AUTONOMOUS ARTIFICIAL ENVIRONMENT GENERATION, CONTROL, AND EXPLORATION SYSTEM FOR DISCOVERY OF NOVEL ENVIRONMENTAL CONDITIONS

FULL PATENT SPECIFICATION DRAFT

Inventor: Omar Mohamed Rageh Kamal Fawzy

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ABSTRACT

An autonomous artificial environment generation, control, and exploration system is disclosed for producing, monitoring, modifying, and investigating experimental environments having combinations of physical, atmospheric, thermal, electromagnetic, material, illumination, flow, and other controllable conditions. The system comprises an environmental chamber, environmental conditioning devices, sensors, a computational control system, a data storage system, and optionally an autonomous exploration device. Environmental parameters are selectively modified to generate predetermined, randomized, constrained, or computationally proposed environmental states. Sensor information is collected and processed to evaluate interactions between environmental variables, materials, energy conditions, and observed responses. An exploration device may navigate within the generated environment and collect spatially distributed information. A computational discovery engine may compare experimental results, identify unusual or previously untested responses, generate candidate environmental conditions, and initiate or recommend additional experimental cycles. The system provides a controlled platform for investigating hypothetical, planetary analogue, extreme, and previously untested environmental conditions while maintaining a recorded environmental history and experimental data library.

1. TECHNICAL FIELD

The disclosure relates to systems for generating and investigating controlled experimental environments. More particularly, it relates to an integrated platform comprising an environmental chamber, parameter-control devices, sensing systems, computational control and discovery functions, and optionally robotic exploration equipment for generating, controlling, exploring, recording, and comparing novel combinations of environmental conditions.

2. BACKGROUND OF THE INVENTION

Environmental simulation systems commonly reproduce known conditions such as selected temperature, humidity, pressure, atmosphere, or test-standard requirements. Robotic and analytical systems may separately investigate environments. A need remains for an integrated architecture that can generate sequences of controlled environmental states, explore them using distributed sensors or autonomous devices, analyze results, identify unusual behavior, propose new candidate conditions, and maintain a reusable library of experiments.

3. SUMMARY OF THE INVENTION

The system comprises an environmental chamber; an environmental control core connected to thermal, pressure, atmosphere, humidity, illumination, magnetic, flow, material, or other conditioning subsystems; a plurality of sensors; a computational controller; a data storage and analysis system; and optionally an exploration robot. A discovery engine may select new parameter combinations based on predefined ranges, constraints, randomization, optimization, novelty scoring, simulation output, observed anomalies, or user-defined hypotheses.

4. OVERALL SYSTEM ARCHITECTURE

The architecture may include an environmental chamber, sensor array, environmental control core, conditioning subsystems, actuator network, data storage and analysis unit, environmental library, autonomous exploration device, and safety or isolation subsystem. The system can be centralized, distributed, or hybrid and may be implemented at compact laboratory scale or expanded to multiple chambers.

5. ENVIRONMENTAL CHAMBER

The chamber provides a controlled experimental volume containing one or more material beds, terrain surfaces, samples, test objects, fixed sensors, and optionally a mobile exploration device. It may include access ports, docking interfaces, observation regions, service penetrations, material-delivery ports, drainage features, isolation structures, and replaceable internal modules. Operating ranges should be engineered for the equipment and maintained within applicable safety requirements.

6. ENVIRONMENTAL PARAMETER CONTROL

The system may control two or more of temperature, pressure, humidity, gas composition, flow, illumination spectrum, illumination intensity, magnetic conditions, acoustic conditions, surface composition, terrain geometry, and liquid conditions. The control core compares measured and target values and operates permitted actuators including heaters, cooling devices, valves, pumps, fans, lighting modules, and material-delivery equipment.

7. SENSING AND DATA ACQUISITION

Sensors may measure temperature, pressure, humidity, gas properties, flow, illumination, magnetic conditions, electrical conditions, vibration, material response, and imaging information. Sensors can be fixed, mobile, embedded in samples, or carried by an exploration device. Observations may be synchronized with setpoints, timestamps, spatial locations, and experiment identifiers.

8. AUTONOMOUS EXPLORATION DEVICE

An optional exploration device may move within the chamber or operate from a fixed or articulated mounting system. It may include cameras, depth or range sensors, environmental sensors, sampling tools, manipulators, processors, communication equipment, and power systems. The device can execute an observation path, inspect materials, collect spatially distributed information, and generate an environmental map.

9. ENVIRONMENTAL DISCOVERY ENGINE

The discovery engine analyzes observations and generates or ranks candidate environmental states. Candidate generation may use parameter sweeps, constrained combinations, simulation results, novelty metrics, anomaly detection, optimization objectives, or user-defined scientific goals. Candidates can be ranked according to difference from prior observations, repeatability, material response, spatial variation, or other selected criteria.

10. CLOSED-LOOP OPERATION

A representative cycle comprises selecting a candidate environment; configuring chamber parameters; stabilizing the environment; verifying target conditions; exploring with fixed and/or mobile sensors; collecting observations; analyzing results; identifying unusual or informative responses; generating a subsequent candidate; and repeating the cycle subject to defined operating constraints.

11. ENVIRONMENT LIBRARY AND EXPERIMENTAL MEMORY

The system may store each generated environment with parameter values, timing information, sensor records, exploration paths, material identifiers, images, observations, control actions, and verification results. The library can support comparison, reproducibility, identification of unexplored parameter regions, and generation of future experimental candidates.

12. EXAMPLE EMBODIMENTS

Example embodiments include a planetary-analogue terrain module; an extreme thermal cycling module; a variable atmosphere and humidity module; an adaptive terrain module; a computational discovery mode that recommends the next experiment; and a distributed multi-chamber system operating in parallel with a shared environmental library.

13. FIGURE DESCRIPTIONS

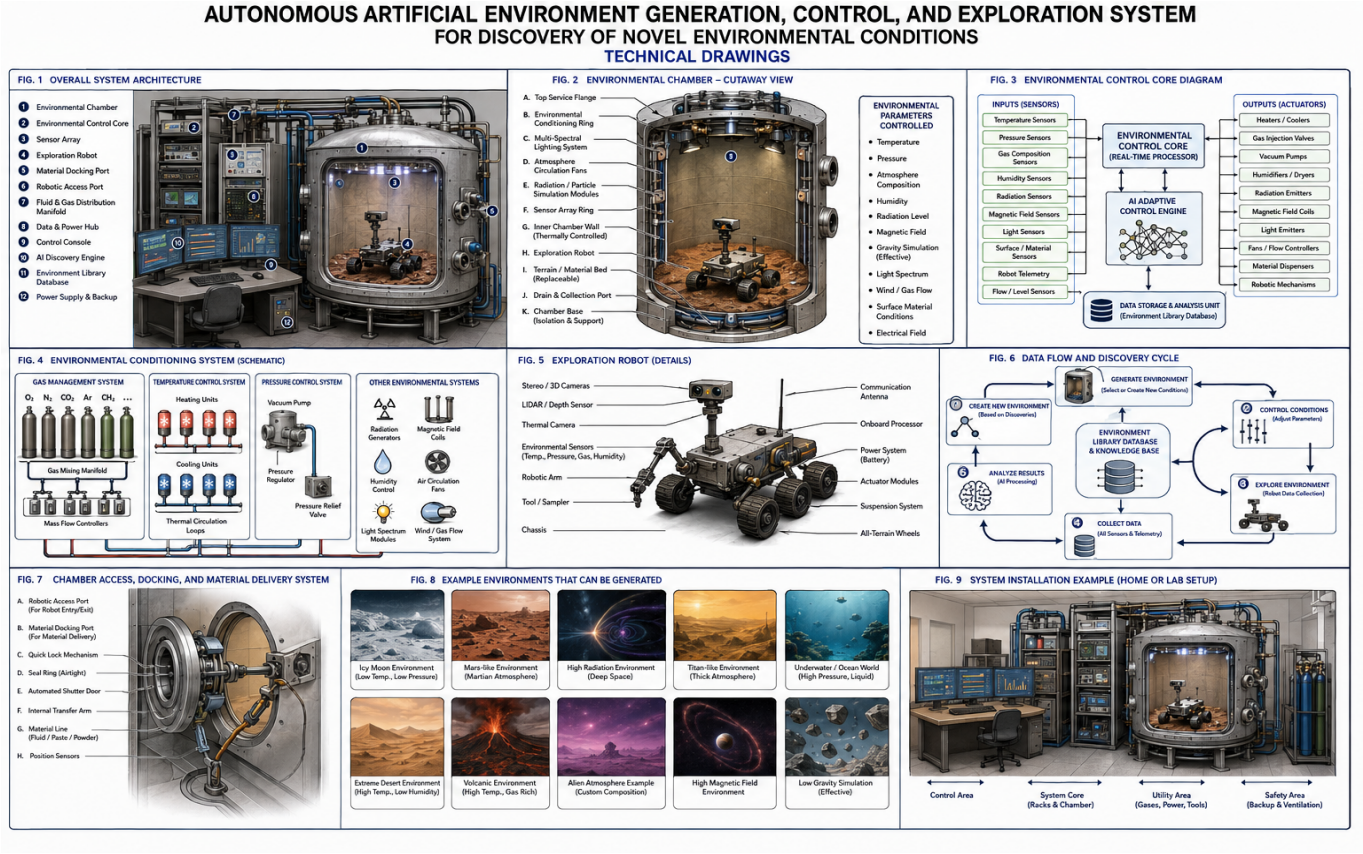
FIG. 1 illustrates the overall architecture. FIG. 2 illustrates a chamber cutaway. FIG. 3 illustrates the environmental control core. FIG. 4 illustrates conditioning subsystems. FIG. 5 illustrates an exploration robot. FIG. 6 illustrates the data flow and discovery cycle. FIG. 7 illustrates access, docking, and material delivery. FIG. 8 illustrates example environment classes. FIG. 9 illustrates a compact home or laboratory installation arrangement.

14. INDUSTRIAL APPLICABILITY

The technology may be applied to environmental science, materials testing, robotics development, education, controlled environmental research, space analogue research, infrastructure material research, sensor development, and computational experimentation.

15. TECHNICAL DRAWINGS

Patent-style technical drawings illustrating the system architecture, chamber, control core, conditioning systems, exploration robot, discovery cycle, access and material delivery, example environment classes, and installation arrangement.



16. CLAIMS

1. An autonomous artificial environment generation and exploration system comprising an environmental chamber, a plurality of environmental conditioning devices configured to modify environmental parameters within the chamber, a plurality of sensors configured to measure conditions within the chamber, a computational control system, and a data analysis system, wherein the computational control system is configured to generate or select an environmental state and operate the conditioning devices to establish the environmental state.

2. The system of claim 1, wherein the environmental parameters comprise two or more of temperature, pressure, humidity, gas composition, flow, illumination, surface condition, liquid condition, magnetic condition, acoustic condition, or material configuration.

3. The system of claim 1, wherein the environmental chamber comprises a replaceable terrain or material module.

4. The system of claim 1, wherein the conditioning devices comprise at least one of a heater, cooling device, valve, pump, humidification device, dehumidification device, fan, illumination module, material delivery device, or field-generating device.

5. The system of claim 1, wherein the computational control system performs closed-loop control using sensor information.

6. The system of claim 1, further comprising an environmental library storing records associated with previously generated environmental states.

7. The system of claim 6, wherein each record includes parameter values and sensor observations associated with an experimental cycle.

8. The system of claim 6, wherein the environmental library stores an identifier for a material, terrain, or test object associated with an environmental state.

9. The system of claim 1, further comprising an autonomous exploration device configured to acquire spatially distributed observations within the environmental chamber.

10. The system of claim 9, wherein the autonomous exploration device comprises an imaging sensor.

11. The system of claim 9, wherein the autonomous exploration device comprises an environmental sensor.

12. The system of claim 9, wherein the autonomous exploration device is configured to generate a map or spatial representation of a chamber environment.

13. The system of claim 1, wherein the data analysis system identifies a response that differs from a baseline observation.

14. The system of claim 13, wherein the data analysis system identifies an anomalous or unusual response based on comparison with prior environmental records.

15. The system of claim 1, wherein a discovery engine generates candidate environmental states according to combinations of environmental parameters.

16. The system of claim 15, wherein candidate environmental states are generated according to predefined parameter ranges and constraints.

17. The system of claim 15, wherein candidate environmental states are ranked according to an information, novelty, anomaly, optimization, or user-defined criterion.

18. The system of claim 15, wherein the discovery engine selects a subsequent environmental state based at least in part on observations from a preceding environmental state.

19. The system of claim 1, further comprising a stabilization procedure configured to verify target conditions before an exploration operation.

20. The system of claim 1, wherein the environmental chamber comprises a docking interface for the exploration device.

21. The system of claim 20, wherein the docking interface provides at least one of charging, data transfer, positioning, or tool exchange.

22. The system of claim 1, wherein the environmental chamber comprises a material delivery port configured to introduce terrain material, test material, or an experimental object.

23. The system of claim 1, wherein a plurality of sensors are positioned at spatially separated locations within the chamber.

24. The system of claim 23, wherein sensor observations are associated with spatial location information.

25. The system of claim 1, wherein the control system is configured to repeat a sequence comprising environment generation, stabilization, exploration, data collection, analysis, and candidate generation.

26. The system of claim 25, wherein a result of one sequence influences selection of a subsequent sequence.

27. The system of claim 1, further comprising a supervisory user interface configured to display current conditions, historical environmental states, exploration data, and candidate experiments.

28. A method of discovering novel environmental conditions comprising selecting or generating a candidate combination of environmental parameters, configuring an environmental chamber to establish the candidate combination, collecting observations from one or more sensors, analyzing the observations, determining a difference, anomaly, or informative response, generating or ranking a subsequent candidate combination, and repeating the method.

29. The method of claim 28, wherein collecting observations comprises operating an autonomous exploration device.

30. The method of claim 28, wherein generating the subsequent candidate combination comprises identifying an unexplored region of a permitted environmental parameter space.

31. The method of claim 28, further comprising storing the candidate combination and corresponding observations in an environmental library.

32. The method of claim 28, further comprising reproducing a previously stored environmental state for verification or comparison.

33. A controlled environmental research platform comprising a plurality of environmental chambers, each chamber configured to generate a different environmental state, wherein a shared computational system compares observations across the plurality of chambers.

34. The platform of claim 33, wherein the shared computational system identifies environmental states producing different responses for a common material, object, or exploration device.

35. An environmental discovery controller comprising a processor and memory storing instructions that cause the processor to receive environmental observations, compare the observations with stored experimental records, generate candidate environmental conditions subject to predefined constraints, and output control instructions for establishing a selected candidate condition.

36. The controller of claim 35, wherein the predefined constraints include equipment capability limits or safety limits.

37. A modular environmental chamber comprising a controlled experimental volume, a plurality of sensor interfaces, a plurality of conditioning interfaces, a replaceable internal material module, and a docking interface for an exploration device.

38. The modular environmental chamber of claim 37, wherein the replaceable internal material module defines a terrain, surface, sample holder, liquid region, or combination thereof.

39. The system of claim 1, wherein environmental conditions are represented as a multidimensional parameter vector and stored with corresponding experimental observations.

40. The system of claim 39, wherein the discovery engine selects a candidate parameter vector based on a predicted difference from previously stored parameter vectors or responses.

17. CONCLUDING DISCLOSURE

The disclosed system provides a closed-loop platform for generating, controlling, exploring, recording, and comparing controlled environmental states. The integration of environmental generation, distributed sensing, autonomous exploration, computational analysis, environmental memory, and iterative candidate selection supports systematic investigation of previously untested or informative combinations of conditions.

18. PATENT DEVELOPMENT NOTICE

Before filing, a focused prior-art search and novelty mapping should be conducted, especially around the integrated closed-loop relationship between environmental generation, exploration, result comparison, environmental library storage, and iterative selection of subsequent candidate states.