SIERRA: A Modular Framework for Research Automation

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ABSTRACT
Modern intelligent systems researchers employ the scientific method: they form hypotheses about system behavior, and then run experiments using one or more independent variables to test their hypotheses. We present SIERRA, a novel framework structured around that idea for accelerating research developments and improving reproducibility of results. SIERRA makes it easy to quickly specify the independent variable(s) for an experiment, generate experimental inputs, automatically run the experiment, and process the results to generate deliverables such as graphs and videos. SIERRA provides reproducible automation independent of the execution environment (HPC hardware, real robots, etc.) and targeted platform (arbitrary simulator or real robots), enabling exact experiment replication (up to the limit of the execution environment and platform). It employs a deeply modular approach that allows easy customization and extension of automation for the needs of individual researchers, thereby eliminating manual experiment configuration and result processing via throw-away scripts.

KEYWORDS
Scientific Method, Research Automation, Simulation, Real Robots

1 INTRODUCTION
In modern intelligent agents research, reproducibility is crucial. Configuring experiments for testing hypotheses can be time consuming, and further compounded by the need to deal with different configurations for specific platforms (e.g., ROS [9]) and execution environments (e.g., SLURM [10] clusters). Ad hoc tools and scripts are frequently developed to meet these needs on a per-project basis, and reused or modified as needed between projects. Scripts for processing and visualizing experimental results are developed similarly. In this paper, we present SIERRA, a framework to automate the process of hypothesis testing and results processing. SIERRA is complementary to other reproducibility-enhancing tools for AI research such as Robotarium [7] and IEEE Code Ocean.

SIERRA is modular, and can be extensively customized to meet a diverse range of researcher needs. Originally developed for robotics research, its modular design makes it capable of supporting almost any platform and execution environment in AI research.

SIERRA experiments are fully reproducible, regardless of the platform targeted and the execution environment on which the experiments are run. SIERRA currently supports the ARGoS [8], Gazebo [5], and ROS [9] platforms. To the best of our knowledge no automation exists for these platforms for hypothesis testing and results processing—crucial parts of intelligent systems research. Some partial automation of Webots [6] was done in [2]; such automation is a subset of SIERRA’s capabilities. Independent from the targeted platform, SIERRA currently supports several execution environments for running experiments: PBS/SLURM clusters, real robots, and the local machine. New execution environment or platform support can be easily added as python modules. Through automation, SIERRA streamlines the process of publishing reproducible research: all automation provided by SIERRA is idempotent.

SIERRA is a cohesive framework for end-to-end automation of the scientific method in intelligent systems research. SIERRA automates the pipeline described in Section 2 and Fig. 1, eliminating the need for throw-away scripts, greatly reduces menial re-configuration of experimental inputs across platforms and execution environments, and provides a uniform interface for generating camera-ready deliverables such as graphs and videos for inclusion in academic papers. Essentially, SIERRA handles the “backend” parts of research, allowing researchers to focus on the “research” aspects: developing theories and testing hypotheses via experimental evaluation.

2 SIERRA OVERVIEW
SIERRA supports research queries: a hypothesis expressed as a query of an independent variable over some range, expressed in a user-defined command line syntax (e.g., population_size.Log8 for representing varying the number of agents across [1,2,4,8]). The expressed query is used to define a batch experiment: a set of experiments each with a different value of the independent variable (number of agents in the above example). Each experiment consists of one or more experimental runs which can be simulation runs or real robot trials. For some types of research, multiple experimental runs are required due to randomness (e.g., imperfect sensors/actuators on real robots); SIERRA provides configurations for managing this complexity and for generating and plotting statistical distributions over results, and handles all necessary platform and execution environment configuration. However, it does not attempt to homogenize configurations such that the results of a research query can be answered in a platform and execution environment independent way (which is not possible in general).

SIERRA has been used for several publications in top conferences [3, 4] using ARGoS and PBS/SLURM HPC clusters. In this
work, we further demonstrate its utility by generating experiments for ROS and real robots. We also demonstrate how SIERRA can be used to explore independent variables in a short demonstration. SIERRA addresses the need for reproducibility and research acceleration in intelligent systems, and we therefore strongly argue for its inclusion in any researcher’s toolbox.

2.1 Experimental Input Generation
To generate the batch experiment, a template XML file is modified according to the research query, with one experiment generated for each “value” of the independent variable(s), so that by comparing results across experiments in the batch, changes in behavior in response to the different “values” can be observed. Each “value” may correspond to a single change to the template via (e.g., population_size, Log8 for changing the number of agents), or it can correspond to multiple changes (e.g., testing across a set of environments which require setting multiple XML parameters for each one). SIERRA also supports changing additional parts of the template input file uniquely for each experiment in the batch, or uniformly for all experiments, providing unparalleled expressiveness to support research automation through experiment generation.

2.2 Running Experiments
Experimental run inputs are executed on some simulator or real-robot platform in some execution environment. For example, a researcher may want to run simulations targeting ARGoS [8] on a SLURM managed cluster, or to run experiments generated from the same research query on the ROS [9] platform with a real robot (e.g., Turtlebot3 [1]). Switching between platforms and/or execution environments naturally requires some code changes (e.g., cross-compiling). However, a lot of additional researcher time is spent figuring out how to get an experiment to run within a given environment, which slows down the actual research. SIERRA handles this complexity, reducing the burden on researchers.

2.3 Processing Experimental Results
Outputs from executed experiments are processed. This includes statistical distribution generation across experimental runs for each experiment in a batch, as well as across experiments in a batch, and converting output .csv files into images which can be stitched together into videos during stage 4.

2.4 Generating Deliverables
Processed experimental results are used to generate deliverables to accompany or be part of published research. This can include graphs or videos showing different aspects of the system’s response to the research query. SIERRA’s automation in this stage makes it easy to modify a specific graph or video, if, for example, one needs to be modified at a reviewer’s request, eliminating the tedious process of locating previously written throw-away scripts to regenerate it, again saving time. Furthermore, this automation also improves reproducibility: with a single SIERRA command on a properly configured environment researcher B could reproduce the exact results of researcher A if both were using SIERRA and they had access to researcher A’s agent code.

2.5 Deliverable Comparison
After deliverable generation, multiple deliverables are combined to provide side-by-side comparisons. For example, comparing the performance of a new reinforcement learning method against the current state-of-the-art method, each of which was independently generated during the previous stage may be desirable.
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