and at least one quality parameter value; generating, with at least one processor, a time-sequenced data structure comprising the manufacturing data, wherein each parameter of the plurality of parameters is associated with a time in the time-sequenced data structure; transforming, with at least one processor, the time-sequenced data structure to a positionally-dimensioned data structure based on timing data associated with the plurality of stages, wherein each parameter of the plurality of parameters is associated with at least one position; determining, with at least one processor, a new value for the at least one process parameter value based on the positionally-dimensioned data structure and at least one algorithm; and optimizing the manufacturing process based on the new value.

[0019] Clause 2: The computer-implemented method of clause 1, wherein transforming the time-sequenced data structure to the positionally-dimensioned data structure comprises: identifying, with at least one processor, a zone for each parameter of the plurality of parameters; determining, with at least one processor, for each parameter, a time delay factor based on a length of the zone for the parameter and a line speed of the zone; and generating, with at least one processor, the positionally-dimensioned data structure using a data matrix transformation based on the time-sequenced data structure, the zone for each parameter, and the time delay factor for each parameter.