Labs of the Future

Sebastian Grabill, Dr. Tyrel McQueen, Dr. David Elbert
Johns Hopkins University, Baltimore, MD, USA

Introduction

The advent of autonomous systems is revolutionizing the way scientific research is conducted, particularly in the field of laboratory automation. This poster presents an overview of the integration of data acceleration, automation, and AI-driven decision-making in research environments. By focusing on molten zone characterization and the development of microcontroller-based Graphical User Interfaces (GUIs), this study illustrates how these technologies contribute to the creation of autonomous laboratories where human intervention is minimized.

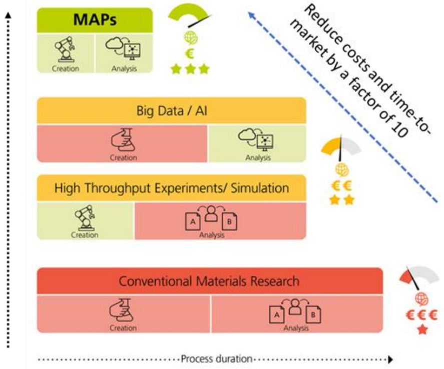

Fig. 1: path to Materials Acceleration Platforms.

Data acceleration is key to achieving autonomy in laboratories. By enabling rapid processing and real-time analysis, it supports quicker and more accurate decision-making. This section discusses how faster data handling enhances research efficiency, particularly in processes that require immediate adjustments, such as molten zone characterization.

Fig. 3: High Pressure Floating Zone Furnace.

Molten zone characterization involves studying material properties under extreme temperatures. Automation in this process allows for precise control over critical variables like temperature and rotation speed. The integration of AI ensures real-time monitoring and adjustments, improving the accuracy and repeatability of experimental outcomes.

Fig. 2: Molten zone during growth in High Pressure Floating Zone Furnace.

Development Process

Graphical User Interfaces (GUIs) play a vital role in laboratory automation by facilitating seamless interaction between researchers and complex hardware systems. Utilizing the Qt framework, signals and slots enable effective communication between the GUI and hardware components, allowing real-time monitoring and control of experimental parameters.

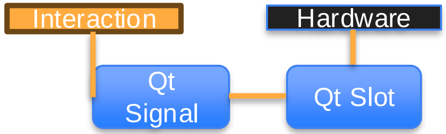

Fig. 4: Definition of Qt information pipeline

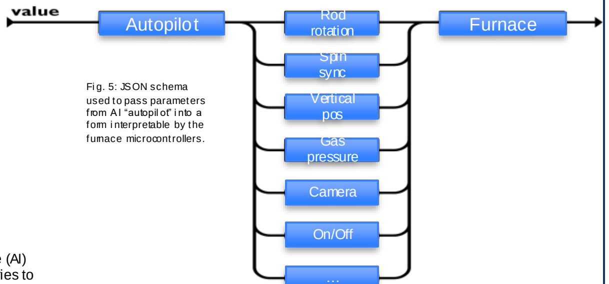

Fig. 5: JSON schema used to pass parameters from AI "autopilot" into a form interpretable by the furnace microcontrollers.

Artificial Intelligence (AI) empowers laboratories to operate autonomously by interpreting sensor data and making real-time adjustments to the experimental setup. This section covers the AI model's capabilities in reducing human oversight, ensuring precision, and enhancing the overall efficiency of research operations.

Fig. 6: Diagram of real-time processing between furnace microcontrollers and autopilot.

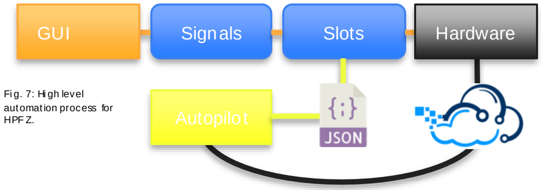

Fig. 7: High level automation process for HPFZ.

Automation Candidate

The Laser Diode Floating Zone Furnace is an ideal candidate for automation due to its need for precise control in high-temperature material synthesis. Implementing AI-driven decision-making and advanced GUIs could enhance both accuracy and efficiency, while also enabling large-scale control over critical systems through digital interfaces, highlighting the potential for automating complex research processes.

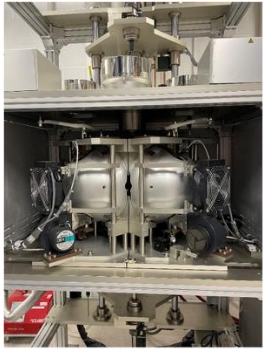

Fig. 8: Internals of Laser Diode Floating Zone Furnace.

Future work

Future efforts will focus on refining AI-driven decision-making and enhancing data acceleration techniques to further reduce human oversight. Improvements to microcontroller-based GUIs will aim to support more complex hardware interactions. Additionally, research will explore the scalability of these autonomous systems across diverse laboratory settings.

Acknowledgments

We would like to thank the NSF and PARADIM for supporting this research project.