

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau

(43) International Publication Date
25 May 2023 (25.05.2023)



(10) International Publication Number
WO 2023/091623 A1

- (51) **International Patent Classification:**
G06F 30/27 (2020.01) *G05B 17/02* (2006.01)
- (21) **International Application Number:**
PCT/US2022/050338
- (22) **International Filing Date:**
18 November 2022 (18.11.2022)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
63/281,952 22 November 2021 (22.11.2021) US
- (71) **Applicant:** **WATLOW ELECTRIC MANUFACTURING COMPANY** [US/US]; 12001 Lackland Road, St. Louis, MO 63146 (US).
- (72) **Inventors:** **YUAN, Hanwen**; 12001 Lackland Road, St. Louis, MO 63146 (US). **ZHANG, Sanhong**; 12001 Lackland Road, St. Louis, MO 63146 (US). **BREWER, Grant**; 12001 Lackland Road, St. Louis, MO 63146 (US). **XU, Mengkai**; 12001 Lackland Road, St. Louis, MO 63146 (US).
- (74) **Agent:** **PATSARIKAS, George, A.**; Burris Law, PLLC, 300 River Place Drive, Suite 1775, Detroit, MI 48207-4291 (US).
- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.
- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,

(54) **Title:** METHOD OF GENERATING A DIGITAL TWIN OF THE ENVIRONMENT OF INDUSTRIAL PROCESSES

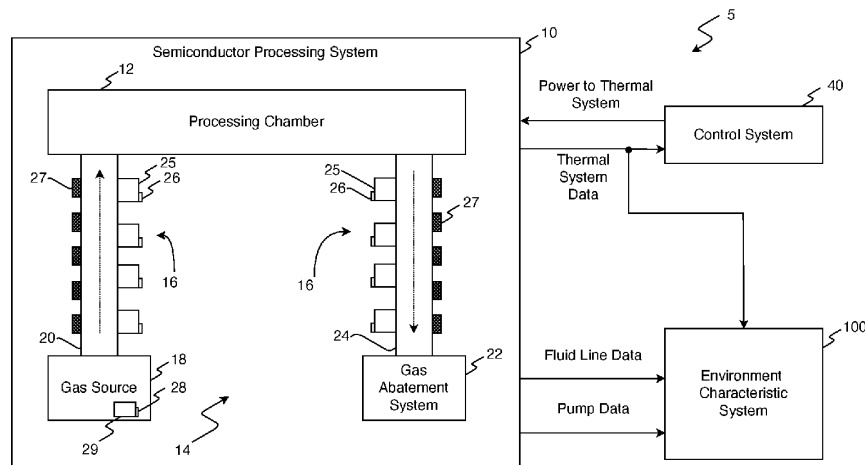


FIG. 1

(57) **Abstract:** A method of generating a digital twin of an environment (10) includes generating one or more mathematical-based variables based on a mathematical model (304) of the environment and sensor data from one or more sensors of the environment, generating one or more machine learning-based variables based on a machine learning-based model of the environment (308) and the sensor data, and stacking the one or more mathematical-based variables and the one or more machine learning-based variables based on a meta-learning model to generate a machine learning input (312) for predicting a performance characteristic of the environment (320).

[Continued on next page]

TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*