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Utilizing Automation Standards in Engineering Education

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Abstract

Many manufacturers throughout the world manufacture equipment and controllers with proprietary software to control their own equipment for the 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 packaging machines called PackML. The OMAC Packaging Working Group (OPW) consists of control vendors, OEM's and end users, which collaborate on definitions that endeavor to be consistent with ISA S-88, and consistent with the technology and the changing needs of a *majority* of packaging machinery. 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.

This paper will (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.

Introduction

PackML has been implemented by users and machine builders on a wide variety of control platforms. Those

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]. ISA-S88 Part 5 (Make2Pack) was written to provide a standard 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 are 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 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 encourage industry innovation. PackML was adopted as part of the ISA88 industry standard in August 2008. PackML has been 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 sample software that follows the guide.

PackML Objective

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

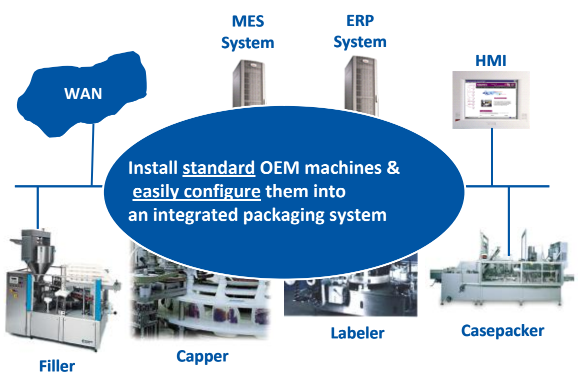

Figure 1 - System Configuration for a Packaging Machine

PackML Overview

The components for packaging machine 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 two major parts of PackML standard are Machine Mode and State Model and PackTags Data Definitions

Machine Mode and State Models

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

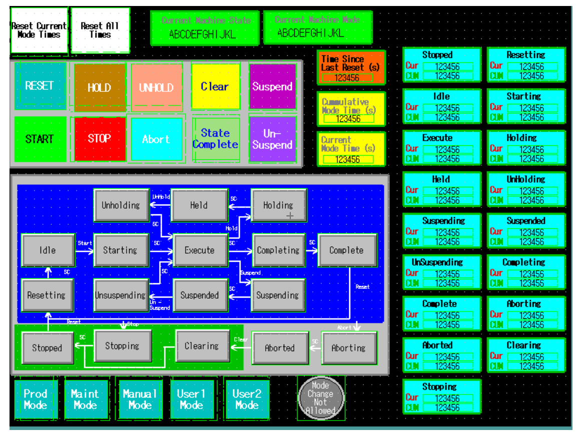

Figure 2 - Example display of machine mode and state models

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

Mode Manager

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

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

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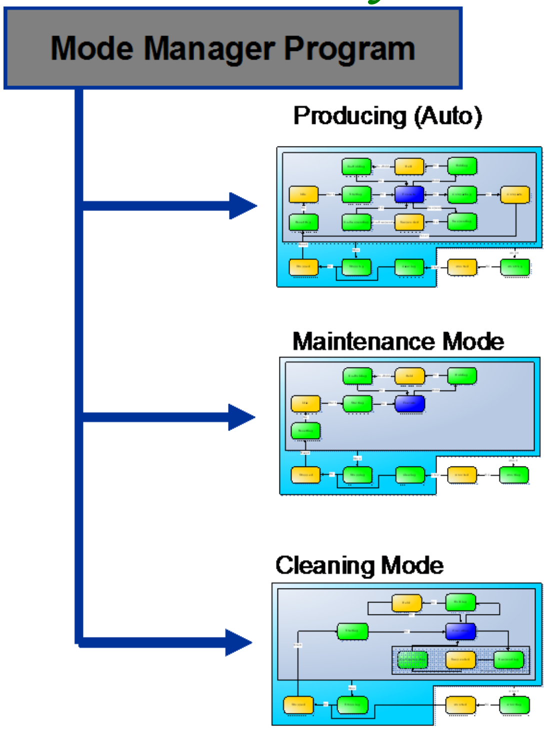


Figure 3 - Flowchart for mode manager program

PackTags

PackTags are similar to 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 communication; however, there are additional benefits for improving overall system efficiency if a machine can process the performance information from downstream or upstream machines in the same line.

– and consistent end user specifications results in developing standard machines that can be used by many end users without extensive customization

PackML Benefits

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

Benefits to the End Users

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

- Faster startup of a packaging line because of the ease of integrating different types located at different part of the plant floor.
- Higher-level information systems for machines results in:
  - Interoperability of different machine types
  - Identically configured common network tags
- Better system uptime since standard PackML Mode and State Machines provide a consistent operations and look-and-feel and reduce the learning curve for users to troubleshoot machine problems.
- Easier to add features to machines or to a line due to re-usability of the code and software objects that conform to the PackML standard.
- Reduced overall investment and operating costs because of less learning is required for subsequent machine implementations.

Benefits to OEMs

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

- Faster development time because of the following reasons:
  - using modular, re-usable code for each mode and state resulting in reduced development time
  - utilizing pre-developed PackML template codes from automation supplier, thus eliminates the need to develop machine programs from scratch

- More robust programming because of the uniform libraries for easier acceptance and faster proliferation and shorten debug time
- Easier after sales support because of the consistent and reused code and less training required

- 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 also benefits the automation system suppliers. Because of the consistent end user specifications, it 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 allows the automation suppliers to compete based on features instead of user preferences. It also reduces costs for the automation suppliers because of the standard implementation and reduced training requirements from OEMs and end users.

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.

OMAC OPW and PackML Development

The OMAC Packaging Working Group PackML Subcommittee was chartered to develop a method to quickly integrate machines without using 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.

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.

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

PackML Promotion

The OMAC Users Group is also undertaking aggressive PackML promotion activities to increase the adoption of the standard.

A great deal of effort has been concentrating on promoting end user acceptance of PackML so that the PackML requirements are specifically stated in their equipment procurement specifications.

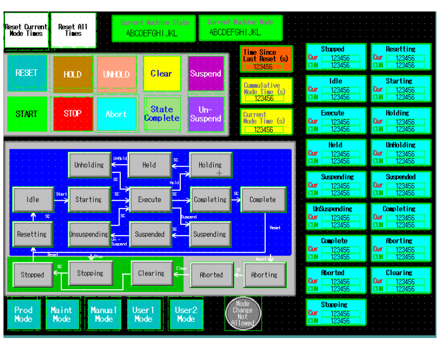
Mitsubishi Electric PackML Solutions

Mitsubishi Electric Automation, Inc. (MEAU) has been a strong supporter of OMAC and the PackML standard. Mitsubishi PackML OEM Implementation

Template Solutions were released in early 2010. The key features of the Mitsubishi Electric PackML solutions are: PackML implementation template PLC and HMI programs with a set of detailed OEM Implementation guides

- Conformation to OMAC PackML standard and the "OMAC PackML Implementation Guide"
- Utilizing Mitsubishi iQ system hardware platform and integrated iQ Works programming environment
- Implementation of the full set of PackTags

The Mitsubishi PackML Solutions include PLC template programs which are conforming to OMAC PackML Implementation Guide, sample HMI screens and motion controller configurations, pre-configured Kepware OPC server configuration files to handle all PackTags, and a complete set of user guides.



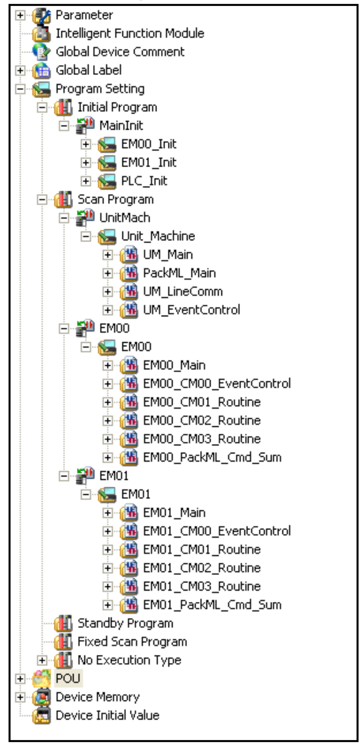


Figure 4 – Mitsubishi PackML OEM Implementation Template Solutions

PackML Education

One important factor to increase the acceptance of PackML standard in the industry is to educate engineering students about the benefits of implementing international and industry standards and specifically, the details and benefits of the PackML standard.

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

Education Approaches

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

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

- 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 and how PackML standard is used in these areas will provide students with a fundamental understanding of the standard and the technologies.

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.

MAPTEC

Mitsubishi Electric Automation, Inc., in cooperation with the Purdue University Calumet, has created a Mitsubishi Automation Products Technical Education Center (MAPTEC) on the Purdue Campus. The goal of MAPTEC is to support and provide a fully equipped facility 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 MAPTEC. 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 cooperation also allows Mitsubishi to leverage the university's research and development capability.

Mitsubishi Sponsored Experimental Project

Mitsubishi sponsors PackML Experimental Projects with Purdue University through MAPTEC. 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

Summary

The packaging industry requires fast and accurate machineries. Interconnection of these machines is critical to 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 presents a challenge to machine builders and integrators. Implementing industry standard requires common implementation agreements. The OMAC Users Group are devoting great effort to accomplish efficient implementation of the PackML standard 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 that focused on packaging machinery. This program is strengthened by two NSF grants and generous industry support. In particular, Mitsubishi Electric established a training center at Purdue University Calumet to train engineers, technician and students. Test and training equipment have been delivered and testing procedures are 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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Biographies

MASOUD FATHIZADEH is an associate professor of Electrical and Mechatronic Engineering Technology at Purdue University Calumet. He earned his B.S. degree from University of Science and Technology (Electrical Engineering 1978), MS from University of Toledo, OH (Electrical Engineering 1982) and Doctor of Engineering (Electrical Engineering) 1987 from Cleveland State University. Dr Fathizadeh worked for NASA, Argonne and Fermi National Laboratories and then established his engineering and consulting company where he designed and installed emergency power and automation systems for many private and public companies. Dr. Fathizadeh is currently teaching at Purdue University Calumet. His areas of interest are in electrical power, control, energy and renewable energy sources.

JERRY YEN received his M.S. Physics in 1976 and M.S.E.E. in 1980 from the Ohio State University. He later received his Master of Business Administration degree in 1988 from the University of Michigan in Ann Arbor. He worked for Westinghouse Electric Company for three years before joining General Motors Corporation in 1983. Jerry joined the GM CCRW group in 2006 and led the technology investigation and development for next generation controls architecture and Plant Floor System Integration. Jerry joined Mitsubishi in 2008 as the Director of Engineering, Custom Solutions Center and subsequently the Engineering Group. Jerry is one of the key persons in the development of the open, modular architecture controller (OMAC) concept and requirements. Jerry is also instrumental in forming the industry-wide OMAC Users Group in the U.S. He was recently re-elected to serve on the Board of Directors of the OMAC Users Group.