Integration of PackML in Engineering Education

Masoud Fathizadeh, Jerry Yen, Mark Werthman

Abstract- Packaging industry requires fast, accurate and reliable equipment to address the need of its growing demand. Many manufacturers throughout the world manufacture equipment and controllers with proprietary software to control their own equipment for packaging industry. Controllers are designed to communicate with equipment from the same manufacturer due to economy, patent or other considerations. In these situations, replacing equipment from one manufacturer with another one becomes impossible or very difficult. Since the early 2000's the Packaging Working Group within the OMAC (Organization for Machine Automation and Control) Users Group has been using a variety of information sources and technical documents to define a common approach, or machine language, for packing machines called PackML. The primary benefits being to encourage a common "look and feel" across a plant floor, and to enable, encourage and focus on industry innovation. PackML has been implemented by users and machine builders on a wide variety of control platforms.

Those implementing PackML are realizing cost benefits of higher reliability, better supply chain integration, reduced engineering and training costs, and shorter project cycles.

Mechatronics students should be able to understand and implement PackML. The purposes of this paper are to (1) introduce PackML and OMAC Users Group, (2) discuss the importance of educating students on the implementation of industry standards, and (3) recommend curriculums such as integrating PackML into course studies, conducting experimental projects, executing case study projects by converting the software of an existing packaging machine to conform to the PackML standard using Mitsubishi PackML template software, defining measurement criteria, and documenting and presenting the benefits of PackML integration.

I. INTRODUCTION

In the late 1980s the International Society of Automation (ISA) began an effort to develop a set of standards for the Batch Control Industry with the intent of providing improved system performance and programming efficiencies by way of a standard set of models and procedures [1].

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Masoud Fathizadeh, PhD, PE, Purdue University Calumet
Department of Engineering Technology, 2200 69th Street Hammond, IN 46323, (219)989-2757, fathizad@purduecal.edu
Jerry Yen, Director of Engineering, Custom Solutions Center
Mitsubishi Electric Automation, Inc.*(248)767-6180*
Jerry.Yen@meau.com
Mark Werthman, Sr. Manager Technical Support Group Mitsubishi Electric,(847)478-2238 www.meau.com

ISA-S88 Part 5 (Make2Pack) was written to provide a standard specifically for Equipment Modules and Control Modules [2]. Starting in the early 2000s Organization for Machine Automation and Control (OMAC) began work on a similar standard [3] that embraced some of the basic concepts developed for the Batch Control Industry with the intent of providing the same benefits to the Machine Control Industry, specifically for Packaging Machines. These standards continued in parallel development until 2008 when an ISA sanctioned technical report was written to harmonize these standards [4].

Since its inception, the Packaging Machine Language (PackML) group has been using a variety of information sources and technical documents to define a common approach, or machine language, for packing machines. The primary benefits being to encourage a common "look and feel" across a plant floor, and to enable, encourage and focus on industry innovation. The PackML group consists of Control Vendors, OEM's and End Users, which collaborate on definitions that endeavour to be consistent with ISA S-88, and consistent with the technology and the changing needs of a ***majority*** of packaging machinery [5]. Using the above as a basis, these ideas have led to the following:

1. Definition of machine state types
2. Definition of machine operating modes
3. Definition of machine mode manager
4. State models, State descriptions and transitions

PackML, which stands for Packaging Machine Language, defines a common approach, or machine language, for automated machines. The primary goals are to encourage a common "look and feel" across a plant floor and to enable and encourage industry innovation. PackML was adopted as part of the ISA88 industry standard in August 2008. PackML has been implemented by users and machine builders on a wide variety of control platforms. Those implementing PackML are realizing cost benefits of higher reliability, better supply chain integration, reduced engineering and training costs, and shorter project cycles [5].

Procter & Gamble has developed this PackML Implementation Guide to aid software developers in achieving a clean and efficient implementation of PackML. This guide includes software and help files for an implementation on Rockwell's ControlLogix platform. The

OMAC Packaging Workgroup (OPW) has adopted this guide and encourages technology providers to develop example software that follows the guide.

II. PACKML OBJECTIVE

The objective of PACMAL is to enable a common "look and feel" and operational consistency to all machines that make up a Packing Line. Figure 1 depicts the overall system configuration for a packaging machine.

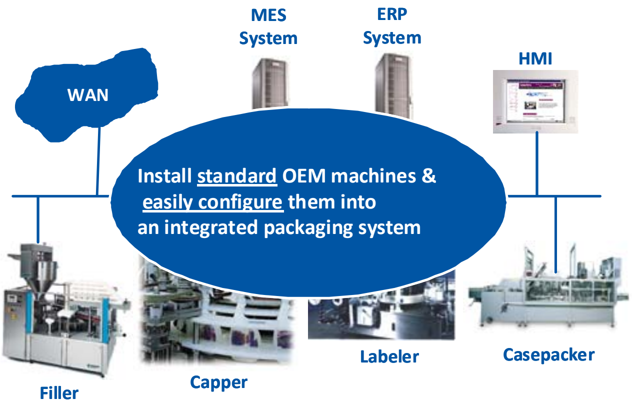

Fig 1 - System Configuration for a Packaging Machine

III. PACKML OVERVIEW

The components for packaging machines require consistent machine mode, state model definitions, and common PackTags data definitions. The methods shall encourage common procedural programming structure and forming the foundation for easy horizontal machine integration. The ISA technical report –TR88.00.02 is approved and used to demonstrate the application of ISA-88 concepts in packaging machinery.

The major parts of PackML standard are Machine Mode and State Model and PackTags Data Definitions.

IV. MACHINE MODE AND STATE MODELS

The mode and state models for a packaging system are defined and detailed in the PackML standard. Figure 2 shows a typical implementation of the display of a state machine diagram on an operator interface device of a machine.

The key features of the PackML Mode and State Machine definitions are:

- Consistent definitions of modes and states of a machine;
- Flexible configuration that allow users to define active states in a mode and the modes allowed in a system;
- Consistent mode transition requirements;
- Consistent state transition requirements;
- Accumulated time and current time for modes and states.

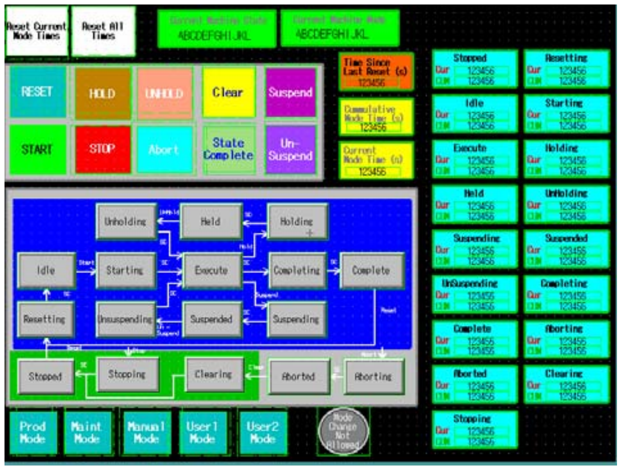

Fig 2 - Example display of machine mode and state models

V. MODE MANAGER

The implementation of a PackML Mode Manager is necessary for a PackML based system because it is used to determine how a machine can make transition from one operation mode to another.

The Mode Manager handles the necessary interlocks to prevent the machine transition out of its current mode when it is at inappropriate state. However, the specifics and timing of mode transitions for a particular machine are left for the machine builder to determine and implement.

VI. PACKTAGS

PackTags can be considered as a date dictionary that provides a uniform set of naming conventions for data elements and common nomenclatures in order to facilitate easy data interface implementation and reduce interface complexity. Using PackTags can drive a data standard of common and basic machine data record with defined Name, Descriptor, Data types, Units of Measure, and Ranges of each data item.

PackTags are generally used to transfer machine information to external MES or IT systems for further monitoring and analyzing machine performance and system productivity. Currently, PackTags are not commonly used for machine to machine communications but there are certainly additional benefits for improving overall system efficiency if a machine can process the performance information from downstream or upstream machines in the same line.

VII. PACKML BENEFITS

Implementing the PackML standard benefits not only the end users but also suppliers such as machine builders and automation system suppliers.

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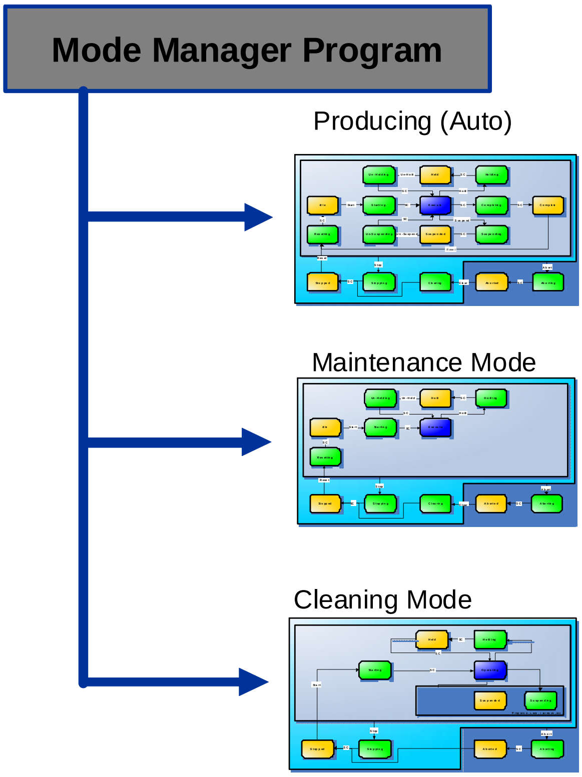

Fig 3 - Flowchart for mode manager program

Benefits to the End Users

When packaging machines on a line conform to the PackML standard, the end users can achieve the following benefits:

1. Fast start up of a packaging line because of the ease of integration of different machine types and between the plant floor machines with the higher-level information systems. The key factors are:
    a. Interoperable among different machine types.
    b. Identically configured common network tags.
2. Maximized system uptime because standard PackML Mode and State Machines provide a consistent operations and look-and-feel to reduce the learning curve for users when troubleshooting machine problems.
3. Easy to add features to machines to a line because of reusable code and software objects that conform to the PackML standard.
4. Reduced overall investment and operating costs since learning is provided for subsequent machine implementations.

Benefits to OEMS

PackML standard allows the machine OEMs to realize the following benefits:

1. Reduced development time because of the following reasons:
    a. Using modular, re-usable code for each mode and state resulting in reduced development time.
    b. Utilizing pre-developed PackML template code from automation supplier thus eliminates the need to develop machine programs from scratch.
    c. Consistent end user specifications results in developing standard machines that can be used by many end users without extensive customization.
2. More robust programming because of the uniform libraries for easier acceptance and faster proliferation and shorten debug time.
3. Easier after-sales support because of the consistent and reused code and less required-training.
4. Without devoting extensive engineering resources in repetitive machine development activities, the OEMs are able to engaged greater focus on machine feature innovations.

Benefits to Automation System Suppliers

Providing solutions that conform to the PackML standard benefits the automation system suppliers greatly. Because of the consistent end user specifications, PackML provides more opportunities for automation suppliers to compete based on performance and capability of the solutions instead of dedicated user standards that are based on single supplier architecture.

By providing uniform libraries, the PackML template solutions from an automation supplier can be easily accepted by OEMs resulting in greater and faster proliferation. It also allows the automation suppliers to compete based on features instead of user preferences. Additionally, it reduces costs for the automation suppliers because of the standard implementation and reduced training requirements from OEMs and end users.

VIII. OMAC USERS GROUP OVERVIEW

The OMAC Users Group was originally formed by a group of large end user companies with the purposes of driving common solutions among companies, sharing manufacturing lessons learned and defining industry standards.

The group has since transitioned to the current form to support machine automation and operational needs of manufacturing. The membership categories of OMAC consist of End User Companies, OEMs and Technology Providers. A new category of System Integrators may be added in the near future.

Two major working groups within OMAC are OMAC Packaging Working Group (OPW) and OMAC Machine Tool Working Group (MTWG). The PackML Standard is a result of the work of OMAC Packaging Working Group after many years of cooperative efforts among the members of OMAC and other Industry participants. The OMAC Packaging Working Group PackML Subcommittee was

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chartered to develop a method to quickly integrate machines without concerning fieldbus and communication technologies. The PackML standard is extended from ISA S88 Part 1 to Packaging Industry, and PackML was approved as ISA-TR88.00.02 as an implementation example of ISA-88 [3].

IX. OMAC PACKML IMPLEMENTATION GUIDE

The OMAC Users Group released an OMAC PackML Implementation Guide in 2009 when it became apparent that poor and inconsistent implementations of PackML standard by users, OEMs, and automation suppliers did not provide the anticipated benefits. The inconsistencies resulted from different interpretations of PackML requirements and different approaches in implementing the PackML state machines.

Proctor and Gamble engineers realized the issues and took the initiatives to create the PackML Implementation Guide directing how the standard should be interpreted and how the machine modes and states should be implemented. The Implementation Guide was given to the OMAC Users Group and subsequently released as the OMAC PackML Implementation Guide to assist PackML implementers to create more consistent solutions [4].

The key elements of the OMAC PackML Implementation Guide are:

- Machine Program Structure Conforming to S88 Part5: Make2Pack Modular Programming Hierarchy
- Selective use of key PackTags
- Consistent ways of implementing PackML states and modes
- Added event handling capability

X. PACKML EDUCATION

In order to increase the acceptance of PackML standard in the industry the engineering students must be educated about the benefits of implementing international and industry standards and specifically the specifically the details and benefits of the PackML standard.

Integrating PackML in engineering education provides benefits to the students such as understanding the requirements of Packaging Industry, realization of industry cooperation and standard implementation, applying theoretical knowledge to actual systems and projects, and gaining hands-on experience on standard implementations. The industry also benefits from having “job-ready” engineers that can execute job functions immediately without extensive training and learning periods.

XI. EDUCATION APPROACHES

Two basic approaches can be utilized to achieve the education goals mentioned above.

From theoretical and technical knowledge perspective, it is important to integrate the relevant PackML elements into the existing engineering curriculum, especially in the following technical topics:

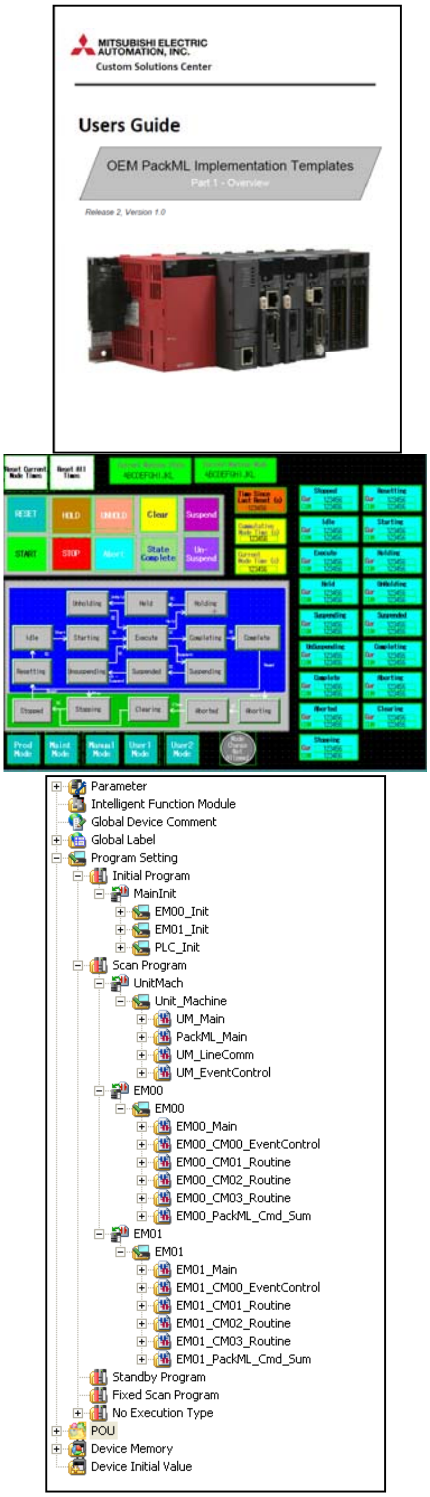

Fig 4 – Mitsubishi PackML OEM Implementation Template Solutions

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- Machine communication technologies and requirements
- Machine to IT system integration
- Control theory and State Machine Models
- Modular programming and re-usability
- Productivity and Equipment Efficiency

Understanding the principles of these technical areas as well as implementation of PackML standards will provide the students' understanding of the standard and the technologies.

A new curriculum emphasizing the PackML standard is being defined and will be implemented. Examples of the courses and workshops that will be included in this curriculum are:

- Workshops
  - Workshop #1: Introduction to Industrial Network Protocols (1 day)
  - Workshop #2: Factory Automation System Architecture
  - Workshop #3: PackML Implementation

From the experimental perspective, it will be extremely beneficial to conduct actual PackML implementation projects on actual machines and product lines. Students can gain valuable experience in integrating electrical and mechanical systems, integrating sequential control and servo control systems, implementing structured software programs, designing for reusability, constructing electrical system, and learning machine safety requirements.

Mitsubishi Electric Automation, Inc., in cooperation with the Purdue University Calumet, has created a laboratory called, "Mechatronic Engineering Laboratory, A collaboration between Mitsubishi Electric Automation and Purdue University Calumet" , on the Purdue University Calumet Campus. The purpose of this laboratory is to support and provide a fully equipped facilities to expand Mitsubishi University based automation product training.

Purdue University Calumet is able to obtain state-of-the-art manufacturing automation products for student education, leverage industry professionals to provide real-world experiences to students, and gain training revenues and equipment.

Mitsubishi also benefits greatly from this collaboration. The Mitsubishi training capability is expanded by utilizing a dedicated training center associated with a world class university, and a pipe-line of well trained and educated student with hands-on experience. The collaboration also allows Mitsubishi to leverage the university research and development capability.

XII. MITSUBISHI SPONSORED EXPERIMENTAL PROJECT

Mitsubishi sponsor PackML Experimental Projects with the Purdue University Calumet are as follows. The main objective of conducting these projects is to obtain qualitative and quantitative benefits of PackML implementation.

The elements of the PackML Experimental projects include

- Defining benefit measurement criteria;
- Converting the software of an existing packaging machine to conform to the PackML standard using Mitsubishi PackML template software;
- Measuring and documenting the benefits of PackML integration.

An actual packaging machine will be used to conduct these experimental projects. The machine currently has the automation system from a particular supplier and the machine control logic was implemented using the traditional method without utilizing PackML. The experimental projects will include the following tasks by the students:

- Determine a set of critical machine performance measures that can be used to define the effectiveness and efficiency of the machine operations, such as cycle time, simplicity of fault diagnostics, ease of operator interaction, etc.
- Collect the data based on the measurement criteria selected.
- Implement PackML States and Modes on the same machine.
- Collect the data using the same measurement criteria.
- Analyze and report the efficiency improvement of the machine.

Additional projects can also include replacing the control system with Mitsubishi control system with existing PackML template programs, and compare the advantages in implementing PackML using pre-defined templates.

XIII. SUMMARY

Automation and packaging industry require fast and accurate machineries. Interconnection of these machines is critical in the performance of the overall system. However, many factories and packaging industries use machines and controllers from different manufacturers due cost, technology or other reasons. Interconnecting such machine with different format and communication protocols presented a challenge to machine builders and integrators. The Implementing industry standards require common implementation agreements and the OMAC Users Group are devoting a great deal of effort to accomplish efficient implementation of the PackML standards by endorsing the implementation guide and promoting the acceptance of the PackML standard. Purdue University Calumet (PUC) established the first mechatronic engineering technology baccalaureate degree focused on packaging machinery. This program enjoys from two NSF grants and generous industry support. In particular, Mitsubishi Electric established a training center at Purdue University Calumet to train the engineers, technician and students. Test and training equipment has delivered and testing procedures are being written. This paper presents an overview of PackML and the collaboration between Mitsubishi and PUC in developing technical procedure and equipment set-ups.

It is beneficial to educate students on the concept of standardization in manufacturing. Cooperation among companies and academic institutions is critical to the success and advancement of manufacturing in general and PackML standard in particular.

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