PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT6802592

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
INTELLERGY, INC.	11/26/2019

RECEIVING PARTY DATA

Name:	GREENWAVE INNOVATIONS INC
Street Address:	UNIT B- 649 SOLOMON CRESCENT
City:	REGINA
State/Country:	CANADA
Postal Code:	S4N 6H9

PROPERTY NUMBERS Total: 2

Property Type	Number
Application Number:	62190317
Patent Number:	10489716

CORRESPONDENCE DATA

Fax Number: (207)669-8306

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 2072663564
Email: steenberg@msn.com
Correspondent Name: CARSTEN M STEENBERG
Address Line 1: 29 OAKLEYS CAMP ROAD
Address Line 4: PENOBSCOT, MAINE 04476

NAME OF SUBMITTER:	CARSTEN M STEENBERG
SIGNATURE:	/carsten steenberg/
DATE SIGNED:	07/08/2021
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 33
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DEVELOPMENT SERVICES AND PURCHASE AGREEMENT

This Development Services and Purchase Agreement (this "**Agreement**"), dated as of June 30, 2021, is entered into between **Intellergy, Inc**., a Maine corporation ("**Intellergy**") and **Greenwave Innovations Inc**., a Saskatchewan corporation ("**Greenwave**").

WHEREAS, Intellergy has expertise in software application development and wishes to provide services to Greenwave, and to sell certain assets to Greenwave and Greenwave wishes to acquire such services and to purchase certain assets from Intellergy, subject to the terms and conditions set forth herein;

NOW, THEREFORE, in consideration of the mutual covenants and agreements hereinafter set forth and for other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the parties hereto agree as follows:

ARTICLE I
Purchase and Sale of Assets

Section 1.01 Purchase and Sale of Assets. Subject to the terms and conditions set forth herein, Intellergy shall sell, assign, transfer, convey and deliver to Greenwave, and Greenwave shall purchase from Intellergy, all of Intellergy's right, title and interest in the Purchased Assets, free and clear of any mortgage, pledge, lien, charge, interest, security interest, claim or other encumbrance ("**Encumbrance**").

Section 1.02 Definition of Purchased Assets. The Purchased Assets are the assets described in Schedule "A" attached hereto, including without limitation the results of the Services, the Deliverables, the Patent, the Software and the Purchased IP (all as hereinafter defined).

Section 1.03 No Assumption of Liabilities. Greenwave shall not assume any liabilities or obligations of Intellergy of any kind, whether known or unknown, contingent, matured or otherwise, whether currently existing or hereinafter created.

ARTICLE II
Services

Section 2.01 Services. Greenwave agrees to retain Intellergy to provide certain application development services (the "**Services**") in accordance with the development roadmap, the milestones and the time lines summarized in Schedule "B" attached hereto.

Section 2.02 Statement of Work. The development roadmap attached to Schedule "B" is a summary of the Services which Services will be further particularized in a statement of work (a **"Statement of Work**") to be finalized and to form part of Schedule "B". A Statement of Work shall contain, unless the parties agree otherwise, a description of the work to be conducted, the functional requirements and technical specifications applicable to the work, the work schedule and milestones, the deliverables ("**Deliverables**") and delivery schedule, acceptance criteria and other information specified in Schedule "B". All terms and conditions of a Statement of Work must be

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approved in writing by Greenwave prior to the commencement of any Services relating to such Statement of Work.

Section 2.03 Performance of Statement of Work. Subject to the terms and conditions of this Agreement, Intellergy shall perform the Services as set forth in Schedule "B" and in accordance with any subsequent Statement of Work that may be finalized. Timely performance of the Services is a matter of paramount importance and Intellergy agrees to perform and complete the Services diligently and professionally in accordance with the milestones and delivery dates set forth in Schedule "B".

Section 2.04 Acceptance of Deliverables. Subject to the provisions of Schedule "A", Greenwave shall, within twenty (20) business days of the delivery by Intellergy of a Deliverable, either accept or reject such Deliverable by reference to the applicable acceptance criteria. If the Deliverable is not accepted, Greenwave shall, within such twenty (20) business day period, provide Intellergy with written notice of the deficiencies in respect of the Deliverable. If no such notice is received by Intellergy within such twenty (20) business day period, such Deliverable shall be deemed to have been accepted by Greenwave. Upon resolution of any deficiencies identified by Greenwave's written notice of same, Intellergy shall deliver the corrected Deliverable to Greenwave for acceptance, and the foregoing acceptance procedure shall apply, except that the time period for Greenwave either accepting or rejecting the Deliverable shall be ten (10) business days.

Section 2.05 Purchase of Hardware. Notwithstanding Section 1.01, if in the opinion of Greenwave, acting reasonably, the value of any hardware (the "**Hardware**") forming part of the Purchased Assets has not been demonstrated as part of the Service milestones referenced in Schedule "B", Greenwave may elect not to purchase some or all of the Hardware and any payment relating thereto shall be adjusted as appropriate.

ARTICLE III
Payment

Section 3.01 Payment. Greenwave agrees to pay the amounts for the Services and the purchase of the Purchased Assets in accordance with Schedule "B" and the completion of milestones for payment as set out therein. Payment shall be subject to satisfactory performance of the Services and receipt of the Purchased Assets and subject to Section 2.05. Such amounts shall be paid no later than ten (10) business days following acceptance of the Deliverables in accordance with Section 2.04. All amounts set out are denominated in Canadian Dollars to be paid by Greenwave to Intellergy in United States Dollars. The Canadian Dollar amounts set forward were established using the current CAD:USD exchange rate of 1.2219. The US Dollar payment amount will fluctuate as the exchange rate changes.

Section 3.02 Withholding Tax. Greenwave shall be entitled to deduct and withhold from any amount payable hereunder all taxes that Greenwave may be required to deduct and withhold under any applicable tax law. All such withheld amounts shall be treated as delivered to Intellergy hereunder.

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ARTICLE IV
Consulting Agreements

It is a fundamental term and condition of this Agreement that each of Carsten Steenberg, Curtis Meadow and Richard Merrill (each a "**Consultant**" and collectively, the "**Consultants**") execute and deliver a consulting agreement in a form satisfactory to Greenwave (each a "**Consulting Agreement**" and collectively, the "**Consulting Agreements**") and that each Consultant performs the services as set out in his respective Consulting Agreement. It is acknowledged and agreed by Intellergy and Greenwave that: (i) the Consulting Agreements are a material inducement to Greenwave entering into this Agreement with Intellergy, (ii) Greenwave would not have entered into this Agreement without the agreement of each Consultant to the covenants in his respective Consulting Agreement, and (iii) the Consulting Agreements and the services rendered by each of the Consultants thereunder are necessary to maintain or preserve the value of the Purchased Assets. Greenwave shall have the option to terminate this Agreement if there are fundamental breaches of the Consulting Agreements by the Consultants such that the contracted services are not provided.

ARTICLE V
Documentation

Section 5.01 Documentation

(a) Intellergy shall deliver to Greenwave the following:

(i) a bill of sale and general conveyance in form and substance satisfactory to Greenwave (the "**Bill of Sale and General Conveyance**") duly executed by Intellergy, transferring the Purchased Assets to Greenwave;

(ii) assignments in form and substance satisfactory to Greenwave (the "**IP Assignments**") duly executed by Intellergy, transferring all of Intellergy's right, title and interest in and to all copyright registrations, domain name registrations, the Patent, any other patents and patent applications and trademark registrations and applications included in the Purchased Assets to Greenwave;

(iii) each of the Consulting Agreements;

(iv) a certificate of the President or Secretary of Intellergy certifying as to:

(A) the resolutions of the board of directors of Intellergy, duly passed or consented to and in effect, which authorize the execution, delivery and performance of this Agreement and the transactions contemplated hereby; and

(B) the names and signatures of the officers of Intellergy authorized to sign this Agreement and the documents to be delivered hereunder;

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(v) all prosecution files, including original registration certificates, for all Intellectual Property in respect of the Purchased Assets, in such form and medium as reasonably requested by Greenwave, and all such other documents, correspondence, and information as are necessary to register, own, or otherwise use any Intellectual Property in respect of the Purchased Assets;

(vi) such other customary instruments of transfer, assumptions, filings or documents, in form and substance reasonably satisfactory to Greenwave, as may be required to give effect to this Agreement.

ARTICLE VI
Representations and Warranties of Intellergy

Intellergy represents and warrants to Greenwave that the statements contained in this Article VI are true and correct as of the date hereof. For the purposes of this Article VI, "**Intellergy's Knowledge**", "**Knowledge of Intellergy**" and any similar phrases shall mean the actual or constructive knowledge of any director or officer of Intellergy, after due inquiry.

Section 6.01 Incorporation and Authorization of Intellergy; Enforceability.

(a) Intellergy is a corporation incorporated and validly existing under the laws of Maine and has not been discontinued or dissolved under such law.

(b) Intellergy has the corporate power and capacity to enter into this Agreement and the documents to be delivered hereunder, to carry out its obligations hereunder and to consummate the transactions contemplated hereby.

(c) The execution, delivery and performance and the documents to be delivered hereunder and the consummation of the transactions contemplated hereby have been duly authorized by all requisite corporate action on the part of Intellergy.

(d) This Agreement and the documents to be delivered hereunder have been duly executed and delivered by Intellergy, and (assuming due authorization, execution and delivery by Greenwave), this Agreement and the documents to be delivered hereunder constitute legal, valid and binding obligations of Intellergy, enforceable against Intellergy in accordance with their respective terms.

Section 6.02 No Conflicts; Consents. The execution, delivery and performance by Intellergy of this Agreement and the documents to be delivered hereunder, and the consummation of the transactions contemplated hereby, do not and will not:

(a) violate or conflict with the articles of incorporation, by-laws or any unanimous shareholder agreement of Intellergy;

(b) violate or conflict with any judgment, order, decree, statute, law, ordinance, rule or regulation applicable to Intellergy or the Purchased Assets;

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(c) conflict with, or result in (with or without notice or lapse of time or both) any violation of, or default under, or give rise to a right of termination, acceleration or modification of any obligation or loss of any benefit under any contract or other instrument to which Intellergy is a party or to which any of the Purchased Assets are subject; or

(d) result in the creation or imposition of any Encumbrance on the Purchased Assets.

No consent, approval, waiver or authorization is required to be obtained by Intellergy from any person or entity (including any governmental authority) in connection with the execution, delivery and performance by Intellergy of this Agreement and the consummation of the transactions contemplated hereby.

Section 6.03 Title to Purchased Assets. Intellergy owns and has good and valid title to the Purchased Assets, free and clear of all Encumbrances.

Section 6.04 Condition of Assets. The tangible personal property included in the Purchased Assets are in good condition and are adequate for the uses to which they are being put, and none of such tangible personal property are in need of maintenance or repairs except for ordinary, routine maintenance and repairs that are not material in nature or cost.

Section 6.05 Hardware. All computer hardware, monitors, sensors, gateways, raw materials, work in progress, packaging, supplies, parts and other inventories included in the Purchased Assets consist of quality and quantity usable or salable in the ordinary course of business.

Section 6.06 Intellectual Property and Software

(a) In this Agreement, the following terms shall have the following meanings:

(i) "**Documentation**" means all documentation whether in human or machine readable form) describing or relating to the Software, including each of the following: operating, installation, administrator, and user manuals and training materials; technical, functional, service level, and other requirements and specifications; file and record layouts and fields; schematics; flow charts; algorithms; architectural diagrams; data models; build instructions; compilation instructions; testing and configuration documentation; developer annotations, programming notes, and technical data; programming, hardware, system, network design, and configuration documentation; and any other documents describing or relating to the creation, design, development, installation, implementation, execution, structure, function, performance, correction, modification, improvement, or use of the Software or the Software's operating environment, and all updates, upgrades, corrections, modifications, translations, releases, versions, derivative works and improvements of each of the foregoing items

(ii) "**Intellectual Property**" means any and all of the following in any jurisdiction throughout the world:

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(A) trademarks, including all applications and registrations and the goodwill connected with the use and symbolized by the foregoing;

(B) copyrights and industrial designs, including all applications and registrations relating to the foregoing;

(C) trade secrets and confidential know-how;

(D) the Patent and any other patents and patent applications;

(E) websites and internet domain name registrations; and

(F) other intellectual property and related proprietary rights, interests and protections (including all rights to sue and recover and retain damages, costs and legal fees, disbursements and charges for past, present and future infringement and any other rights relating to any of the foregoing);

(iii) "**Open Source Software**" means " means any Software that is distributed as "free software", "open source software" or pursuant to any licence identified as an "open source licence" by the Open Source Initiative (www.opensource.org/licenses) or other licence that substantially conforms to the Open Source Definition (http://opensource.org/osd) (including the GNU General Public License (GPL), GNU Lesser General Public License (LGPL), GNU Affero General Public License (AGPL), MIT License (MIT), Apache License, Artistic License, and BSD Licenses);

(i) "**Patent**" means United States Patent No. 10,489,716 Fast Machine-Learning Algorithm and all applications, any substitutions, divisions, continuations, continuations-in-part (but only to the extent that they cover the same invention claimed in the foregoing), revisions, reissues, renewals, registrations, confirmations, re-examinations, extensions, supplementary protection certificates, patent term extensions, patent term adjustments, and the like, and any provisional applications, of any such patent or patent application, and any foreign or international equivalent of any of the foregoing;

(ii) "**Software**" means any and all computer software and code, including all new versions, updates, revisions, improvements, and modifications thereof, whether in Source Code, object code, or executable code format, including systems software, application software (including mobile apps), application programming interfaces, firmware, middleware, programming tools, scripts, routines, interfaces, libraries, and databases, and all related specifications and Documentation, including developer notes, comments and annotations, user manuals, and training materials relating to any of the foregoing, in respect of, or in relation to the Purchased Assets; and

(iv) "**Source Code**" means the human readable source code of the Software to which it relates, in the programming language in which the Software was

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written, together with all related flow charts and technical documentation, including a description of the procedure for generating object code, all of a level sufficient to enable a programmer reasonably fluent in such programming language to understand, build, operate, support, maintain, and develop modifications, upgrades, updates, adaptations, enhancements, new versions, and other derivative works and improvements of, and to develop computer programs compatible with, the Software;

(b) Intellergy owns or has adequate, valid and enforceable rights to use all the Intellectual Property included in the Purchased Assets (the "**Purchased IP**"), free and clear of all Encumbrances. Intellergy is not bound by any outstanding judgment, injunction, order or decree restricting the use of the Purchased IP or restricting the licensing thereof to any person or entity.

(c) Intellergy is the registered owner of the Patent and the registration of the Patent remains in good standing.

(d) Intellergy is not a party to or bound by any contract or commitment to pay any royalty, license fee or management fee pertaining to the Purchased Assets.

(e) Intellergy has not disclosed, delivered, licensed, or otherwise made available, and does not have a duty or obligation (whether present, contingent, or otherwise) to disclose, deliver, licence, or otherwise make available, any Source Code for any Purchased Assets to any other person or entity, other than:

(i) an employee, independent contractor, or consultant of Intellergy pursuant to a valid and enforceable written agreement prohibiting use or disclosure except in the performance of services for the Business; or

(ii) an independent third-party escrow agent pursuant to a valid and enforceable written source code escrow agreement providing for limited release only upon the occurrence of specified release events, and no such release event has occurred, and no circumstance or condition exists that would reasonably be expected to result in the occurrence of any such release event.

Without limiting the foregoing, neither the execution of this Agreement nor the consummation of any of the transactions contemplated by this Agreement will, or would reasonably be expected to, result in the release from escrow or other delivery to any person or entity of any Source Code for any Purchased Asset.

(f) Neither Intellergy's prior and current use of the Purchased Assets or the provision of the Services have and do not and will not infringe, violate, dilute or misappropriate the Intellectual Property of any person or entity and there are no claims pending or threatened by any person or entity with respect to the ownership, validity, enforceability, effectiveness or use of the Purchased Assets, and neither Intellergy nor any affiliate of Intellergy has made or asserted any claim, demand or notice against any person or entity alleging any such infringement, misappropriation, dilution or other violation.

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(g) As of the date hereof, there has been no unauthorized theft, reverse engineering, decompiling, disassembling, or other unauthorized disclosure of or access to any Source Code for any Purchased Asset.

(h) No Open Source Software is or has been used by Intellergy in the development of or incorporated into, combined with, linked with, distributed with, provided to any person or entity as a service, provided via a network as a service or application, or otherwise made available with, any Purchased Asset.

(i) Intellergy has not used any Open Source Materials in a manner that does, will or would reasonably be expected to, require the:

(i) disclosure or distribution of any Purchased Asset in Source Code form;

(ii) licence or other provision of any Purchased Asset on a royalty-free basis; or

(iii) grant of any patent licence, non-assertion covenant or other rights under any Intellectual Property or rights to modify, make derivative works based on, decompile, disassemble, or reverse engineer any Purchased Asset.

(j) All Services and Purchased Assets:

(i) comply with all applicable Laws and industry standards, including with respect to security; and

(ii) conform to all applicable contractual commitments, express and implied conditions and warranties (to the extent not subject to legally effective express exclusions thereof), representations and claims in packaging, labeling, advertising and marketing materials, and applicable specifications, user manuals, training materials, and other documentation.

(k) None of the Purchased Assets contain any bug, defect, or error that materially adversely affects, or could reasonably be expected to materially adversely affect, the value, functionality, or performance of such Purchased Asset.

(l) The Purchased Assets are reasonably sufficient for the immediate and anticipated needs of Greenwave, including as to capacity, scalability, and ability to process current and anticipated peak volumes in a timely manner.

(m) The Purchased Assets are in sufficiently good working condition to perform all information technology operations and include sufficient licensed capacity (whether in terms of authorized sites, units, users, seats, or otherwise) for all Software.

(n) In the last three (3) years, there has been no unauthorized access, use, intrusion, or breach of security, or failure, breakdown, performance reduction, or other adverse event affecting any Purchased Asset, that has caused or could reasonably be expected to cause any:

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(i) substantial disruption of or interruption in or to the use of such Purchased Asset;

(ii) loss, destruction, damage, or harm of or to the business of Intellergy or its operations, personnel, property, or other assets; or

(iii) liability of any kind to the business of Intellergy.

(o) Intellergy has taken all reasonable actions, consistent with applicable industry best practices, to protect the integrity and security of the Purchased Assets and the data and other information stored thereon.

(p) Intellergy maintains commercially reasonable back-up and data recovery, disaster recovery and business continuity plans, procedures and facilities, acts in material compliance therewith, and tests such plans and procedures on a regular basis, and such plans and procedures have been proven effective in all material respects upon such testing.

Section 6.07 Compliance With Laws. Intellergy has complied, and is now complying, with all applicable federal, state, provincial, territorial and local laws and regulations applicable to ownership, creation and use of the Purchased Assets.

Section 6.08 Legal Proceedings. There is no claim, action, suit, proceeding or governmental investigation (each, an "**Action**") of any nature pending or, to Intellergy's Knowledge, threatened against or by Intellergy:

(a) relating to or affecting the Purchased Assets; or

(b) that challenges or seek to prevent, enjoin or otherwise delay the transactions contemplated by this Agreement.

No event has occurred or circumstances exist that may give rise to, or serve as a basis for, any such Action.

Section 6.09 Brokers. No broker, finder or investment banker is entitled to any brokerage, finder's or other fee or commission in connection with the transactions contemplated by this Agreement based upon arrangements made by or on behalf of Intellergy.

Section 6.10 Full Disclosure. No representation or warranty by Intellergy in this Agreement and no statement contained in the Schedules to this Agreement or any certificate or other document furnished or to be furnished to Greenwave under this Agreement contains any untrue statement of a material fact, or omits to state a material fact necessary to make the statements contained therein, in light of the circumstances in which they are made, not misleading.

ARTICLE VII
Representations and Warranties of Greenwave

Greenwave represents and warrants to Intellergy that the statements contained in this Article VII are true and correct as of the date hereof. For the purposes of this Article VII, "Greenwave's Knowledge" and any similar phrases shall mean the actual or constructive knowledge of any director or officer of Greenwave, after due inquiry.

Section 7.01 Incorporation and Authority of Greenwave; Enforceability.

(a) Greenwave is a corporation incorporated and validly existing under the laws of the Province of Saskatchewan.

(b) Greenwave has the corporate power and capacity to enter into this Agreement and the documents to be delivered hereunder, to carry out its obligations hereunder and to consummate the transactions contemplated hereby.

(c) The execution, delivery and performance by Greenwave of this Agreement and the documents to be delivered hereunder and the consummation of the transactions hereby have been duly authorized by all requisite corporate action on the part of Greenwave.

(d) This Agreement and the documents to be delivered hereunder have been duly executed and delivered by Greenwave, and (assuming due authorization, execution and delivery by Intellergy) this Agreement and the documents to be delivered hereunder constitute legal, valid and binding obligations of Greenwave enforceable against Greenwave in accordance with their respective terms.

Section 7.02 No Conflicts; Consents. The execution, delivery and performance by Greenwave of this Agreement and the documents to be delivered hereunder, and the consummation of the transactions contemplated hereby, do not and will not:

(a) violate or conflict with the articles of incorporation, by-laws or any unanimous shareholder agreement of Greenwave; or

(b) violate or conflict with or result any judgment, order, decree, statute, law, ordinance, rule or regulation applicable to Greenwave.

No consent, approval, waiver or authorization is required to be obtained by Greenwave from any person or entity (including any governmental authority) in connection with the execution, delivery and performance by Greenwave of this Agreement and the consummation of the transactions contemplated hereby.

Section 7.03 Legal Proceedings. There is no Action of any nature pending or, to Greenwave's Knowledge, threatened against or by Greenwave that challenges or seeks to prevent, enjoin or otherwise delay the transactions contemplated by this Agreement. No event has occurred or circumstances exist that may give rise to, or serve as a basis for, any such Action.

Section 7.04 Brokers. No broker, finder or investment banker is entitled to any brokerage, finder's or other fee or commission in connection with the transactions contemplated by this Agreement based upon arrangements made by or on behalf of Greenwave.

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Section 7.05 Investment Canada Act. Greenwave is not a "non-Canadian" within the meaning of the *Investment Canada Act*.

ARTICLE VIII
Covenants

Section 8.01 Public Announcements. Unless otherwise required by applicable law, neither party shall make any public announcements regarding this Agreement or the transactions contemplated hereby without the prior written consent of the other party (which consent shall not be unreasonably withheld or delayed).

Section 8.02 Further Assurances. Each of the parties hereto shall execute and deliver such additional documents, instruments, conveyances and assurances and take such further actions as may be reasonably required to carry out the provisions hereof and give effect to the transactions contemplated by this Agreement and the documents to be delivered hereunder.

ARTICLE IX
Confidential Information

Section 9.01 Confidential Information. For purposes of this Agreement "Confidential Information" means confidential and proprietary information relating to each party's business operations, products, designs, business plans, strategies, business opportunities, finances, research, development, technical information, intellectual property, know-how and personnel, historical financial statements, financial projections and budgets, historical and projected sales, capital spending budgets and plans, personnel training techniques and materials, the names and addresses of the customers and suppliers and their particular business requirements and the names and addresses of employees. Each party acknowledges and agrees that, the disclosure of any of Confidential Information to competitors of each party and their successors and assigns (collectively, the "Protected Parties") or to the general public, or the unauthorized use of any Confidential Information by either party, would be highly detrimental to the best interests of the Protected Parties. Each party further acknowledges and agrees that the right to maintain confidential the Confidential Information constitutes a proprietary right which the Protected Parties are entitled to protect. Accordingly, each party covenants and agrees that they shall not, directly or indirectly, disclose any Confidential Information to any person or entity, or in any way make use of any Confidential Information in any manner except as reasonably required for the purposes of this Agreement. Without limiting the generality of the foregoing, at all times during the term of this Agreement and for a period of three (3) years subsequent to the termination or expiry of this Agreement, no party will use or take advantage of the Confidential Information for the purpose of creating, maintaining or marketing or aiding in the creation, maintenance or marketing of any product or service which is competitive with any product or service developed, owned, licensed, sold, performed or marketed by the other party. Without limiting the generality of the foregoing, Intellergy acknowledges and agrees that confidential and proprietary information relating to the Purchased Assets shall constitute Confidential Information of Greenwave and Intellergy further agrees that it shall not reverse engineer, disassemble, decompile or design around any such Confidential Information relating to the Purchased Assets except as reasonably required for the purposes of providing the Services.

Confidential Information does not include any information or data which (i) is or becomes publicly known without breach of this Agreement or in the case of Confidential Information relating to the Purchased Assets is released by Greenwave to the general public, (ii) is approved in writing for disclosure by both Parties without restriction by a duly authorized officer of the Parties, (iii) is independently developed by a party without reference to any Confidential Information provided by the other party, (iv) becomes known from a source other than the other Party without breach of this Agreement, or (v) is required by law to be disclosed, provided that prior written notice of such disclosure requirement is given and the other party has had an opportunity to make such disclosure subject to a protective order or confidentiality agreement. Nothing herein restricts Greenwave from using and releasing any Confidential Information relating to the Purchased Assets.

Section 9.02 Non- Disclosure. Each of the parties hereby covenants and agrees not to disclose any Confidential Information to any third party, except to those of its employees, agents or subcontractors who have a need-to-know such information, and then only to the extent necessary to perform under this Agreement. Each party shall maintain the confidentiality of the Confidential Information in its possession by exercising the same security measures it normally exercises with respect to its own confidential information. To this end, each party agrees to take appropriate action by way of instruction or agreement with its employees, consultants or other agents who are permitted access to Confidential Information, to ensure that such employees, consultants and other agents understand the confidentiality and non-disclosure obligations hereunder.

Section 9.03 Non-Solicitation. Intellergy hereby covenants and agrees that it, its directors, officers, shareholders and the Consultants, will not, during the at any time during the period commencing on the date hereof and ending one (1) year after the later of the termination or expiration of this Agreement or of the termination or expiration of each of the Consulting Agreements (the "**Restrictive Period**"), directly or indirectly, in any capacity whatsoever, alone or in association with any other person or entity, or as employee, consultant, contractor, partner, principal, agent, proprietor, officer, director or stockholder of any other person or entity:

(a) solicit or aid in or abet the solicitation of any customers or clients of Greenwave;

(b) hire any employees of or consultants of or contractors of Greenwave; and/or

(c) solicit or induce or attempt to induce any persons who were employees of or consultants or contractors to Greenwave at the time of such termination or expiry or during the ninety (90) day period immediately preceding such termination or expiry, to terminate their employment, consulting agreement or contract for services with Greenwave.

Section 9.04 Non-Competition. Intellergy, its directors, officers and shareholders, shall not, directly or indirectly, at any time during the Restrictive Period own any interest in, provide financing or financial assistance to, operate, manage, control, participate in, consult with, advise, provide services to, sell products to, or in any other manner carry on, engage in or assist any business (whether individually or through or in association with any other person or entity) that develops, produces, distributes and sells products directly competitive with the business of Greenwave in Canada. Notwithstanding the foregoing restrictions, Intellergy, its directors, officers and shareholders may acquire securities of any entity (i) of a class or series that is traded on any

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stock exchange or over the counter if such securities represent not more than 5% of the issued and outstanding securities of such class or series, (ii) of a mutual fund or other investment entity that invests in a portfolio the selection and management of which is not within the control of the investor, or (iii) held in a fully managed account where the investor does not direct or influence in any manner the selection of any investment in such securities.

Section 9.05 Non-Disparagement. During the Restrictive Period, Intellergy shall not say, do, or willingly permit to be said or done, anything that would be reasonably likely to cause prejudice, loss or injury to Greenwave or its employees, directors and officers.

Section 9.06 Return of Confidential Information. Upon the request of Greenwave, and in any event upon the termination or expiry of this Agreement, Intellergy will immediately return to Greenwave all materials, including all copies in whatever form, containing the Greenwave Confidential Information which are in the possession or control of Intellergy or which are in the possession or control of any persons for whom Intellergy is legally responsible.

ARTICLE X
Termination

Section 10.01 Termination. Either party may terminate this Agreement for cause if:

(a) the other party is in default of any of its material obligations hereunder and such default is not remedied within thirty (30) days of the date of receipt of written notice thereof; or

(b) the other party ceases to conduct business in the normal course; the other party becomes insolvent or bankrupt; the other party makes any assignment for the benefit of creditors; proceedings are instituted by or against the other party seeking relief, reorganization or rearrangement under any laws relating to insolvency; a receiver, liquidator or trustee is appointed in respect of any property or assets of the other party; or an order is made for the liquidation, dissolution or winding up of the other party.

Any termination of this Agreement does not affect Greenwave's right, title and interest in and to any Purchased Assets delivered to Greenwave prior to termination.

Section 10.02 Set-Off. Intellergy acknowledges and agrees that, without limiting the rights and remedies otherwise available to Greenwave, if at any time Intellergy or a Consultant is in material breach of any of the terms of this Agreement or a Consulting Agreement, Greenwave may withhold payment of any amounts payable to Intellergy hereunder.

Dispute Resolution. The parties desire to resolve disputes arising out of this Agreement without litigation. Accordingly, except for an action seeking a temporary restraining order or injunction related to the purposes of this Agreement or an action to compel compliance with this dispute resolution process, the parties agree to use the following alternative dispute resolution procedures as their sole remedy with respect to any controversy or claim arising out of or relating to this Agreement or its breach: at the written request of a party, each party will appoint a knowledgeable, responsible representative to meet and negotiate in good faith to resolve any dispute arising under

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this Agreement. The parties intend that these negotiations be conducted by non-lawyer, business representatives. The location, format, frequency, and conclusion of these discussions shall be left to the discretion of the representatives. Upon agreement, the representatives may utilize other alternative dispute resolution procedures such as mediation to assist in the negotiations. Discussions and correspondence among the representatives for purposes of these negotiations shall be treated as confidential information developed for purposes of settlement, exempt from discovery and production and shall not be admissible in any lawsuit or action without the concurrence of all parties. Documents identified in or provided with such communications that are not prepared for purposes of the negotiations are not so exempted and may, if otherwise admissible, be admitted in evidence in any lawsuit or action. If the negotiations do not resolve the dispute within sixty (60) calendar days of the initial written request, each party retains and reserves all its rights under applicable laws. In the event that litigation results, the substantially prevailing party, in addition to any and all other rights and remedies obtained, shall be entitled to recover from the other party reasonable attorneys' fees and costs incurred in such litigation. In the interest of obtaining, by way of the dispute resolution procedures required hereby, a speedier and less costly resolution of any controversy, dispute, or claim between the parties, the parties hereby irrevocably waive the right to trial by jury, even if such right is specifically provided by statute. A party may bring no action or demand for dispute resolution arising out of this Agreement more than one (1) year after the cause of action has accrued, and the parties waive the right to invoke any different limitation on the bringing of actions under provincial, state, or federal law.

ARTICLE XI
Indemnification

Section 11.01 Survival. All representations, warranties, covenants and agreements contained herein and all related rights to indemnification shall survive the termination or expiration of this Agreement.

Section 11.02 Indemnification by Intellergy. Subject to the other terms and conditions of this Article XI, Intellergy shall defend, indemnify and hold harmless Greenwave, its affiliates and their respective shareholders, directors, officers and employees from and against all claims, judgments, damages, liabilities, settlements, losses, costs and expenses, including legal fees, disbursements and charges, arising from or relating to:

(a) any inaccuracy in or breach of any of the representations or warranties of Intellergy contained in this Agreement or any document to be delivered hereunder; or

(b) any breach or non-fulfillment of any covenant, agreement or obligation to be performed by Intellergy under this Agreement or any document to be delivered hereunder; or

(c) any liabilities or other claims or obligations respecting the Purchased Assets which arose prior to the date hereof; or

(d) any claim by any person or entity alleging that Intellergy's use of the Purchased Assets infringes the Intellectual Property rights of such person or entity.

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Section 11.03 Indemnification By Greenwave. Subject to the other terms and conditions of this Article XI, Greenwave shall defend, indemnify and hold harmless Intellergy, its affiliates and their respective shareholders, directors, officers and employees from and against all claims, judgments, damages, liabilities, settlements, losses, costs and expenses, including legal fees, disbursements and charges, arising from or relating to:

(a) any inaccuracy in, or breach of, any of the representations or warranties of Greenwave set out in this Agreement or in any document to be delivered hereunder; or

(b) any breach or non-fulfillment of any covenant, agreement or obligation to be performed by Greenwave under this Agreement or any document to be delivered hereunder.

Section 11.04 Indemnification Procedures.

(a) Whenever any claim shall arise for indemnification hereunder, the party entitled to indemnification (the "**Indemnified Party**") shall promptly provide written notice of such claim to the other party (the "**Indemnifying Party**").

(b) In connection with any claim giving rise to indemnify hereunder resulting from or arising out of any Action by a person or entity who is not a party to this Agreement, the Indemnifying Party, at its sole cost and expense and upon written notice to the Indemnified Party, may assume the defence of any such Action with counsel reasonably satisfactory to the Indemnified Party.

(c) The Indemnified Party shall be entitled to participate in the defence of any such Action with its counsel and at its own cost and expense.

(d) If the Indemnifying Party does not assume the defence of any such Action, the Indemnified Party may, but shall not be obligated to, defend against such Action in such manner as it may deem appropriate, including, but not limited to, settling such Action, after giving notice of it to the Indemnifying Party, on such terms as the Indemnified Party may deem appropriate and no action taken by the Indemnified Party in accordance with such defence and settlement shall relieve the Indemnifying Party of its indemnification obligations herein provided with respect to damages resulting therefrom.

(e) The Indemnifying Party shall not settle an Action without the Indemnified Party's prior written consent (which consent shall not be unreasonably withheld or delayed).

Section 11.05 Effect of Investigation. Greenwave's right to indemnification or other remedy based on the representations, warranties, covenants and agreements of Intellergy set forth herein will not be affected by any investigation conducted by Greenwave, or any knowledge acquired by Greenwave at any time, with respect to the accuracy or inaccuracy of, or compliance with, any such representation, warranty, covenant or agreement.

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Section 11.06 Cumulative Remedies. The rights and remedies provided in this Article XI are cumulative and are in addition to, and not in substitution for, any other rights and remedies available at law or in equity or otherwise.

ARTICLE XII
Miscellaneous

Section 12.01 Expenses. All costs and expenses incurred in connection with this Agreement and the transactions contemplated hereby shall be paid by the party incurring such costs and expenses.

Section 12.02 Notices. All notices, requests, consents, claims, demands, waivers and other communications hereunder shall be in writing and shall be deemed to have been given:

(a) when delivered by hand (with written confirmation of receipt);

(b) when received by the addressee if sent by a nationally recognized overnight courier (receipt requested);

(c) on the date sent by facsimile or email of a PDF document (with confirmation of transmission) if sent during normal business hours of the recipient, and on the next business day if sent after normal business hours of the recipient; or

(d) on the third day after the date mailed, by certified or registered mail, return receipt requested, postage prepaid.

Such communications must be sent to the respective parties at the following addresses (or at such other address for a party as shall be specified in a notice given in accordance with this Section 12.02):

If to Intellergy:	124 Main Street PO Box 1747 Bucksport ME 04416	
	Facsimile:	207-669-8306
	Email:	carsten@intellergy.net
	Attention:	CEO
If to Greenwave:	Unit B- 649 Solomon Crescent Regina, SK S4N 6H9	
	Email:	dean@greenwaveinnovations.ca
	Attention:	Dean Clark, Chairman and CEO
with a copy to:	McKercher LLP 800-1801 Hamilton Street Regina, SK S4P 4B4	
	Facsimile:	306-565-6565
	Email:	p.warsaba@mckercher.ca
	Attention:	Patricia J. F. Warsaba, Q.C.

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Section 12.03 Headings. The headings in this Agreement are for reference only and shall not affect the interpretation of this Agreement.

Section 12.04 Severability. If any term or provision of this Agreement is invalid, illegal or unenforceable in any jurisdiction, such invalidity, illegality or unenforceability shall not affect any other term or provision of this Agreement or invalidate or render unenforceable such term or provision in any other jurisdiction.

Section 12.05 Entire Agreement. This Agreement and the documents to be delivered hereunder constitute the sole and entire agreement of the parties to this Agreement with respect to the subject matter contained herein and therein, and supersede all prior and contemporaneous understandings and agreements, both written and oral, with respect to such subject matter. In the event of any inconsistency between the statements in the body of this Agreement and documents to be delivered hereunder, or the Schedules (other than an exception expressly set forth as such in Schedule), the statements in the body of this Agreement will control.

Section 12.06 Successors and Assigns. This Agreement shall be binding upon and shall enure to the benefit of the parties hereto and their respective successors and permitted assigns. Neither party may assign its rights or obligations hereunder without the prior written consent of the other party, which consent shall not be unreasonably withheld or delayed. No assignment shall relieve the assigning party of any of its obligations hereunder.

Section 12.07 No Third-Party Beneficiaries. Except as provided in Article XI, this Agreement is for the sole benefit of the parties hereto and their respective successors and permitted assigns and nothing herein, express or implied, is intended to or shall confer upon any other person or entity any legal or equitable right, benefit or remedy of any nature whatsoever under or by reason of this Agreement.

Section 12.08 Amendment and Modification. This Agreement may only be amended, modified or supplemented by an agreement in writing signed by each party hereto.

Section 12.09 Waiver. No waiver by any party of any of the provisions hereof shall be effective unless explicitly set forth in writing and signed by the party so waiving. No waiver by any party shall operate or be construed as a waiver in respect of any failure, breach or default not expressly identified by such written waiver, whether of a similar or different character, and whether occurring before or after that waiver. No failure to exercise, or delay in exercising, any right, remedy, power or privilege arising from this Agreement shall operate or be construed as a waiver thereof; nor shall any single or partial exercise of any right, remedy, power or privilege hereunder preclude any other or further exercise thereof or the exercise of any other right, remedy, power or privilege.

Section 12.10 No Partnership. This Agreement shall not be construed to create any association, partnership, joint venture, employee or agency relationship between Intellergy and Greenwave for any purpose.

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Section 12.11 Governing Law. This Agreement shall be governed by and construed in accordance with the laws of the Province of Saskatchewan and the federal laws of Canada applicable therein.

Section 12.12 Forum Selection. Any action or proceeding arising out of or based upon this Agreement or the transactions contemplated hereby may be brought in the courts of Province of Saskatchewan, and each party irrevocably submits and agrees to attorn to the exclusive jurisdiction of such courts in any such action or proceeding.

Section 12.13 Time. Time shall be of the essence of this Agreement.

Section 12.14 Specific Performance. The parties agree that irreparable damage would occur if any provision of this Agreement were not performed in accordance with the terms hereof and that the parties shall be entitled to specific performance of the terms hereof, in addition to any other remedy to which they are entitled at law or in equity.

Section 12.15 Counterparts. This Agreement may be executed in counterparts, each of which shall be deemed an original, but all of which together shall be deemed to be one and the same agreement. A signed copy of this Agreement delivered by facsimile, email or other means of electronic transmission (including e-signature software such as DocuSign or Adobe Sign) shall be deemed to have the same legal effect as delivery of an original signed copy of this Agreement.

[***REMAINDER OF PAGE LEFT INTENTIONALLY BLANK. SIGNATURE PAGE FOLLOWS***]

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IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed as of the date first written above by their respective officers thereunto duly authorized.

INTELLERGY, INC.

Per: _____

Name: Carsten M. Steenberg

Position: CEO

I have authority to bind the corporation

GREENWAVE INNOVATIONS INC.

Per: _____

Name: Dean Clark

Position: President

I have authority to bind the corporation

Schedule "A"
Purchased Assets

Hardware

- This deal gives Greenwave ownership of all the Hardware products (8 products in total) The Hardware products are:
  - **inGate commercial-grade gateway**
  - **inControl**
  - **inDAC Sensor controller**
  - **inBridge Wireless ModBus bridge connetion tool**
  - **inSense Wireless Temp & RH SensorinDAC Sensor controller**
  - **inSense Relative Humidity & Temp Sensor**
  - **inSense VOC Relative Humidity & Temperature Sensor**
  - **inSense CO2, Relative Humidity and Temperature Sensor**
- All hardware will be re-brand as Greenwave
- Includes all the product design, technical drawings, diagrams, Gerber files and BOM / parts list for each of the 8 mentioned devices.
- Includes the manufacturer's commitment for production under the Greenwave brand
- Devices collect & feed data via the gateway to the cloud from own & 3rd party sensors and meters.
- Control devices that can be used to control our client's equipment (i.e. HVAC, Lighting & more).

Software

This deal gives Greenwave ownership of the following Software platform:

- InView Professional Software core platform (Greenwave BEMS)
- The software is critical to develop the Greenwave IP. All hardware will interface through the inGate to provide data and communicate with the cloud.
- This software platform will soon (according the milestones) receive data from the AccuEnergy AcuRev 2100 device.
- GreenWave will have access to the full source code for said platform – Source code will reside on the Greenwave servers.

Patent

This deal gives Greenwave ownership of the following patent:

- US Patent United States Patent 10,489,716 Method for performing automated analysis of sensor data time series.

Inventory

This deal gives Greenwave ownership of the following Hardware Inventory:

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Intellergy/PowerWise for GreenWave 3/4/2021			
Product Name	*Qty.*	*Value*	*Purchase cost*
Chameleon 2.0 Programmable Web Server, Zigbee	50	$11,900.00	$5,129.00
Chameleon 2.0 I/O Control, Zigbee	5	$1,143.00	$522.45
Wireless inSense Relative Humidity and Temperature	5	$495.00	$281.60
600A CT - 2.00" - Split Core	2	$114.00	$96.00
inSense Relative Humidity/Temp	1	$90.00	$44.31
WattNode - 208/120	2	$900.00	$449.28
400A CT - 2.00" Window	1	$70.00	$53.09
inSense C02, RH, Temp	5	$1,975.00	$947.85
inSense VOC, RH, Temp	4	$1,160.00	$377.32
50A CT - 0.75" - Split Core	3	$141.00	$87.00
50A AAC - VDC Split Core	4	$208.00	$128.00
10A AAC - VDC Split Core	2	$104.00	$64.00
1-Wire Temperature Sensor	5	$100.00	$17.40
50A CT - 0.35" - LCF Split Core	1	$49.00	$34.00
50A CT - 0.35"	2	$90.00	$77.92
inDac/InGate Power Supply - 12VDC (18W)	50	$750.00	$412.50
200A CT - 0.78"	1	$47.00	$32.46
400A CT - 1.25" - Split Core	5	$300.00	$165.00
600A CT - 1.25" - Split Core	18	$1,080.00	$594.00
400A CT - 2.00" - Split Core	2	$120.00	$96.00
150A CT - 0.78" - Revenue Grade	1	$65.00	$41.97
PowerWise Sensor Hub	5	$985.00	$250.00
Sensor Hub Power Supply - 12VDC (12W)	5	$50.00	$24.75
300A CT - single	9	$855.00	$522.00
PowerWise ZigBeeThermostat	5	$1,375.00	$575.00
	193		
	TOTAL	**$24,166.00**	**$11,022.90**

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Carsten M. Steenberg
CEO/Intellergy, Inc.

7/1/2021

Schedule "B"

Description of Services, payment milestones and completion dates

Payment Amount	Payment Event	Completion Date
$36,657	Core database and code to Greenwave servers	June 30, 2021
$24,438	Casino Regina consumption data delivered and maintained on Greenwave server	July 31, 2021
$36,657	Energy Performance Reports (Priority 1)	September 30, 2021
$36,657	Energy Performance Reports (Priority 2)	November 30, 2021
$24,438	BMS Integration with Conditional Alarming	January 31, 2022
$24,438	BMS Integration with Equipment Predictive Maintenance	January 31, 2022
$61,095	Hardware purchase and inventory acquisition	March 31, 2022

** As noted in main portion of contract, all funds shown above are in Canadian Dollars

United States Patent **10,489,716**
Meadow **November 26, 2019**

Method for performing automated analysis of sensor data time series

Abstract

A method using a fast algorithm automated analysis of time series sensor data that can find an optimal clustering value k for k-means analysis by using statistical analysis of the results of clustering for a stated maximal upper value of k.

Inventors: **Meadow; Curtis** (Newport, ME)

Applicant:

Name	City	State	Country	Type
Meadow; Curtis	Newport	ME	US	

Assignee: **Intellergy, Inc.** (Penobscot, ME)

Family ID: **60910907**
Appl. No.: **15/206,165**
Filed: **July 8, 2016**

Prior Publication Data

Document Identifier	Publication Date
US 20180012132 A1	Jan 11, 2018

Current U.S. Class: **1/1**
Current CPC Class: G06N 7/005 (20130101)
Current International Class: G06N 7/00 (20060101)
Field of Search: ;706/15,45

References Cited [Referenced By]

U.S. Patent Documents

10410135	September 2019	Shumpert
2013/0096835	April 2013	Chok

2016/0342903 November 2016 Shumpert

Primary Examiner: Vincent; David R
Attorney, Agent or Firm: Pellegrini; Anthony D.

Claims

I claim:

1. In a system comprising a piece of equipment with one or more sensors installed thereon, said one or more sensors capable of obtaining data relevant to the operation of said equipment and capable of forwarding said data to a computing device, said computing device capable of populating a database with said data and of performing calculations on data contained therein, a method comprising the following steps: A1. Obtain multiple data points from the one or more sensors over regular intervals for a fixed period of time, whereby each data point is a value reported by said one or more sensors attached to said equipment; A2. Store data points in said computer readable database; A3. Perform an initial cluster analysis on the set of stored data points to obtain a maximum of N clusters for some N which is larger than an expected optimal number of clusters (designated "k"); A4. Reject false clusters containing only two members when such clusters are identifiable as an anomaly caused by the one or more sensors; A5. Calculate cluster centroids (mean values) for each non-rejected cluster; A6. Store non-rejected clusters and their corresponding centroids in said computer readable database; B1. Build a vector of input values from each of the stored cluster centroids from the set of clusterings, whereby the input is a set of clustering obtained by repeating Steps A1-A4 one or more times; B2. Compute all possible clusterings from 1 to N-1 using said vector of input values and for each said clustering compute a distortion function; B3. Select as k the optimal clustering that produces the largest difference in the distortion function; B4. Store the optimal clustering in the database together with means, standard deviations, number of members, and pre-computed confidence interval values; C1. Take the clustering from Step B4 and test for overlapping confidence intervals and compute the pooled standard deviations, yielding a single clustering that represents a set of operating states for the equipment, said clustering having discrete boundaries given by confidence intervals; C2. Using a series of sensor measurements over time, test each measurement to see which operating state it represents, corresponding to cluster 0 through k, building a chain of operating states over time; C3. Traverse the chain of operating states to yield a set of state transitions as well as the count, mean, and standard deviation of the time spent in each state; C4. Using the set of state transitions, construct a transition matrix that gives the probability of changing to state Y, given any state X; C5. Apply an equipment specific set of criteria based on the state counts and/or duration and the transition probabilities whereby states with low duration and relatively equal transition probabilities indicate the removal of transitional or spurious operating states caused by anomalies of the measurement sensor or known properties of the equipment; and C6. Store the final set of operating states in a database table and use same to provide information to an end-user or to alert the end-user to conditions requiring human attention.

2. The method of claim 1 wherein Step A1 involves one sensor reading per minute.

3. The method of claim 1 wherein Step A3 involves performing the initial cluster analysis over a period of multiple days.

4. The method of claim 1 wherein Step A3 involves performing the initial cluster analysis over a period ranging from 5 days to 90 days.

5. The method of claim 1 wherein Step A3 involves choosing initial cluster seeds from a mean set of previous clusterings.

6. The method of claim 1 wherein Step A3 involves developing initial cluster seeds by applying a k-means++ algorithm.

7. The method of claim 1 wherein Step B1 further involves computing pooled variance when the centroids represent distributions rather than single observations.

8. The method of claim 1 wherein the distortion function computed in Step B2 is the distortion function defined by Sugar and James.

9. The method of claim 1 further comprising the following step: B3A. If the optimal clustering contains only two members, as determined using a threshold test of the coefficient of variability, reject said clustering and repeat Step B3, whereby Step B3A follows Step B3.

10. The method of claim 1 wherein clusters are collapsed in Step C1 if necessary.

11. In a system comprising a piece of equipment with one or more sensors installed thereon, said one or more sensors capable of obtaining data relevant to the operation of said equipment and capable of forwarding said data to a computing device, said computing device capable of populating a database with said data and of performing calculations on data contained therein, a method comprising the following steps: A1. Obtain multiple data points from the one or more sensors over regular intervals for a fixed period of time, whereby each data point is a value reported by said one or more sensors attached to said equipment, with one sensor reading per minute; A2. Store data points in said computer readable database; A3. Perform an initial cluster analysis on the set of stored data points over a period of multiple days ranging from 5 to 90 to obtain a maximum of N clusters for some N which is larger than an expected optimal number of clusters (designated "k"), whereby initial cluster seeds are chosen from the mean set of previous clusterings if such exist, or if previous clusterings do not exist the initial cluster seeds are developed by applying a k-means++ algorithm; A4. Reject false clusters containing only two members when such clusters are identifiable as an anomaly caused by the corresponding sensor; A5. Calculate cluster centroids (mean values) for each non-rejected cluster; A6. Store non-rejected clusters and their corresponding centroids in said computer readable database; B1. Build a vector of input values from each of the stored cluster centroids (mean values) from the set of clusterings, whereby the input is a set of clustering obtained by repeating Steps A1-A4 one or more times, computing pooled variance where necessary; B2. Compute all possible clusterings from 1 to N-1 using said vector of input values and for each said clustering compute a distortion function; B3. Select as k the optimal clustering that produces the largest difference in the distortion function; B4. If the optimal clustering contains only two members, as determined using a threshold test of the coefficient of variability, reject said clustering and repeat Step B3; B5. Store the optimal clustering in the database together with means, standard deviations, number of members, and pre-computed confidence interval values; C1. Take the clustering from Step B5 and test for overlapping confidence intervals, collapsing clusters if necessary, and compute the pooled standard deviations, yielding a single clustering that represents a set of operating states for the equipment, said clustering having discrete boundaries given by confidence intervals; C2. Using a series of sensor measurements over time, test each measurement to see which operating state it represents, corresponding to cluster 0 through k, building a chain of operating states over time; C3. Traverse the chain of operating states to yield a set of state transitions as well as the count, mean, and standard deviation of the time spent in each state; C4. Using the set of state transitions, construct a transition matrix that gives the probability of changing to state Y, given any state X; C5. Apply an equipment specific set of criteria based on the state counts and/or duration and the transition probabilities whereby states with low duration and relatively equal transition probabilities indicate the removal of transitional or spurious operating states caused by anomalies of the measurement sensor or known properties of the equipment; and C6. Store the final set of operating states in a database table and use same to provide information to an end-user or to alert the end-user to conditions requiring human attention.

12. In a system monitoring a number of pieces of equipment with one or more sensors installed thereon, with some of said pieces of equipment of a known type and other of said pieces of equipment of an unknown type, a method for performing operating state analysis to tentatively identify said equipment of unknown types, said method comprising the following steps: A1. Obtain multiple data points from the one or more sensors over regular intervals for a fixed period of time, whereby each data point is a value reported by said one or more sensors attached to said equipment; A2. Store data points in said computer readable database; A3. Perform an initial cluster analysis on the set of stored data points to obtain a maximum of N clusters for some N which is

larger than an expected optimal number of clusters (designated "k"); A4. Reject false clusters containing only two members when such clusters are identifiable as an anomaly caused by the one or more sensors; A5. Calculate cluster centroids (mean values) for each non-rejected cluster; A6. Store non-rejected clusters and their corresponding centroids in said computer readable database; B1. Build a vector of input values from each of the stored cluster centroids from the set of clusterings, whereby the input is a set of clustering obtained by repeating Steps A1-A4 one or more times; B2. Compute all possible clusterings from 1 to N-1 using said vector of input values and for each said clustering compute a distortion function; B3. Select as k the optimal clustering that produces the largest difference in the distortion function; B4. Store the optimal clustering in the database together with means, standard deviations, number of members, and pre-computed confidence interval values; C1. Take the clustering from Step B4 and test for overlapping confidence intervals and compute the pooled standard deviations, yielding a single clustering that represents a set of operating states for the equipment, said clustering having discrete boundaries given by confidence intervals; C2. Using a series of sensor measurements over time, test each measurement to see which operating state it represents, corresponding to cluster 0 through k, building a chain of operating states over time; C3. Traverse the chain of operating states to yield a set of state transitions as well as the count, mean, and standard deviation of the time spent in each state; C4. Using the set of state transitions, construct a transition matrix that gives the probability of changing to state Y, given any state X; C5. Apply an equipment specific set of criteria based on the state counts and/or duration and the transition probabilities whereby states with low duration and relatively equal transition probabilities indicate the removal of transitional or spurious operating states caused by anomalies of the measurement sensor or known properties of the equipment; C6. Store the final set of operating states in a database table; D1. Use stored operating state analyses over a period of time for each piece of equipment, performing a four dimensional optimal cluster analysis on the operating state analyses of known equipment with similar sensors, using the following dimensions: number of operating states, mean duration of each operating state, relative amplitude of each operating state, and distance between the state transition matrices; D2. Accept as valid types those clusters that have narrow confidence intervals in each dimension; D3. Compute the Euclidean distance in four dimensions between the operating state analyses of the unknown piece of equipment and the accepted clusters of equipment types; D4. If each dimension falls within the n % confidence intervals of each component of some cluster, then it can be accepted as belonging to that cluster; D5. If some dimensions match and others do not, the overall clustering can be repeated and if nothing changes except the one cluster containing the unknown equipment and that cluster continues to have acceptably narrow confidence intervals, then it can be accepted as belonging to that cluster; and D6. Otherwise the unknown piece of equipment is rejected as a member of any known type.

Description

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of provisional application, U.S. Ser. No. 62/190,317, filed Jul. 9, 2015, entitled METHOD FOR PERFORMING AUTOMATED ANALYSIS OF SENSOR DATA TIME SERIES, by Curtis Meadow, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to a method comprising, in one embodiment, an ultra-fast software-based algorithm operating on high volumes of real time data to find patterns that may indicate improper equipment activity. It can be used for other purposes including, but not limited to, monitoring of time spent in a running state in order to indicate when maintenance is due; analyzing operating efficiency over time; and finding ways to operate equipment more efficiently.

2. Description of Prior Art

Data is gathered in real time with regard to the operation of a piece of equipment, such as a refrigeration unit. The data can be any meaningful metric corresponding to the proper activity of the equipment, for example, electricity usage during each predetermined time period. Over time, a large amount of data is gathered corresponding to the equipment's activities, and the data is stored in an electronic database accessible by a computer. Patterns emerge from the data. By analyzing the data using computer software and comparing the patterns against known norms, the activity of the equipment can be determined to be within proper usage metrics or outside of those metrics, thereby requiring attention. Such pattern recognition over large volumes of data, however, is very costly in terms of necessary computer resources, and is thus impractical for widespread use.

There is thus demonstrated the need for a method for analyzing large volumes of data for determining optimum activity for equipment use.

It is thus an object of the present invention to present a method for analyzing large volumes of data for determining optimum activity for equipment use.

It is a further object of the present invention to present a method that analyzes large volumes of data by incorporating k-means clustering.

It is yet a further object of the present invention to present a method that finds an optimal clustering that corresponds to operating states of the equipment.

It is yet a further object of the present invention to present a method that uses centroids from an initial, expensive clustering as proxies for data points.

It is yet a further object of the present invention to present a method that can be processed in a fraction of the time required to prepare the initial clustering.

Other objects of the present invention will be readily apparent from the description that follows.

SUMMARY OF THE INVENTION

The present invention overcomes the difficulty of analyzing large volumes of data by incorporating k-means clustering and finding an optimal clustering that corresponds to operating states of the equipment. Raw data is initially clustered using a standard, computationally-intensive algorithm and then the resulting clusters are used as proxies for the actual data points in finding a global optimal solution. K-means clustering is an NP-hard problem, meaning that it cannot be solved except by applying the brute force approach of trying every possible clustering for the number of clusters K. Heuristic algorithms such as Lloyd's Algorithm and k-means++ work well but they are nevertheless computationally expensive. There is considerable disagreement as to the upper complexity bound of heuristic k-means algorithms but there is general agreement that it is superpolynomial. Given the likely presence of exponential terms, it is clear there is an enormous difference in running time for values of n between around n of 50,000 and around n of 100. Regardless of the optimality metric used, any algorithm to find an optimal clustering with K or fewer clusters for a set of n elements, for example, requires K-1 times the computational time required to create the initial clustering. If n is large, this is very expensive. However, by using the centroids from an initial, expensive clustering as proxies for the data points, an approximation of an optimal clustering can be determined that may be processed in a fraction of the time of the initial clustering. This is because the problem size is reduced by several orders of magnitude.

The algorithms used assume that centroids are standard normal distributions, and known facts about the number of data points and the variance within each cluster are used to achieve the reclustering. The usage can be extended to clusters with other probability distribution types provided that the distribution type has certain statistical properties.

It is to be understood that the foregoing and following description of the invention is intended to be illustrative and exemplary rather than restrictive of the invention as claimed. These and other aspects, advantages, and

features of the invention will become apparent to those skilled in the art after review of the entire specification, accompanying figures, and claims incorporated herein.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow chart showing the method steps of one embodiment of the invention.

FIG. 2 is a table showing a transition probability matrix for a household refrigerator with an LED light bulb. Seven states are identified in the optimal clustering.

FIG. 3 is a table showing how the transition probability matrix shown in FIG. 2 is used to filter out transitional states.

FIG. 4 is a table showing the operating states of the refrigerator used in FIGS. 2 and 3 as identified by the operating state analysis, including 98% confidence intervals for each state.

FIG. 5 is a graph showing one day of normal operation of the refrigerator used in FIGS. 2 through 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

The present invention uses a fast algorithm for automated analysis of time series sensor data.

The algorithm was developed for electric circuit analysis but can easily be extended to other types of sensor data, including flow meters, temperature and weather data, air quality sensors, and so on.

In k-means clustering given a set of n data points in a d-dimensional space, the problem is to find a cluster of k points, called centroids, that minimize the mean squared distance from each data point to its nearest centroid. In practical terms, the problem is to determine clusters of observations that represent normal equipment operating states.

To analyze sensor data in terms of operating states one first needs to establish the optimal value for k; in other words, one needs to know how many operating states there are. In an arbitrary vector of sensor data the optimal number is unknown. Several heuristic optimality algorithms are known. One such method for establishing the optimal value of k is known as the"jump method" [See Sugar, C A and James, G H, "Finding the Number of Clusters in a Dataset: An Information-Theoretic Approach", Journal of the American Statistical Association, Vol. 98, No. 463 (September 2003).]

Each possible k-means clustering from 1 to N (where N is the maximum value of k) has to be computed before a heuristic optimality test can be applied. K-means clustering is computationally very expensive, as described above. The present invention utilizes a fast algorithm that can find an optimal clustering value k using statistical analysis of the results of clustering for a stated maximal upper bound of k. This analysis has been applied tractably to data sets as large as 120,000 observations. Given an optimal clustering, each centroid is treated as the mean value of an operating state. Thus valid confidence intervals are defined for upper and lower bounds of each state. A time series can then be analyzed for normal operation and means and confidence intervals for operating state duration can be derived, as well as transition matrices or Markov chains for operating state transitions.

For example, given a sensor that reports data each minute, over the course of one day 1440 data points are obtained, and over the course of 30 days, 43,200 points are obtained. By using the centroids from an initial clustering of the raw data into 12 clusters, the data set can be reduced to 12 points. There is clearly a risk that if the initial clustering is not very good (a risk of heuristic algorithms) then computing an optimal reclustering using the centroids may not be much better. For that reason a series of clusterings over time are used as inputs to a second stage calculation. One week of relatively expensive 30-day clusterings (computed daily) yields a maximum of 84 data points for k=12 in the daily clusterings.

This results in a highly effective body of data for determining incidence of abnormal operation. Abnormal operation for electrical equipment can occur when 1) operating wattage is outside the confidence intervals of all operating states, 2) there is a transition from state A to state B that does not occur during normal operation, 3) there is a chain of transitions with probability close to 0; or 4) duration of the state lies outside confidence intervals. For particular types of equipment, operating state analysis can be refined to deduce other information about the equipment, such as defrost cycles and compressor duty cycles for refrigerators. If the equipment type is known, then other patterns indicating abnormal operation can be detected. For example, it is possible to determine the number of daily defrost cycles in a refrigerator, or detect a problematic operating pattern called "short-cycling" in heating and cooling units.

The specifics of the algorithm and its implementation in the present invention are as follows:

The algorithm is based on certain known properties of the input dataset. In one embodiment it is designed for analysis of data reported by sensors attached to pieces of equipment, which could include data points describing electrical power consumption, temperatures, flow rates, and the like. An example of a type of equipment that produces data amenable to this clustering process is any type of refrigeration or cooling equipment. Electrical consumption and temperatures tend to follow predictable patterns. An example of a type of data that is not amenable to the clustering process is the determination of the number of clusters of galaxies in a set of astronomical data.

Properties of data sets that are amenable to the clustering algorithm are:

an optimal clustering must have a fairly small number of clusters (e.g., $n<12$ or $n<20$);

each cluster should represent a true Gaussian distribution, or some other distribution that meets certain statistical tests; and

data sets are repeated over time to yield a set of clusterings that can improve over time.

The algorithm as implemented relies on two other algorithms:

a standard k-means clustering algorithm; and

the Sugar and James "jump method" of determining an optimal clustering.

One of the issues in establishing optimality is that there is no objective measure of optimality. Such measures depend on the goal(s) of the cluster analysis. In the present case a goal is to minimize the variability within clusters (a fairly common goal) but also to minimize the number of clusters identified and avoid clusters with indistinct boundaries.

The jump method is used because it is an information theoretic approach based on rate distortion theory. The jump method selects a clustering that minimizes the distortion of the clustering. Rate distortion theory is widely applied in lossy compression algorithms such as jpeg compression. The k-means algorithm used here is also a form of lossy compression: cluster means are used as proxies for the points contained in the cluster.

Example of the Algorithm Applied to a Refrigeration Unit:

The algorithm has three stages. The input to the first stage is a set of one-minute interval sensor readings representing 30 days of minute data (43,200 points if fully populated). A simple, non-optimized clustering of this data is performed and the results are stored in a database. The second stage takes a set of clusterings over time from Stage 1 and computes an optimal clustering of this data.

Stage 1.

Input: a vector v of one-minute sensor readings representing 30 days of minute data (43,200 points if fully populated). Output: a (likely) non-optimal clustering which is stored in a database with the mean, standard deviation, and number of cluster members.

1. Perform an initial cluster analysis on the raw data, requesting a maximum of N clusters for some N which should be larger than the expected optimal value of k. In one example N=12. Given the nature of the problem domain it is conceivable that N could be as high as 20 or 25, depending on equipment type.

A global optimization prior to the application of the k-means algorithm is the removal of zero values, provided that 0 represents an "off" state for the equipment. While not essential to the process, it does provide an often significant empirical reduction in problem size. Whether it can be employed depends on the type of data being clustered; for example, it is appropriate for electrical data, but not for temperature data.

If a series of previous clusterings is available, initial cluster seeds are chosen from the means of centroids of a set of previous clusterings; otherwise, the kmeans++ algorithm is used to create non-random seeds for a "new" set of points.

2. Using the data from the initial analysis, compute descriptive statistics about the clusters: mean, standard deviation, and the number of members in each cluster.

If appropriate for the data type, small clusters containing only two or three data points are rejected at this time. Because sensor data (other than flows) is averaged from 1-second data over a period of one minute, some values may represent an intermediate state that is not a true operating state for the piece of equipment. For example, if a 2000 watt motor is switched on halfway through the minute, the value reported will be 1000 watts. Over a period of time, there will be several intermediate values that will tend to form distinct clusters but do not represent true operating states.

The reason for starting with a value for k that is higher than the expected optimal value is that clusters representing transitional states can be found and rejected.

Stage 2.

Compute optimal clustering. Input: a set of clusterings over a period of time, for example, for one week. Output: a single clustering that represents a set of operating states for the equipment. The single clustering will have discrete boundaries given by confidence intervals.

The initial clustering is computationally intensive because of the large number of points. To achieve optimal clustering, clusters that represent true operating states are identified, in human terms, so that the behavior of the equipment can be analyzed.

The clusters derived from the initial clustering are now treated as if they were the data points, and the cluster means is used to arrive at an "optimal" clustering. The problem size has been reduced from thousands of data points to some number that is 100 or lower. While the k-means algorithm is computationally expensive for large data sets, the problem has been reduced so far that it is now easy and fast to compute trial clusterings with k from 1 to N-1.

Using the cluster means as a proxy for the values that they represent is a form of lossy compression. It can work only if the clusters are true Gaussian distributions, something that can be empirically tested and verified. In theory it can also work with other types of distributions provided that valid confidence intervals can be established.

In general, as the number of clusters for a data set increases, the mean error associated with the clustering should decrease, and when the number of clusters equals the number of points the error is 0. Because one dimensional

data sets are used, the mean squared error (MSE) of the cluster is used as the estimate of distortion for the jump function. To help ensure that the computed clusters are good proxies for the true values the MSE is computed at each step from 1 to N-1 and tested to ensure that it forms a monotonically decreasing sequence. If an increase in MSE is encountered the input clusters are rejected as invalid and an error is reported.

Steps of Stage 2:

1. Build a vector of input values from the input cluster means. If any cluster means match, treat them as a single value but compute the pooled standard deviation because they are really distributions and not single values.

2. Compute all possible clusterings with k ranging from 1 to N-1, and for each clustering compute the distortion function as defined by Sugar and James.

3. Select as the optimal value of k the clustering that produced the largest difference in the distortion function.

4. Test for spurious optimal clusterings with two clusters and pick the second best if this is the case. Spurious optimal clusterings are tested using the coefficient of variability.

5. Store the optimal clustering in the database together with means, standard deviations, number of members, and pre-computed confidence interval values.

Step 4, above, was determined by empirical observation. Because the inputs to the Stage 2 algorithm cluster means that some information is "lost" that was contained in the very large data set represented by a week of minute data, it is to be expected that the selection of k sometimes may be inaccurate.

Stage 3.

Stage 3 uses the results of Stage 2 to analyze the operating states of the equipment.

The inputs to Stage 3 are a date-appropriate optimal clustering from Stage 2, and a vector of sensor readings over time. The output is a set of discrete operating states, characterized by mean value, standard deviation, number of occurrences over time, and a transition matrix that gives the probability of changing to state S2, given any state S1.

The clustering is tested for overlapping confidence intervals, collapsing or merging clusters if necessary, and compute the pooled standard deviations, yielding a single clustering that represents a set of operating states for the equipment, said clustering having discrete boundaries given by confidence intervals.

An example of clusters that may have overlapping confidence intervals can be seen in a simple household refrigerator, because compressors in normal operation consume the most power immediately after they are turned on, and the power consumption then gradually declines over the duration of the compression cycle. Therefore it is quite likely that the highest and lowest values of the compression cycle may form distinct clusters but it may be difficult or impossible to find a discrete boundary between them.

Using the series of sensor measurements, each measurement is tested to determine which operating state it represents, corresponding to clusters 0 through k, building a chain of operating states over time by recording the start time, end time, and duration of each state exhibited by the operating equipment.

Traversing the chain of operating states yields a set of state transitions that are aggregated into a matrix.

The transition matrix gives the probability of changing to state S2, given any state S1.

Using the transition matrix and criteria based on the state duration and the transition probabilities, states with low duration and relatively equal transition probabilities indicate a transitional or spurious operating states

caused by anomalies of the measurement sensor or known properties of the equipment. Such states are filtered or removed

FIG. 1 shows a flow chart showing the method steps described herein.

Following is an example of an application of the fast algorithm for automated analysis of the present invention:

The process in this example begins with an advanced statistical analysis of historic data, especially sensor data, from a refrigeration unit. The automated system performs an initial screening of broad sets of data derived by an initial analysis. It then iterates through screenings of those sets, comparing each for consistency, and reduces the number of sets to functional sets of data with high probabilities of accuracy. Applying the analysis to derivative statistical sets of progressively increasing accuracy, instead of to the raw data itself, greatly increases the speed of this. The core of the present invention is a unique method of creating and analyzing the sets into clusters useful for analysis and pattern discovery in equipment performance.

The following tables show examples of the clustering. The intention is to derive operating states of equipment from raw data. A simple refrigerator has four operating states: 1. Door closed, compressor not running, power consumption 0 (or perhaps a few watts for control circuitry); 2. Door open, power consumption 3 to 40 watts because the light is on; 3. A compressor cycle, which usually dwarfs the light bulb wattage (making it difficult to distinguish compressor running with the door open from compressor running with the door closed); and 4. A defrost cycle, with very high wattage.

Because the compression power is much greater than the light bulb power, it is not useful to consider "compressor on, bulb off" and "compressor on, bulb on" as separate operating states. FIG. 2 shows a transition probability matrix for a household refrigerator with an LED light bulb. Seven states were identified in the optimal clustering.

FIG. 3 shows how the transition probability matrix is used to filter out transitional states.

Any state that is transitional, that is, changing by amounts outside the parameters of the likely cluster amounts, is removed from consideration, increasing the probability of accuracy of the remaining states in this iteration of the data. As non-likely states are removed, actual equipment states are revealed. The more data history there is, the more accurate the analysis becomes. The shaded data is likely transitional, because it fits the rule "mean duration less than 2 minutes and probability of transitioning up or down roughly equal."

FIG. 4 shows the operating states as identified by the operating state analysis, including 98% confidence intervals for each state.

FIG. 5 shows one day of normal operation on this circuit. Some data points, not otherwise easily visible to the eye because there are 1440 points on this chart, are labeled. It can be seen that there is some noise likely introduced by other electrical devices on the circuit. The operating states identified as F2 and F3 are both compression states. Other analysis on refrigeration circuits identifies defrost cycles shortly after 2 pm and around 11 pm. The spikes around 6:30 am and 8 pm are likely some other device operating as the duration of 2-3 minutes falls outside the 99% confidence intervals established for identifying defrost cycles.

In the case of the refrigerator, patterns of electricity usage that represent operating states can be derived, and anomalies in the patterns can be discovered that would indicate equipment malfunction. FIG. 5 shows two defrost cycles in a 24 hour period. Had the spikes been longer in duration, 4 cycles would have been identified, generating a warning of "too many defrost cycles." An equipment profile database can be constructed in a mostly automated process by deducing optimal clustering from detailed data, and populating the database for that equipment. Building history allows more accurate clustering. Data might be gathered from actual equipment data or from "virtual" or recalculated data, such as coefficient of performance data for a heat pump or a boiler, which is calculated from electricity usage data plus a number of other factors.

Modifications and variations can be made to the disclosed embodiments of the present invention without departing from the subject or spirit of the invention as defined in the following claims.

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