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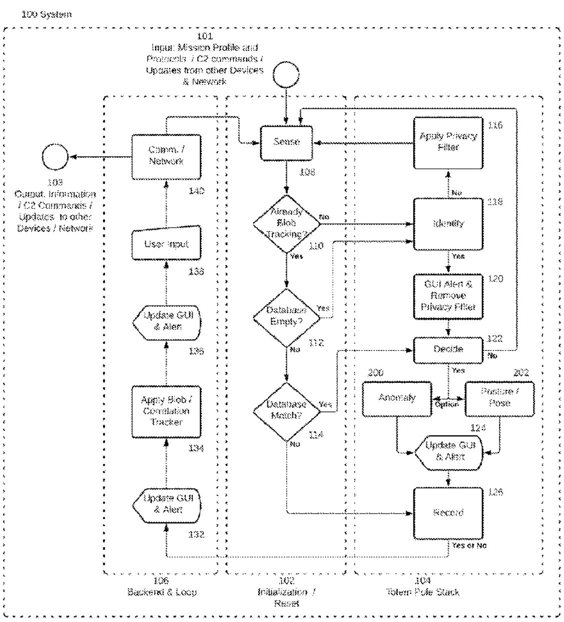

FIG. 2

(57) Abstract: The present disclosure provides a process/architecture that allows for scalable and modularized algorithm fused autonomous deployment of a system without requiring all-autonomous capability in every instance of the system's perception of and interaction with an environment. This results in efficient decision-making that utilizes low computational hardware performance and requires less or no load on human decision-maker(s).

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SYSTEM AND METHOD FOR ENABLING EFFICIENT HARDWARE-TO-SOFTWARE PERFORMANCE

REFERENCE TO RELATED PATENT APPLICATION

The present application claims benefit of U.S. Provisional Application No. 63/004,495 filed on April 2, 2020.

TECHNICAL FIELD

The present disclosure relates to a system and method for enabling efficient hardware-to-software performance utilized with self-contained autonomous robotics/systems that are either mobile or fixed positioned.

BACKGROUND

The First Industrial Revolution used water and steam power to mechanize production. The Second Industrial Revolution used electric power to create mass production. The Third Industrial Revolution used electronics and information technology to automate production. Now a Fourth Industrial Revolution (current industrial revolution) is building on the Third Industrial Revolution, the digital revolution often characterized by a fusion of technologies that is blurring the lines between the physical and digital spheres and is pushing autonomy and/or automation into numerous industries or cross-sectional segments of various neighboring industries to achieve greater efficiencies in their intended processes as compared to the prior or existing process.

The introduction of these technological advancements, including the novel systems and processes described in this specification, continues to generate increasing demand to consume/process large quantities of data (big data) while reacting to computed insights typically at speeds and cognitive abilities that far exceed human-based ability to perceive, correlate, and interpret events in a dynamic and/or complex environment.

One value driver of the current industrial revolution resides in the proper definitions of “automation” and “autonomy” such that these systems are implemented correctly. Automated and autonomous systems can be viewed as a continuum in capability and thereby added value. However, this continuum is sensitive to the law of diminishing returns whereas complexity in autonomy to drive intelligent capabilities can become detrimental to progress and the desired return on investment.

A commonly used definition of automation is a process performed without human assistance. However, the misnomer in this definition is that automation/automated is more procedure than process. A “procedure” is commonly defined as “a series of actions conducted in a certain order or manner” – which is devoid of outcome metrics or success. As such, automation relates to the performance of mundane procedural actions otherwise applicable to only controlled and predictable circumstances. For example, systems configured to place labels onto soda cans, or to provide cruise control functionality to a vehicle are both procedures in which automation relieves user(s) from those specific segments of tasks.

Whereas, autonomy (autonomous capability) requires satisfactory performance under uncertainties in the environment and ability to compensate for system failures without external (human/supervisor) intervention. In contrast, the definition for autonomous capability (autonomy) relies on given satisfactory performance just as the definition of the word process. A “process” is commonly defined as “a series of actions or steps taken in order to achieve a particular end.” As such, autonomy utilizes the implemented artificial intelligence (AI) as a source of learned experience and makes the appropriate choices within the perceptual limitations and finite computation available. Additionally, during the life of this specification and beyond, the learned experiences contained in the datasets will be self-evolving via external refresh/update/augmentation of the dataset(s), internal refresh/update/augmentation of the dataset(s), entirely self-generated dataset(s), or all the above.

As described in later sections of this specification, there are six degrees/levels (starting from zero to five) of autonomy accepted as current industry standard (such as by the Society of Automotive Engineers (SAE), the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) and others). In the highest (sixth) degree/application of autonomy, the fully autonomous system is completely non-reliant on a human operator (external intervention). This is, for example, a desired goal for driverless vehicle development that promises to deliver vehicles that go as far as not including human driver input devices such as the steering wheel or the pedals for acceleration or braking, and so on. The novelty of this specification is that it provides a process/architecture that allows for scalable (that is also open-source friendly) and modularized algorithm fused autonomous deployment of the system without requiring all-autonomous capability in every instance of the system's perception of and interaction with an environment.

The above stated novelty can also be specified using the current industry definition for intelligent systems or (machine) intelligence. Whereas intelligent system is commonly defined as a computationally capable system that uses techniques derived from artificial intelligence, particularly one in which such techniques are central to the operation or design of the system. As a result, the central/core artificial intelligence process can be both computationally intensive and possibly a weak point (vulnerability) of the system, e.g., should it fail to perform its predictions/classifications correctly. Further, the common definition of intelligence (for computational machines/hardware) is a system that manages data gathering as it obtains and processes data, interprets the data, and provides reasoned judgements/decisions/insights as a basis for actions in response to sensed stimulus/anomaly.

While taking into consideration the prior mentioned definitions for intelligent systems and machine intelligence, the novelty of this specification, in terms of these definitions, is that just because one can design an all-intelligent system, it should not always be designed in this manner since these computational processes require additional hardware burden/cost and/or have an increased chance of a system-wide failure. The algorithm fusion system and method presented in this specification describes a novel blend of AI-based and non AI-based algorithms to achieve intelligence without requiring an "all-intelligent" system.

U.S Pat. No. 10586464B2, U.S Pat. No. 10600295B2, U.S Pat. No. 6842674B2, W.O. Pat. No. 2019199967A1, and U.S Pat. No. 20040030571A1 each describe implementation of artificial intelligence within systems. However, they do not capture the algorithm fusion for system-wide hybridization of autonomous processes and automatic procedure to deliver a system that behaves as if it is a full-autonomy capable system even though it contains various modular blocks of code that do not include or leverage AI-based algorithms.

SUMMARY

One objective of the present disclosure is to provide an algorithm fusion method and system for efficient decision-making that utilizes low computational hardware performance and requires less or no load on human decision-maker(s).

To achieve this objective, the present disclosure describes a system and method having autonomous and automated capabilities configured to function as a fully autonomous system, and thereby achieve the benefits of full autonomy, without the high computational cost, development cost, and subsequent hardware costs (including power consumption and heat generation) given the complexity of a truly full-autonomy system. For example, the present disclosure is designed to deliver a pseudo full-autonomy system/architecture from the perspective of the on-board processes and its implemented algorithm fusion while the user perceives the execution and receives the benefits provided by the pseudo full-autonomy system in a fashion that is sufficiently equal to or equal to an analogous system that does implement computational processes that are fully aligned with the current definition of autonomy (at its highest degree/level) that is reliant and robustly developed using artificial intelligence algorithms and their underpinning datasets used for perceiving and tracking the mission-specific requirements.

In addition, the present disclosure describes edge-processed algorithm fusion for robots/systems typically found in industries enabled by unmanned and manned systems dynamically adaptable for travel in aerial, terrestrial, subterranean, indoor, enclosed, irregular, blended, and marine domains, having any constant or dynamic environmental conditions, in a wide range of autonomous or semi-autonomous control regimes, or in human-machine type systems that provide a workload reduction onto the human-in-the-loop (operator) counterpart.

The present disclosure also describes a scalable and modular algorithm architecture that creates one or more computationally efficient processes that enables edge-processed decision-making that is essential to mission operability, navigation operability, or both.

The present disclosure also describes self-contained robots/systems, specifically airborne vehicles/systems or whose power distribution cost is primarily consumed during translation, rotation, and/or interaction with the environment, that require a balance in the cost of deployed hardware, the weight of the system, the size of the system, the power consumption of the system, the intelligent capability of the system to make self-contained decisions and/or decisions consistent with the human-in-the-loop preset needs/requirements, and the ability to balance the SWaP (size, weight, and power) requirements with artificial intelligent-based (AI-based) and traditional algorithms (non-AI-based) algorithms so the system's behavior, perception, and/or interaction is possible without exceeding the computational limits of the computationally limited on-board hardware such as computational power consumption and/or heat typically generated by the on-board computational hardware.

The present disclosure also describes self-contained robots/systems whose on-board or distributed algorithm fusion drives efficiencies in the collaboration of discrete/modular or blended blocks of code responsible for the system's robotic autonomy and automation of tasks/behavior.

Hardware advantages obtained through the present system and method include the following:

1) On-demand calling of algorithm/code: algorithms (AI/non-AI/mix) requiring various levels of computational resources or frame rates are summoned as needed.

2) Algorithm stack interconnectivity: algorithm interconnectivity allows for algorithm fusion so flagged items/things/people/anomalies/etc. are selected for further scrutiny of other/subsequent collaborating algorithms.

3) Algorithm stack crosscheck: allows for algorithm fusion to crosscheck data/information/commands to mitigate misreports/errors, e.g., a mop propped up against the wall may appear to be a human head with braided hair by one algorithm, but fails further crosschecks and is then disregarded. Additionally, what the algorithm "thinks" is errant during crosscheck may be logged into another database for human/operator validation. Crosscheck also enables handling of special situations, e.g., identical twins or perpetrators wearing the same mask are in view, so the algorithm fusion robustness is achieved against this type of sophisticated attack.

4) Local algorithm modification/update: mission/use-case migration/enhancement can be implemented locally within one or more algorithm of the stack and/or by modifying the interconnectivity of data/information from one or more algorithm(s) to the next and/or changing the sequence of the algorithms in the stack and/or adding/removing algorithms of the stack.

5) Hardware/robot/drone control: the algorithm fusion, with optional integration with additional sensors and/or fused sensor data/information, may control actuation partially or entirely of the system while making decisions (e.g., navigation-based decisions, mission-based prioritization decisions, etc.).

As a result, the present system requires less power consumption to run the processing hardware, lowers cost of deployed hardware, increases deployability/compactness (e.g., physically smaller processing hardware), lowers weight of processing hardware in payload sensitive cases, results in less heat being generated by the processing hardware, increases opportunity for processing hardware placement/integration, and reduces (to no) requirement to actively cool (e.g. fan/forced cooling medium) the processing hardware.

Further advantages may include:

1) Privacy and Probable Cause: the algorithms' deployment is configurable to follow an escalation of suspicious activity, e.g., only record once flag(s) are raised and thereby does not intrude on lawful activity, e.g., adjust process flow to satisfy privacy laws.

2) Investigation: the algorithms' deployment is configurable to capture supporting threat actors or unwilling co-conspirators.

3) Legal: The algorithms' deployment is configurable to not characterize anybody as a person of interest or suspect, and to provide evidence management tools, e.g., seamless upload to server.

Technology level advantages may include:

1) Layered tracking: Difficult to confuse multiple algorithms keeping track of the same POI/suspect.

2) Use-case pivot: Changes to flag raising events/objects creates product/system pivot to other use cases (e.g., commercial/non-military).

3) Camera system sophistication: match hardware with use-case, e.g., day/night vision, zoom, pan/tilt, high-definition image, etc.

4) Deployment: stand-alone, battery/plug-in, fixed/mobile, man-portable/robot (drone) carried; customer decides.

High-level advantages may include:

1) Forensics: use gesture/hand tacking algorithm of POI/suspect to document fingerprint, DNA, other bio-tracers to be collected at known locations by forensics team.

2) Prioritization: Use anomaly algorithm to aid in threat level quantification.

3) Damage: Use pose/posture to aid in damage triage.

Details of the present disclosure are illustrated below, including examples of various aspects of the disclosure are described below, and are used for illustrative purposes only.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings illustrate examples of various components of embodiments of the present disclosure and are for illustrative purposes only. Embodiments of the present disclosure are illustrated by way of example and not limitation in the figures of the accompanying drawings, and in which:

FIG. 1 illustrates a block diagram showing one embodiment of a simplified algorithm fusion process and architecture driving the interaction between autonomous and automation algorithms;

FIG. 2 illustrates a block diagram showing one example of a robust algorithm fusion process and architecture driving the interaction between autonomous and automation algorithms having additional AI-based decision-making algorithms that assist in the decision-making block;

FIG. 3 illustrates a pictorial visualization of FIG. 1, according to one embodiment, within the context of an algorithm fusion stack comprising discretized and modularized connected blocks as totems in a totem pole;

FIG. 4 illustrates a pictorial visualization of FIG. 2, according to one embodiment, within the context of an algorithm fusion stack comprising discretized and modularized connected blocks as totems in a totem pole;

FIG. 5 illustrates a pictorial visualization of FIG. 4, according to one embodiment, within the context of an algorithm fusion stack comprising discretized and modularized connected blocks with detailed description of the AI-based and non AI-based algorithms implemented as totems in a totem pole;

FIG. 6 illustrates an application according to one embodiment of a process flow of algorithm fusion applied to a person of interest detection, e.g., “who ate my doughnut” example;

FIG. 7 illustrates an application of the updated process flow of the algorithm fusion applied to a person of interest detection for the “who ate my doughnut” example, according to one embodiment, with additional response to a triggering event that elevates probable cause, prioritization, and target tracking discrimination for a suspect (who ate the doughnut);

FIG. 8 illustrates an implementation of the algorithm fusion process, according to one embodiment, with actual subjects for a mission use-case of finding/tracking and documenting the “who ate my doughnut” example; and

FIG. 9 illustrates a schematic view of an exemplary embodiment of a computer system implementing one or more of the above-described embodiments illustrated in FIGS. 1-8.

DETAILED DESCRIPTION

Reference will now be made to the embodiments illustrated in the drawings, and specific language will be used here to describe the same. It will nevertheless be understood that no limitation of the scope of the claims or this disclosure is thereby intended. Alterations and further modifications of the inventive features illustrated herein, and additional applications of the principles of the subject matter illustrated herein, which would occur to one ordinarily skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the subject matter disclosed herein. The present disclosure is here described in detail with reference to embodiments in the drawings, which form a part here. Other embodiments may be used and/or other changes may be made without departing from the spirit or scope of the present disclosure. The embodiments described in the detailed description are not meant to be limiting of the subject matter presented here.

The six levels (degrees) of autonomy typically accepted for robotic systems, starting from zero to five, are:

(0) – None (no autonomy)

(1) – Low (some automated assistance)

(2) – Partial Sense and Alert

(3) – Conditional Sense and Avoid

(4) – High Sense and Navigate

(5) – Full Navigation & Prioritization

For a robotic system to achieve level 5, the system must deploy perceptive capabilities that are matched by adaptive capabilities to operate in a broad range of environments along with having the ability for error-tolerant decision-making. As such, computationally restrained robotics, for example typically self-contained in communication (wireless) and in power availability (untethered) or networked dispersed/distributed/federated (nodal) robotics are not able to perform the complexity of multithreaded tasks without moderate, severe or complete loss in essential functionality otherwise typically observed as reduced operating/computational speeds, frame rate reduction, refresh rate reduction, decision-making and/or response lag, degradation of confidence factor/ratio in decision-making, and so on. A computational restrained robotic/system, for example, is a robotic/system limited by one or more processing capabilities of the installed/available processor(s), e.g., CPU, GPU, TPU, etc.

To accommodate the need for complex decision-making in computational restrained/limited system(s) or network of system(s), the disclosed system utilizes the more computationally intensive process only as/if needed and otherwise passes tracking of desired/targeted events/objects/people to a generalized “blob”/correlation tracker that does not place any type of classification onto the target (i.e. not AI-based). This system may be referred to as an algorithm fusion system.

For example, if the system is targeting a coffee mug, once it finds the match, it no longer continues to track the mug as a mug, but instead as a blob, and is therefore no longer allocating computational resources to continuously perceiving the coffee mug as a coffee mug in which it already possesses unless the algorithm has discretized checking in time and/or space to occasionally verify that the blob it now possesses continues to indeed be a coffee mug. By doing this, the disclosed algorithm fusion system retains/relieves computational capacity to continue to search for other target mugs that may be or become perceptible. A blob can also be referred to as an object, a portion of an object, a blotch of pixels, a pixel patch, a cluster of pixels, a blot of pixels, a spot of pixels, a mass of pixels, or any other term referring to a group of pixels of an object or portion thereof. In some examples, a bounding box can be associated with a blob.

The disclosed algorithm fusion system is best understood in the context in which it is employed. **FIG. 1** and **FIG. 2** show block diagrams illustrating embodiments of algorithm fusion processes and architecture driving the interaction between autonomous and automation algorithms. However, it should be appreciated that other embodiments may comprise additional or alternative flows and/or architecture, or may omit certain flows or architecture altogether. It should also be appreciated that other embodiments may perform certain execution steps in a different order; steps may also be performed simultaneously or near-simultaneously with one another or otherwise multithreaded.

FIG. 1, for example, depicts an illustrative architecture of an Algorithm Fusion System **100** in which aspects of the present disclosure may operate, hereafter also referred to simply as System **100**. The dotted line boxes indicate constituent processing logic streams of the System **100** itself, the solid-line boxes indicate sub-processing algorithmic or processing nodes of the System **100**, the solid-line diamonds indicate sub-processing status check nodes of the System **100**, the solid-line circles indicate input/out communication and command exchange nodes of the System **100**, the solid-line top-slanted rectangles indicate user input nodes of the System **100**, the solid-line left-pointed to circular-edge shapes indicate graphical user interface and alerting nodes of the System **100**, and the arrows indicate communicative couplings between various components, subcomponents, and nodes of the System **100**.

The Algorithm Fusion System **100** comprises three processing streams: (1) Initialization and Reset **102**, (2) algorithm fused Totem Pole Stack **104**, and (3) Backend and Loop **106**, and comprises of two communication (data/information/command) exchange nodes: (1) Input Data/Information/Command Node **101** and (2) Output Data/Information/Command Node **103**.

The Algorithm Fusion System **100** comprising the Initialization and Reset **102** processing logic stream is initialized by Input **101**, is looped/reset by Backend and Loop **106** processing logic stream, and is recalled from the Totem Pole Stack **104** processing computational stream whereby Sensing **108** sub-processing node is initiated by the aforementioned sub-process Input **101**, looped/reset by the processing logic stream Backend and Loop **106**, and recalled by the processing computational stream Totem Pole Stack **104** such that a series of checks comprising Already Blob Tracking **110** status check node, Empty Database **112** status check node, and Database Match **114** status check node are performed to direct the logic flow to specific algorithm nodes comprised within the processing computational stream Totem Pole Stack **104**. The ability to control/triage the logic flow from the processing logic stream Initialization and Reset **102** onto specific algorithm nodes comprised within the processing computational stream Totem Pole Stack **104** enables the System **100** to achieve greater computational/processing efficiency since certain AI-based algorithms are bypassed depending on existing/returning flags contained in the logic that is set along the path of the overall logic flow of the System **100**.

Once the logic within the processing logic stream Initialization and Reset **102** reaches the sub-processing node Already Blob Tracking **110** if the answer is "no," then the logic is passed to the processing computational stream Totem Pole Stack **104** via Identify **118** sub-process that comprises perception algorithms configured to detect, for example, the presence of people (humanoids) and high importance objects (HIO) based on the available dataset. If the answer is "yes," then the logic cascades down to sub-processing node Database Empty **112**.

Once/if the logic within the processing logic stream Initialization and Reset **102** reaches the sub-processing node Database Empty **112** if the answer is “yes,” then the logic is passed to the processing computational stream Totem Pole Stack **104** via the Identify **118** sub-process that in turn comprise of perception algorithms that detect, for example, the presence of people (humanoids) and high importance objects (HIO) based on the available dataset; however, if the answer is “no,” then the logic cascades down to sub-processing node Database Match **114**.

Once/if the logic within the processing logic stream Initialization and Reset **102** reaches the sub-processing node Database Match **114** if the answer is “yes,” then the logic is passed to the processing computational stream Totem Pole Stack **104** via Decide **122** sub-process that in turn comprises decision-making logic and perception algorithms that may further elevate the level of suspicion (and probable cause) as explained later in the detailed description of **FIG. 2** and further exemplified in **FIGS. 6, 7,** and **8**.

However, if the answer is “no” to the status check of the sub-processing node Database Match **114,** then the logic is passed to the processing computational stream Totem Pole Stack **104** via Record **126** sub-process process that in turn comprise, for example, facial/biometric and/or other feature/pattern algorithms that enable instant PIO/suspect detection. The logic handling process to the Record **126** sub-process from the triggered “no” response of the Database Match **114** sub-process node is important because even though the person of interest (PIO) or HIO is/are already being tracked by the non-AI blob tracker (from a prior flag generated by the Already Blob Tracking **110** node instance) a facial/biometric and/or feature/pattern (for tattoos or other prevailing feature of the PIO/suspect) has not yet been collected and catalogued into the database (e.g., evidence database). As such, should the PIO exit the sensing view of the system then return into view without triggering the Identify **118** sub-process the individual (chain of events) has receded back into anonymity.

For example, consider a situation in which a subject is not facing the camera, but flashes a gun. The System **100** will recognize the subject in possession of the weapon via Identify **118** and Decide **122** sub-processes and subsequently assign the blob tracker to the downgraded subject (now downgraded to person of interest) even though the Record **126** sub-process (may have) failed to capture information for the database. Since the person of interest has not yet been recorded into the database by cataloguing identifying features such as facial features, if the PIO leaves the System's **100** viewing area and later returns without brandishing the gun, the PIO returns to anonymity with the one caveat that a picture and/or video exists of the PIO whose back was turned to the camera while brandishing the gun for investigators to review later or for additional post processing performed by other forensic artificial intelligence tools. However, if the PIO remains in view of the System **100,** the logic subsequently loops via the processing logic stream Backend and Loop **106** which recalls the Initialization and Reset **102** processing logic stream whereby the Sensing **108** sub-processing node is re-initiated, and thus completing the loop.

Once/if the logic within the processing computational stream Totem Pole Stack **104** reaches the sub-processing node Identity **118** if the answer is "no," then the logic is passed to Apply Privacy Filter **116** sub-processing node whereby privacy measures are placed to concern the rights and freedoms of the viewable individuals and their subsequent lawful affairs such that logic is returned the Sense **108** starting node of the processing logic stream Initialization and Reset **102**. The logic flow described in this paragraph is important as it allows for a computationally efficient path of analyzing the viewable sight picture without any use of further classification, recognition, and recording of any kind. For example, if five people are in view of the System **100** and none are displaying a HIO or raising any other object of interest related alerts in the Identify

118 node, then the entire looping logic path resides in the top right corner of the logic path in **FIG. 1** and in **FIG. 2**.

However, if the answer is "yes" to the sub-processing node Identity **118**, then the logic is passed to the GUI Alert & Remove Privacy Filter **120** sub-processing node and subsequently reaches the Decide **122** sub-processing node. The GUI (graphical user interface) Alert & Remove Privacy Filter **120** node is the first indication to the user/stakeholder that the System **100** has detected sufficient probable cause to unmask the privacy filter; therefore, allowing the Decide **122** and Record **126** to gain access to the data feed whereby their subsequent analysis and decisions/actions to record the chain of events and participants takes place. Another benefit in splitting the autonomous processes is that the system allows for discretization of significant real-world considerations: (1) moral/ethical implementation of privacy filtering independent of and ahead of probable cause based scrutiny and analysis thereby the System **100** contains meaningful alignment to the legal mooring of innocence until proven guilty (presumption of innocence) resulting in greater chances of positive presentation and evidence applicability towards proceedings such as in a court of law, (2) continuous operation of the System **100** even if discrete algorithmic processes fail to make an adequate detection rather than stalling the logic flow, and (3) discrete compartmentalization of AI-based algorithms such that implementation of Open Source Algorithms or improvements in proprietary algorithms are integrable or swappable resulting in adaptability and scalability in respect with, but not limited to, code-based improvements, database/trained-data based improvements, mission-based migration, hardware obsolescence, and performance matching to decrease or increase in computational hardware running the System **100**.

Once/if the logic within the processing computational stream Totem Pole Stack **104** reaches the sub-processing node Decide **122,** if the answer is "no," then the logic is returned to the Sense **108** sub-processing node of the processing logic stream Initialization and Reset **102** while bypassing the Apply Privacy Filter **116** node. The return of the logic flow to the Sense **108** node without re-masking the privacy filter is important because the Decide **122** node has more than one trigger: (1) it may be called in step after the GUI Alert & Remove Privacy Filter **120** node or (2) it may be called by the Database Match **114** node. As described earlier, when the Decide **122** node is triggered by the Database Match **114** node the logic carries knowledge that the subject is an existing match in the database, for example as elevated from subject to person of interest. However, additional flags/anomalies may be perceived by the Decide **122** node that may further elevate the POI to the suspect level whereby this process is further disclosed in **FIG. 2** and is further shown in **FIGS. 6, 7,** and **8**.

FIG. 6 illustrates a "who ate my doughnut" example use-case. In this example, a person (female subject A) is in view of the System **100** and displays the threat object (the doughnut) as whereby the Identify **118** node perceives the presence of the person and the threat object. In this example, the Decide **122** perceives the threat object (the doughnut) is in possession of the person and both records the event and elevates subject A's status to POI, also shown in FIG. 6 and subsequently records subject A's unique identifying features (such as facial features) to the POI database. However, possession of the doughnut alone is not a crime, e.g., does not indicate clear intent to eat the doughnut (crime) or proof that subject A is the person who ate the doughnut (committed the crime). Instead, if subject a gives the doughnut to fellow police officer (male subject B) as illustrated in **FIG. 7**, then subject B is added to the POI database and documented by the Decide **122** node. But, in his case, subject B eats the doughnut and is allocated/elevated to the suspect database while having documentation of the event automatically recorded by the System

100, also illustrated in **FIG. 7**. However, the ability to create degrees of sensitivity to suspicious and illicit activity is dependent not only on the return arrow logic flow path of either the "no" or "yes" of the Decide **122** node, but also dependent on additional perception algorithms fused/associated with the Decide **122** node as shown in **FIG. 2** by inclusion of, but not limited to, **Anomaly 200** and/or Posture/Pose **202** nodes. For the System **100** to sense the additional actions which elevates the POI to suspect, in the use-case as illustrated in **FIGS. 6, 7,** and **8**, the posture/pose of the POI in possession of the doughnut gives the System awareness that the doughnut is being eaten by the subject B; therefore, trained dataset and perception algorithms (AI-based or traditional) with close relationship to the Decide **122** node that sets degrees of prioritization, threat level, lethality, or even innocence, for example by way of identification of aggressor versus non-aggressor and so on.

The (threat/ target) prioritization processes and scalability of the System **100** as described in the above paragraph is further applicable to implementation of modular playbooks (terminology coined by the US Military) that defines rules (desired awareness/databases) of interest the Identify **118** node, the Decide **122** node, and the subsequent prioritization nodes such as the Anomaly **200** and the Posture/Pose **202** and so on use to achieve the automatic and autonomous mission use-case of the robotic system deployment this System's **100** architecture. In addition, the perception, prioritization, and awareness generated by the processing computational stream Totem Pole Stack **104** enables mitigation and counteraction of the System **100** since there are various GUI updates and alerts, as shown in nodes **120**, **124**, **132**, **136**, and via Output **103** node are present when/after new perception/awareness is generated.

Further, the Output **103** node may operate/drive/fly a real robotic apparatus hosting or connected to the System **100** by means of issuance of command and control commands (C2) to move towards or away from objects, events, or people. For example, the Identify **118** node perceives two occupants in the presence of a fire (heat source), the Decide **122** associates the fire and occupants as being in danger (for example by proximity or by ambient temperature), the Anomaly **200** and Posture/Pose **202** create awareness that one occupant is lying motionless while the second adult male occupant is seated and waiving at a UAV/drone carrying the edge-processing hardware running the System **100**. Additionally, the Record **126** node recognizes that the male that is waiving to the UAV/drone is identified as a police officer given the on-board “friendlies” database. In this scenario, the Comm./Network **140** node and the Output **103** may be configured to issue command to the C2 to get a closer inspection, while sending back an urgent support request that contains recorded capture (image/video/audio), occupancy, status/triage of victims, location, environmental condition (such as room temperature), and possibly the presence of the nearest access point from the outside or the staircase. Furthermore, the logic as it flows into the processing logic stream Backend and Loop **106** reassigns and tracks the PIO and/or HIO as blobs so computational resources are relieved, and the logic while passing through the User Input **138** node can (optionally) receive user inputs such as the command to land and stay monitoring the victims or carry forward, changes to the System **100** behavior to record continuous, noncontinuous, etc. In contrast, if no User Input **138** is provided, then the System **100** proceeds autonomously to carry the intended mission as originally defined during the initialization and deployment of the System **100** by the Input **101** at the beginning of the operation. In this example, the UAV/drone carrying the System **100** may continue to explore and “look” for victims until the battery dies, or autonomously return home at 40% battery discharge, or attempt to exit the structure from the nearest window, and so on as ordained by the existing Input **101** node mission profile.

As shown in **FIG. 3**, while looping and interconnected structure are removed, the contextualization and intent of the disclosure of the processing computational stream entitled Totem Pole Stack has a co-dependent and communicative relationship as the major algorithmic processes annotated as (0) Tracking, (1) Identification, (2) Decision-making, and (4) Recognition are discretized and otherwise "sit" on top of one another whereby at each modular totem block a higher degree of awareness and autonomy is reached by the disclosed algorithm fusion system.

FIG. 4 illustrates additional decision-making computational algorithms shown provided sitting above the (2) Decision-making totem block whereby additional awareness is achievable by the Totem Pole Stack.

FIGS. 3, 4, and **5** illustrate the underpinning functionality and methods deployed by the embodiments as implemented within the shown totem block algorithmic processes.

FIG. 8 illustrates a non-limiting example of real-world deployment of the "who ate my doughnut" example use-case as utilizing the architecture as disclosed in **FIG. 1** and **FIG. 2**. The three images show what the algorithmic processes are performing at the identification, decision-making, and recording nodes.

In the top row of images, for example, the subject/humanoid is recognized but does not display a threat object or high interest object (HIO) and thereby has his identity concealed/masked such that even if the decision-making or record algorithms attempted to capture information, the privacy filter has masked the facial features.

In the middle row of images, for example, a different subject holding the doughnut (HIO) is identified and tracked. Since the subject is in possession of the HIO, the decision is also made to save the image and capture the distinguishing facial features of the subject who is now recorded into the database and upgraded to person of interest (POI). From here forth, should the POI succeed in leaving the viewing frame, the subject will automatically be upgraded to POI upon return even if the HOI is not displayed. Moreover, the camera, while equipped with pan and tilt actuation, actively tracks the subject having the highest degree of interest such as a suspect rather than person of interest. Likewise, actuation of the system may be influenced, for example, by other perception enabled by the decision-making process such as based on threat profile (e.g., track the POI with a gun rather than the assailant displaying a knife).

In the bottom row of images, for example, the POI holds the HIO to his mouth. This change in posture and/or distance of the HOI to his mouth causes an elevation in suspicion and thereby downgrades his status to suspect while committing his current distinguishing features to the suspect database. The anomaly and pose detection stated above, for example, is equivalent in this embodiment to nodes 200 and 202 described in **FIG. 2**. However, numerous different perception algorithms working/fused with the decision-making node may be deployed to raise the proper awareness/alertness that affects probable cause, mitigation/intervention, and documenting of the chain of events significant to the mission use-case. Further, the pan/tilt installed in the system used to collect the real-world events depicted in **FIG. 8** could expand to other cameras systems. For example, if two cameras were deployed and two individuals were present. While one is a POI and the other is a suspect, the camera systems may communicate with each another so each follows a unique target. (This example is not limited to two cameras and/or two subjects, but could be applied to multiple cameras and multiple subjects.) By extension, if the same were to happen where drones are deployed that have the disclosed architecture, these vehicles may autonomously locate, track, prioritize, alert, record, mitigate, and chose to follow/track disparate assailants autonomously.

Another non-limiting example may include a coffee mug having a colorful design, ornamental shape, and functional attributes. When the coffee mug is twisted, in addition to the color movement and apparent texturing, the coffee mug may resemble a closed helical shape that is wider at the base and narrower at the top, include a handle for holding and spout positioned for sipping just at the perfect angle as one elevates the coffee mug to one's mouth. Further, a plain glass of water may be positioned next to the coffee mug. As physically/mentally healthy humans who enjoy fully autonomous capability (level 5) and have vast libraries/memories (cognitive abilities) to near instantly correlate objects, actions, and places; therefore, the mug and the plain glass of water are easily distinguishable, but at a computational cost to our natural cognitive systems, e.g., the colors, texture, shape, functionality, and the classifications are continuously running in our brain. While this is not commonly believed to be necessarily wasteful for the human brain to continuously process as it (the brain) enjoys the benefits of its electro-chemical function/messages, it does have limitations nonetheless since sensory overflow may prohibit more intelligent thought processes.

In this example, if the coffee mug and the glass of water are sensed with a fully autonomous system, then various internal databases are needed to continuously sense, track, store, and perceive both objects along with all of their individual attributes, which comes at a monetary and computational cost, etc., (e.g., what benefit does the machine continuously receive or offer as an output once it has already understood and documented the relevant features in the first place and at what computational cost?)

Further, if the human subject is presented with the same coffee mug (ornate version described above) and other versions of the coffee mug having fewer and fewer features, then the other version would each require less and less brain power. Ultimately, the perception of a plain mug is that of just a mug rather than having the additional artisanal craft and therefore requires less brain power.

An analogous experiment applied to an algorithm fused system, as described in this specification, only uses AI-based algorithms in "needed sectors" of perception as coded by the programmer but additionally passes the tracking of the object to a completely non AI-based tracker that has no contextual understanding of what it is tracking since it tracks only a generic shape ("blob-ness") of things. Thus, the AI-based algorithms do not have to continuously run and perceive/classify and in some cases are called into use only if other triggering events do or do not call upon it. In this example, if relevant features of the coffee mug match the description of the desired mug, only then it is handled for further processing and its processing occur once or discretely in time as the tracking of the object is passed to the blob/pixel-correlation tracker that follows the mug but it otherwise no longer knowledgeable that it is a mug rather just an object (blob) it was told to track by prior/other fused algorithms.

To achieve lower brain power use in the human brain some sort of sensory deprivation is required since, for example, just the recognition of colors spark additional synapses. To achieve a similar reduction in computational load in machines, for example, the tracking of objects in time and space needs to be similarly "sensory deprived" of its classifications since the machine needs to only to make initial or discrete detections to momentarily achieve the complex perceptive decisions, unlike the perspective continuum afforded to the human brain during either conscious activity and dormancy.

FIG. 9 illustrates a schematic view of an exemplary embodiment of a system implementing one or more of the above-described embodiments illustrated in **FIGS. 1-8**. In this embodiment, the system comprises User Interface **300** and Server **500**, which communicate over Network **400**.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

Embodiments implemented in computer software may be implemented in software, firmware, middleware, microcode, hardware description languages, or any combination thereof. A code segment or machine-executable instructions may represent a sub-program, sub-process, sub-procedure, process, logic, logic flow, procedure, a function, a subprogram, a program, a routine, a subroutine, a module, a software package, a class, or any combination of instructions, data structures, or program statements. A code segment may be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, or memory contents. Information, arguments, parameters, data, etc. may be passed, forwarded, or transmitted via any suitable means including memory sharing, message passing, token passing, network transmission, etc.

The actual software code or specialized control hardware used to implement these systems and methods is not limiting of the methods and embodiments described herein. Thus, the operation and behavior of the systems and methods were described without reference to the specific software code being understood that software and control hardware can be designed to implement the systems and methods based on the description herein.

When implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable or processor-readable storage medium. The steps of a method or algorithm disclosed herein may be embodied in a processor-executable software module, which may reside on a computer-readable or processor-readable storage medium. A non-transitory computer-readable or processor-readable media includes both computer storage media and tangible storage media that facilitate transfer of a computer program from one place to another. A non-transitory processor-readable storage media may be any available media that may be accessed by a computer. By way of example, and not limitation, such non-transitory processor-readable media may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other tangible storage medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer or processor. Disk and disc, as used herein, include compact disc, laser disc, optical disc, digital versatile disc, floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

It is understood that the term database used herein may store a set of instructions, signal data, timestamps, and navigation messages. The database implementations include, but are not limited to, a random access memory (RAM), a read only memory (ROM), a hard disk drive (HDD), a secure digital (SD) card, a magneto-resistive read/write memory, an optical read/write memory, a cache memory, or a magnetic read/write memory. The database may further include one or more instructions that are executable by a processor associated with a server.

It is understood that the term server used herein may be a computing device comprising a processor and non-transitory machine-readable storage capable of executing various tasks and processes described herein. Non-limiting examples of the computing devices may include workstation computers, laptop computers, server computers, laptop computers, and the like. The system architecture may include any number of server computing devices operating in a distributed computing environment.

In accordance with the foregoing, a server may execute an algorithm to perform the algorithm fusion system and method described herein. The server may train a heuristic learning algorithm model, which is configured to emulate resolution patterns or working patterns of the image or object detected corresponding to processing of the application requests of one or more previously-considered images or objects. The heuristic learning algorithm model may be a machine learning data model, which may include data trees. During the training process of the heuristic learning algorithm model, the server may receive an input of a heuristic learning algorithm dataset. The heuristic learning algorithm dataset may include the profile data associated with the one or more images or objects. The server may use a support vector machine with the heuristic learning algorithm dataset as an input to generate the heuristic learning algorithm model. The support vector machine is a supervised learning model with associated learning algorithms that analyze the profile data used for classification and regression analysis. The support vector machine training algorithm builds the heuristic learning algorithm model that assigns new data to one category or the other, making it a non-probabilistic binary linear classifier. The heuristic learning algorithm model is a representation of the data as points in space. The heuristic learning algorithm model may include a network of decision nodes.

The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present subject matter. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the subject matter. Thus, the present subject matter is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

While various aspects and embodiments have been disclosed, other aspects and embodiments are contemplated. The various aspects and embodiments disclosed are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

We claim:

Claim 1. An algorithm fused system, comprising:

one or more processors configured to perform artificial intelligence computational processes designed to collaboratively enable autonomy and automation functionality to a robotic system utilizing the algorithm fused system, wherein

said system employs artificial intelligence based and traditional based algorithms that comprise adaptive functions within the identification, decision-making, prioritization, mitigation, and recording processes of the algorithm fused system, and

said system reclaims computational resources of the one or more processors by switching from an artificial intelligence-based tracking algorithm to a non-artificial intelligence tracking algorithm.

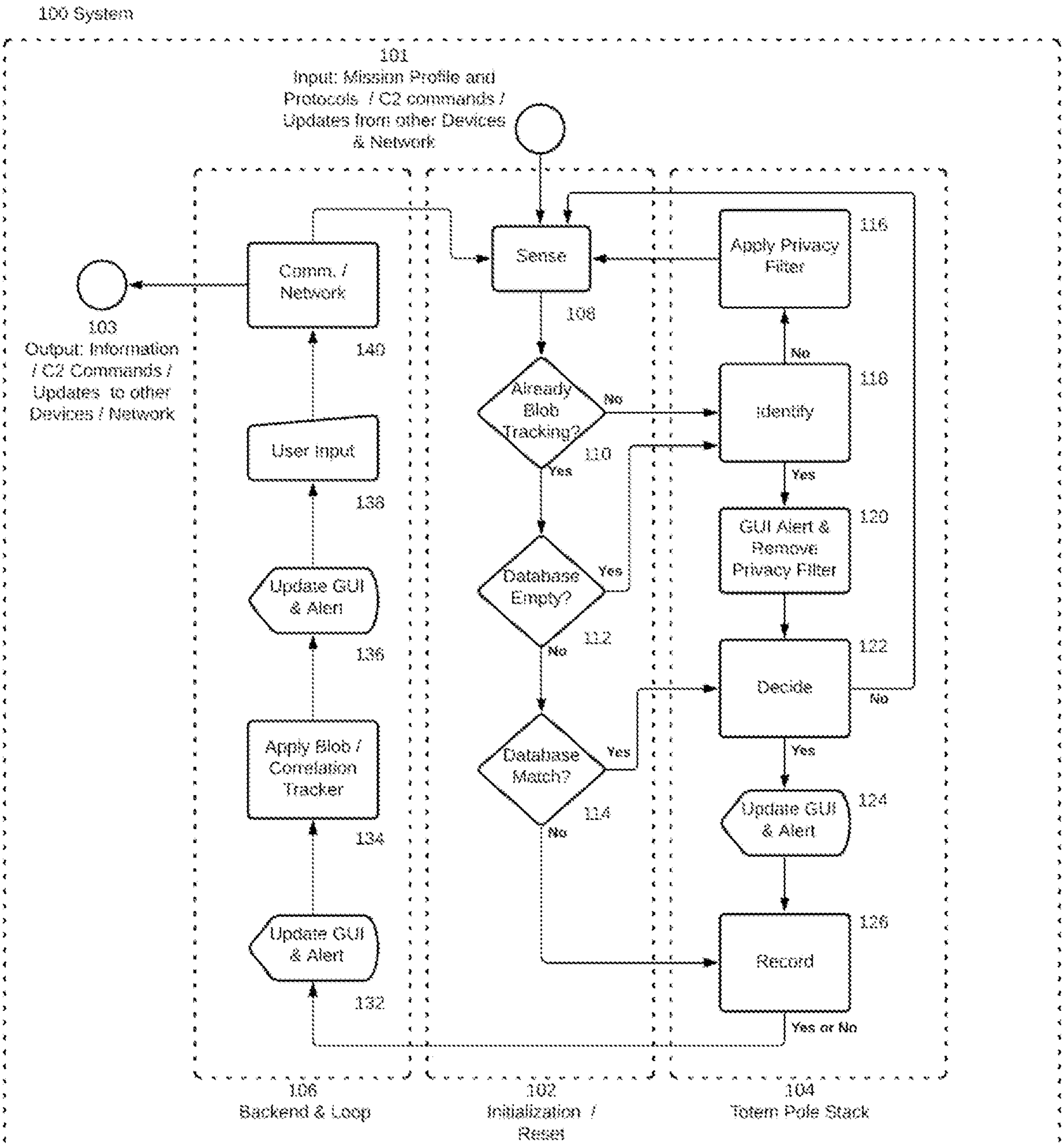
100 System
101
Input: Mission Profile and Protocols / C2 commands / Updates from other Devices & Network
103
Output: Information / C2 Commands / Updates to other Devices / Network
Comm. / Network
140
User Input
138
Update GUI & Alert
136
Apply Blob / Correlation Tracker
134
Update GUI & Alert
132
Sense
108
Already Blob Tracking?
110
No
Yes
Database Empty?
112
Yes
No
Database Match?
114
Yes
No
Apply Privacy Filter
116
Identify
118
No
Yes
GUI Alert & Remove Privacy Filter
120
Decide
122
No
Yes
Update GUI & Alert
124
Record
126
Yes or No
106
Backend & Loop
102
Initialization / Reset
104
Totem Pole Stack

FIG. 1

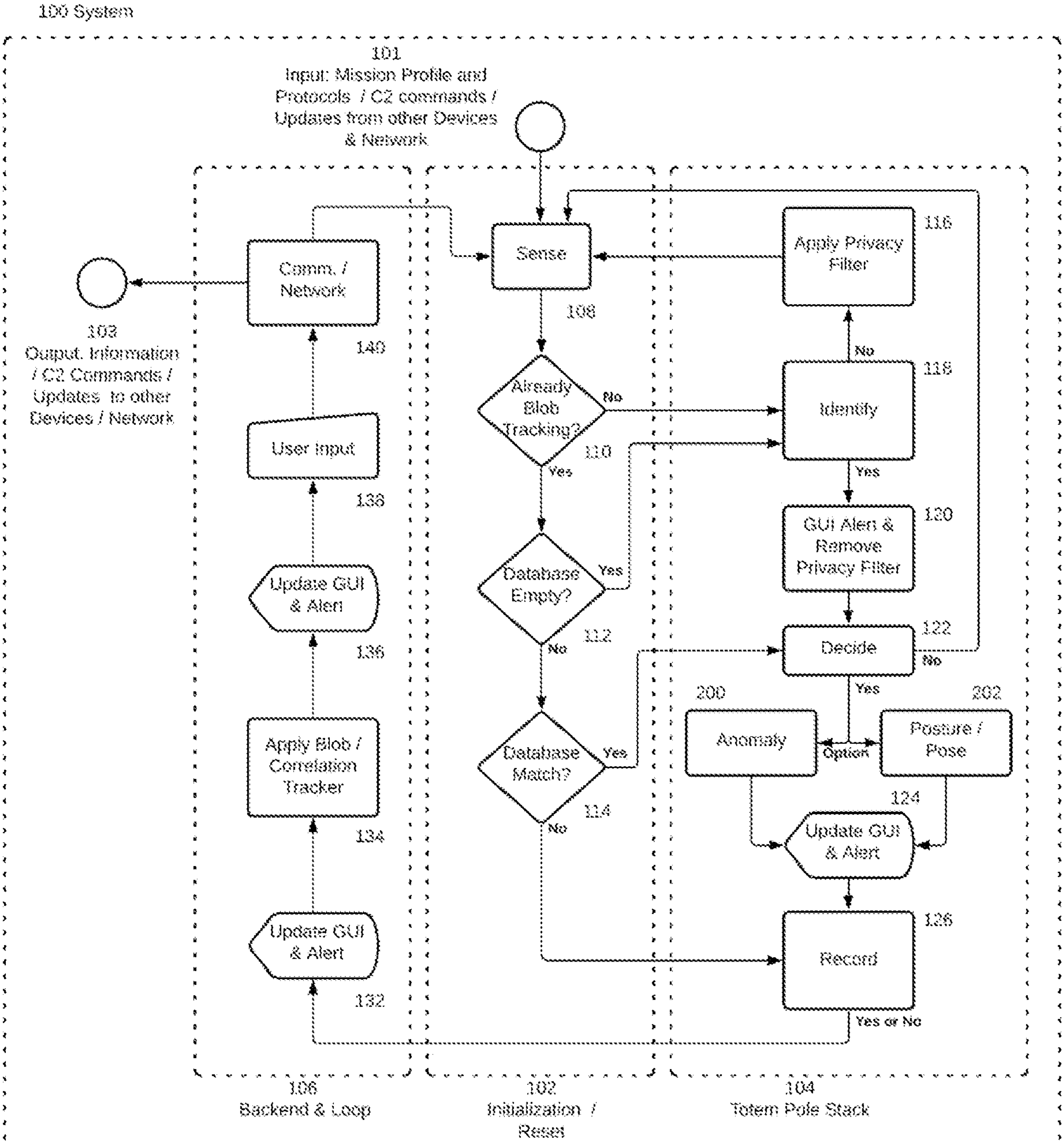
100 System
101
Input: Mission Profile and Protocols / C2 commands / Updates from other Devices & Network
Sense
108
Comm. / Network
103
Output: Information / C2 Commands / Updates to other Devices / Network
140
User Input
138
Update GUI & Alert
136
Apply Blob / Correlation Tracker
134
Update GUI & Alert
132
Already Blob Tracking?
No
Yes
110
Database Empty?
Yes
No
112
Database Match?
Yes
No
114
Apply Privacy Filter
116
No
Identify
118
Yes
GUI Alert & Remove Privacy Filter
120
Decide
122
No
Yes
200
Anomaly
Option
Posture / Pose
202
124
Update GUI & Alert
126
Record
Yes or No
106
Backend & Loop
102
Initialization / Reset
104
Totem Pole Stack

FIG. 2

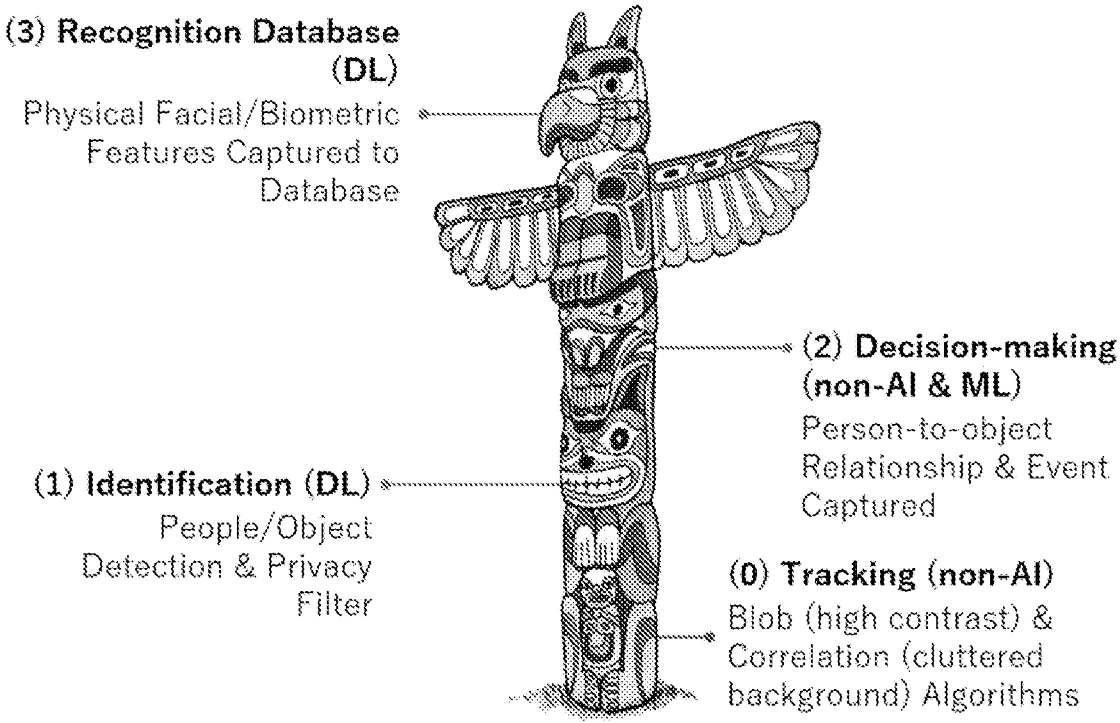
(3) Recognition Database (DL)
Physical Facial/Biometric Features Captured to Database
(2) Decision-making (non-AI & ML)
Person-to-object Relationship & Event Captured
(1) Identification (DL)
People/Object Detection & Privacy Filter
(0) Tracking (non-AI)
Blob (high contrast) & Correlation (cluttered background) Algorithms

FIG. 3

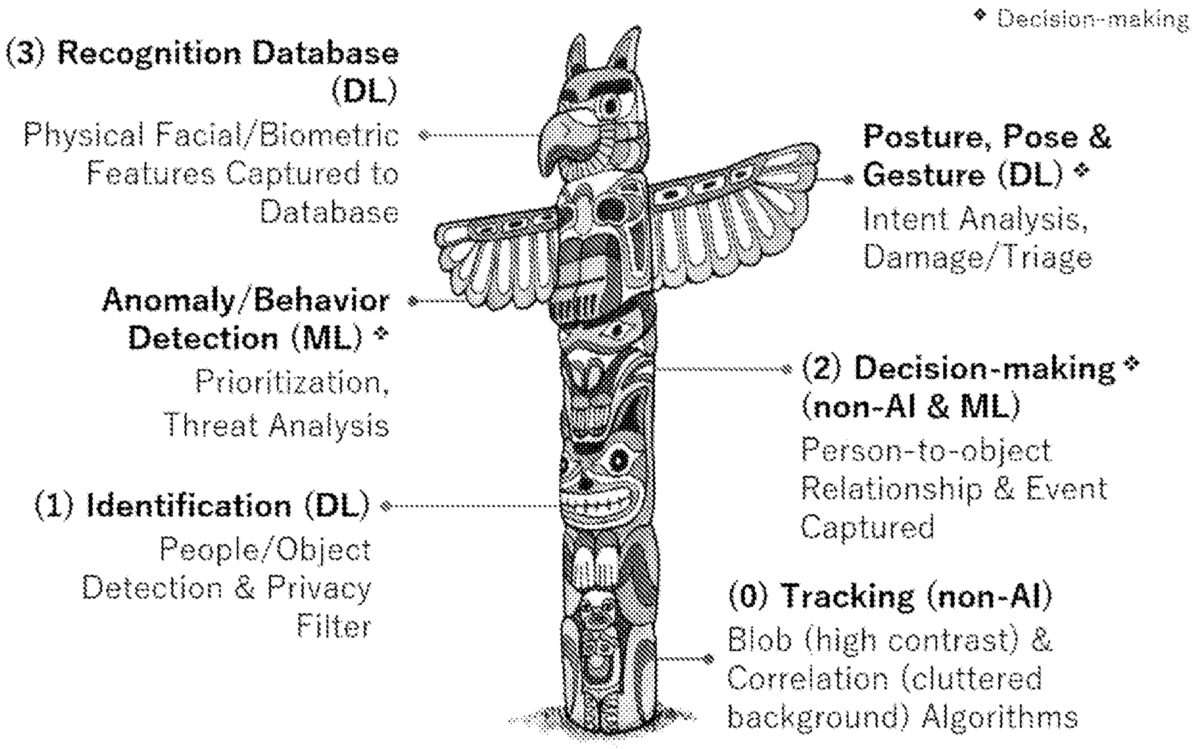
❖ Decision-making
(3) Recognition Database (DL)
Physical Facial/Biometric Features Captured to Database
Posture, Pose & Gesture (DL) ❖
Intent Analysis, Damage/Triage
Anomaly/Behavior Detection (ML) ❖
Prioritization, Threat Analysis
(2) Decision-making ❖ (non-AI & ML)
Person-to-object Relationship & Event Captured
(1) Identification (DL)
People/Object Detection & Privacy Filter
(0) Tracking (non-AI)
Blob (high contrast) & Correlation (cluttered background) Algorithms

FIG. 4

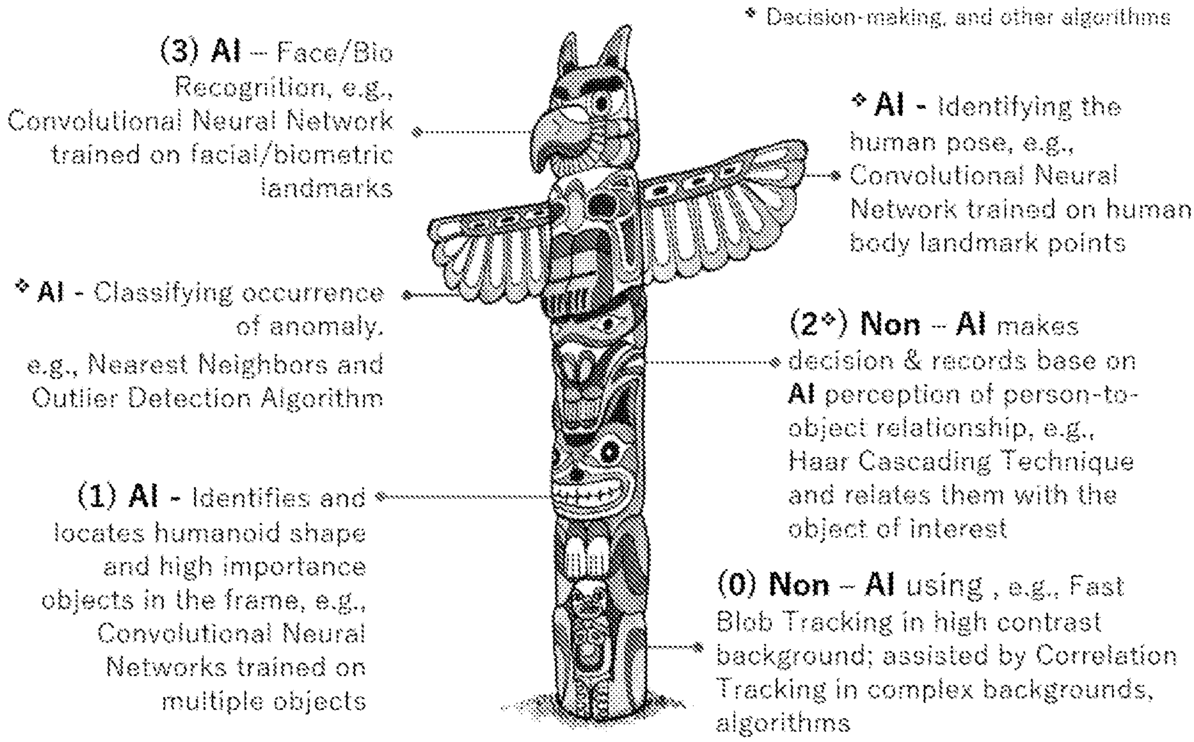
❖ Decision-making, and other algorithms
(3) AI – Face/Bio Recognition, e.g., Convolutional Neural Network trained on facial/biometric landmarks
❖ AI - Identifying the human pose, e.g., Convolutional Neural Network trained on human body landmark points
❖ AI - Classifying occurrence of anomaly. e.g., Nearest Neighbors and Outlier Detection Algorithm
(2❖) Non – AI makes decision & records base on AI perception of person-to-object relationship, e.g., Haar Cascading Technique and relates them with the object of interest
(1) AI - Identifies and locates humanoid shape and high importance objects in the frame, e.g., Convolutional Neural Networks trained on multiple objects
(0) Non – AI using , e.g., Fast Blob Tracking in high contrast background; assisted by Correlation Tracking in complex backgrounds, algorithms

FIG. 5

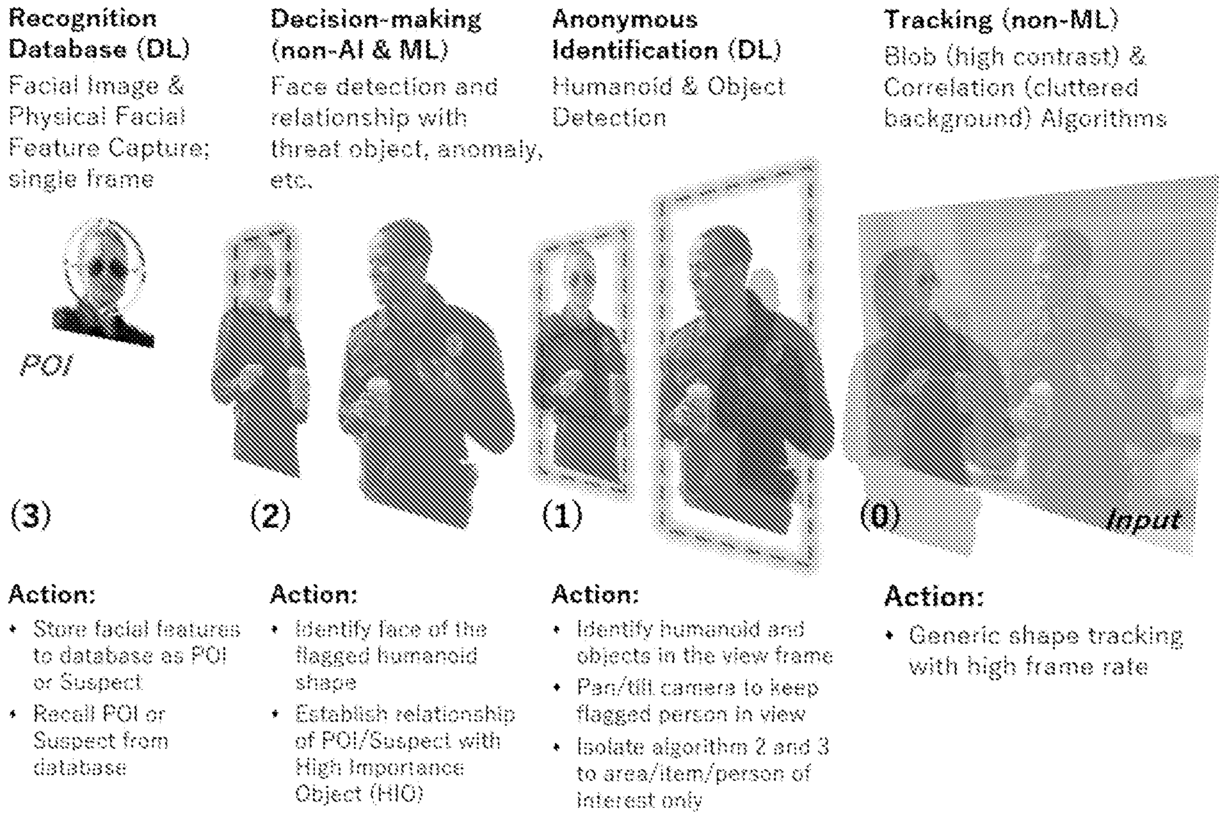
Recognition Database (DL)
Facial Image & Physical Facial Feature Capture; single frame
Decision-making (non-AI & ML)
Face detection and relationship with threat object, anomaly, etc.
Anonymous Identification (DL)
Humanoid & Object Detection
Tracking (non-ML)
Blob (high contrast) & Correlation (cluttered background) Algorithms
POI
(3)
(2)
(1)
(0)
Input
Action:
• Store facial features to database as POI or Suspect
• Recall POI or Suspect from database
Action:
• Identify face of the flagged humanoid shape
• Establish relationship of POI/Suspect with High Importance Object (HIO)
Action:
• Identify humanoid and objects in the view frame
• Pan/tilt camera to keep flagged person in view
• Isolate algorithm 2 and 3 to area/item/person of interest only
Action:
• Generic shape tracking with high frame rate

FIG. 6

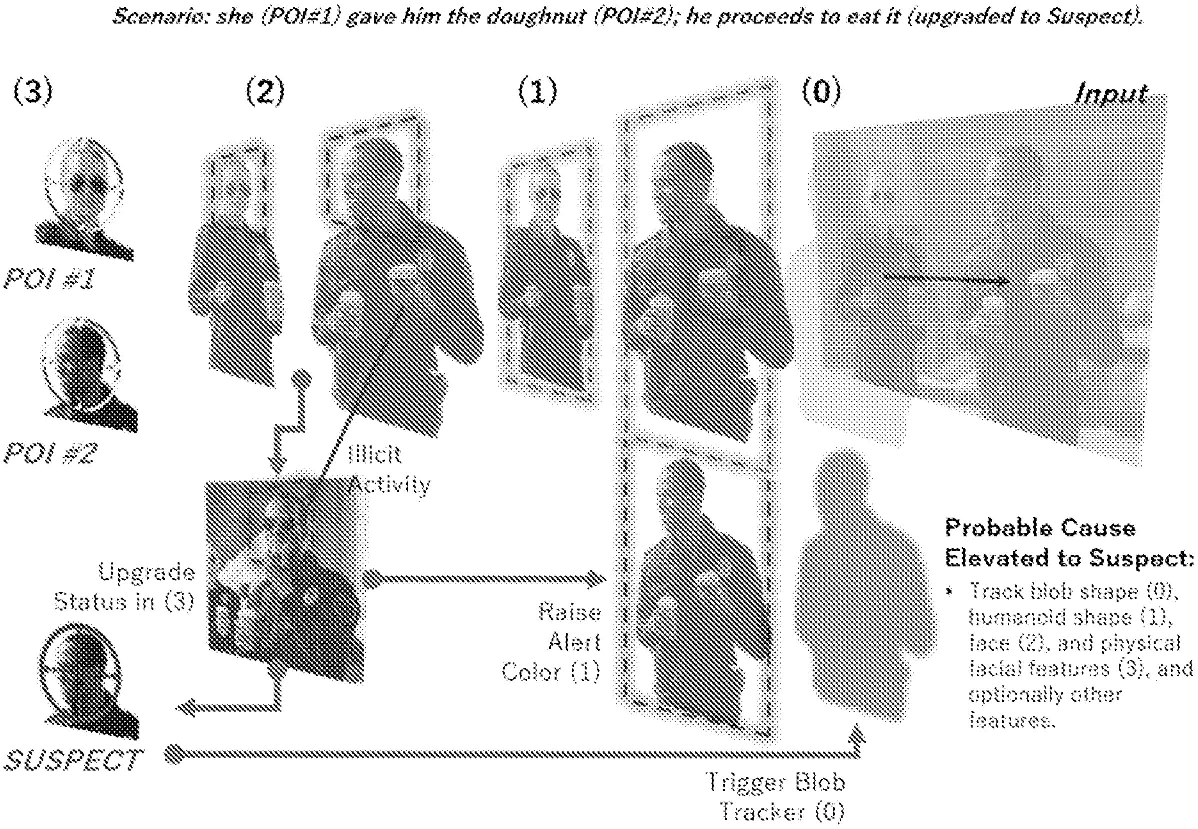
Scenario: she (POI#1) gave him the doughnut (POI#2); he proceeds to eat it (upgraded to Suspect).
(3)
(2)
(1)
(0)
Input
POI #1
POI #2
Illicit Activity
Upgrade Status in (3)
Raise Alert Color (1)
SUSPECT
Trigger Blob Tracker (0)
Probable Cause Elevated to Suspect:
• Track blob shape (0), humanoid shape (1), face (2), and physical facial features (3), and optionally other features.

FIG. 7


FPS : 44.79
person
FPS : 39.46
FPS : 20.43
POI : Database Empty
Suspect : Database Empty
FPS : 38.13
person
donut
FPS : 65.61
POI
FPS : 27.30
POI
POI : MATCH
Suspect : Database Empty
FPS : 45.92
donut
FPS : 61.25
Suspect
FPS : 23.19
Suspect
POI : MATCH
Suspect : MATCH

FIG. 8

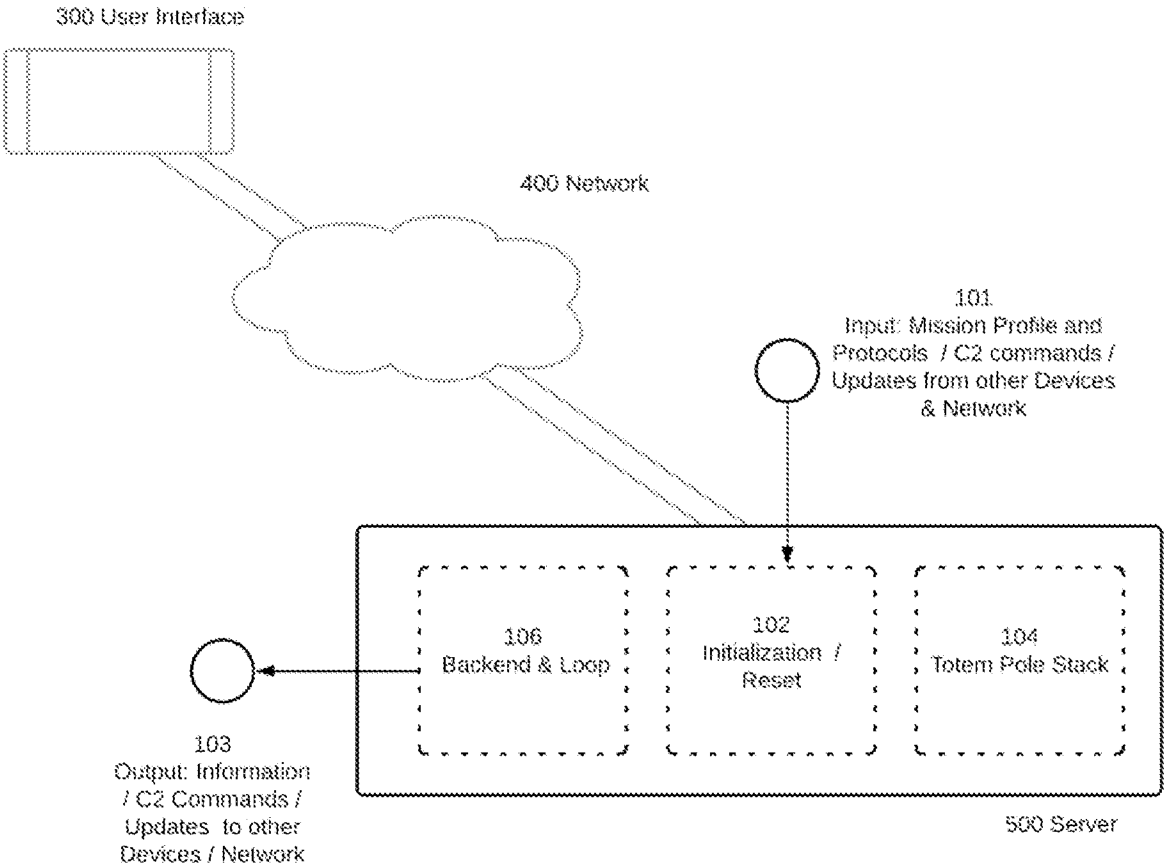
300 User Interface
400 Network
101
Input: Mission Profile and Protocols / C2 commands / Updates from other Devices & Network
106
Backend & Loop
102
Initialization / Reset
104
Totem Pole Stack
103
Output: Information / C2 Commands / Updates to other Devices / Network
500 Server

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/25632

A. CLASSIFICATION OF SUBJECT MATTER

IPC - G05B 19/04 (2021.01)

CPC - B25J 9/161, B25J 9/1661, B25J 9/1666, B25J 9/1664, B62D 57/032, G06F 9/50, G06F 11/2257, G06N 5/04, H04L 41/16, G06N 5/003, G05B 13/027, G05B 13/0275, G05B 13/0285, B21B 37/16, B25J 9/161

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0183569 A1 (Solomon) 25 August 2005 (25.08.2005), entire document especially para [0017]-[0021], [0036], [0055], [0155], [0179]-[0182], [0193], [0207], [0230], [0233], [0245], [0251], [0256], [0264], [0291], [0293]	1
Y	US 2020/0005116 A1 (SONY CORPORATION) 02 January 2020 (02.01.2020), para [0024], [0025], [0030]	1
A	US 2018/0028811 A1 (VAN GERWEN et al.) 01 February 2018 (01.02.2018), para [0097]	1
A	US 2019/0360717 A1 (LG ELECTRONICS INC.) 28 November 2019 (28.11.2019), entire document	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 July 2021 (14.07.2021)	AUG 04 2021

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300