# Outline

1) SB - Description of kitting
2) Test methods
   a) TK - Inputt format (xml, owl)
   b) TK - Output format (Robot canonical command language)
   c) SB - method itself (build kits) with varying part mix and configuration, missing parts, ...
3) metrics
   a) TK - Plan
      i) number of steps
      ii) goal achievement
      iii) optimality
      iv) maintain constraints
      v) number of errors
   b) ZK - Execution
4) assumptions
   a) Work volume totally reachable

# Metrics and Test Methods for Industrial Kit Building

Stephen Balakirsky, Thomas Kramer, and Zeid Kootbally

***Abstract*— The IEEE RAS Ontologies for Robotics and Automation Working Group is dedicated to developing a methodology for knowledge representation and reasoning in robotics and automation. As part of this working group, the Industrial Robots sub-group is tasked with studying industrial applications of the ontology. One of the first areas of interest for this subgroup is the area of kit building or kitting. It is anticipated that utilization of the ontology will allow for the development of higher performing kitting systems. However, the definition of "higher performing" has yet to be defined. This paper addresses this issue by providing the basis for performance methods and metrics that are designed to determine the performance of a kitting system.**

## I. INTRODUCTION

Material feeding systems are an integral part of today's assembly line operations. These systems assure that pars are available where and when they are needed during the assembly operations by providing either a continuous supply of parts at the station, or a set of parts (known as a 'kit') that contains the required parts for one or more assembly operations. In continuous supply, a quantity of each part that may be necessary for the assembly operation are stored at the assembly station. If multiple versions of a product are being assembled, (mixed-model assembly) a larger variety of parts than are used for an individual assembly may need to be stored. With this material feeding scheme, parts storage and delivery systems must be duplicated at each assembly station.

An alternative approach to continuous supply is know as kitting. In kitting, parts are delivered to the assembly station in kits that contain the exact parts necessary for the completion of one assembly object. According to Bozer and McGinnis [1] "A kit is a specific collection of components and/or subassemblies that together (i.e., in the same container) support one or more assembly operations for a given product or shop order". In the case of mixed-model assembly, the contents of a kit may vary from product to product. Kitting itself may be viewed as a specialization of the general bin-picking problem. The use of kitting allows a single delivery system to feed multiple assembly stations.

In industrial assembly of manufactured products, kitting is often performed prior to final assembly. Manufacturers utilize kitting due to its ability to provide cost savings [2] including saving manufacturing or assembly space [4], reducing assembly workers walking and searching times [5], and increasing line flexibility [1] and balance [3].

Several different techniques are used to create kits. A kitting operation where a kit box is stationary until filled at a single kitting workstation is referred to as *batch kitting*. In *zone kitting*, the kit moves while being filled and will pass through one or more zones before it is completed. This paper focuses on batch kitting processes.

In batch kitting, the kit's component parts may be staged in containers positioned in the workstation or may arrive on a conveyor. Component parts may be fixtured, for example placed in compartments on trays, or may be in random orientations, for example placed in a large bin. In addition to the kit's component parts, the workstation usually contains a storage area for empty kit boxes as well as completed kits.

Kitting has not yet been automated in many industries where automation may be feasible. Consequently, the cost of building kits is higher than it could be. We are addressing this problem by proposing performance methods and metrics that will allow for the unbiased comparison of various approaches to building kits in an agile manufacturing environment. The performance methods that we propose must be simple enough to be repeatable at a variety of testing locations, but must also capture the complexity inherent to variants of kit building. The test methods must address concerns such as measuring performance against variations in kit contents, kit layout, and component supply. For our test methods, we assume that a robot performs a series of pick-and-place operations in order to construct the kit. These operations include:

1) Pick empty kit and place on work table.
2) Pick multiple component parts and place in kit.
3) Pick completed kit and place in full kit storage area.

Each of these actions may be a compound action that includes other actions such as end-of-arm tool changes, path planning, and obstacle avoidance.

It should be noted that multiple kits may be built simultaneously. Finished kits are moved to the assembly floor where components are picked from the kit for use in the assembly procedure. The kits are normally designed to facilitate component picking in the correct sequence for assembly. Component orientation may be constrained by the kit design in order to ease the pick-to-assembly process. Empty kits are returned to the kit building area for reuse.

## II. TEST METHODS

Blah, Blah, Blah

S. Balakirsky is with the Intelligent Systems Division, National Institute of Standards and Technology, Gaithersburg, MD, USA (e-mail:stephen.balakirsky@nist.gov)

Z. Kootbally is with the Department of Mechanical Engineering, University of Maryland, College Park, MD, USA (email: zeid.kootbally@nist.gov)

T. Kramer is with the Department of Mechanical Engineering, Catholic University of America, Washington, DC, USA (email: thomas.kramer@nist.gov)

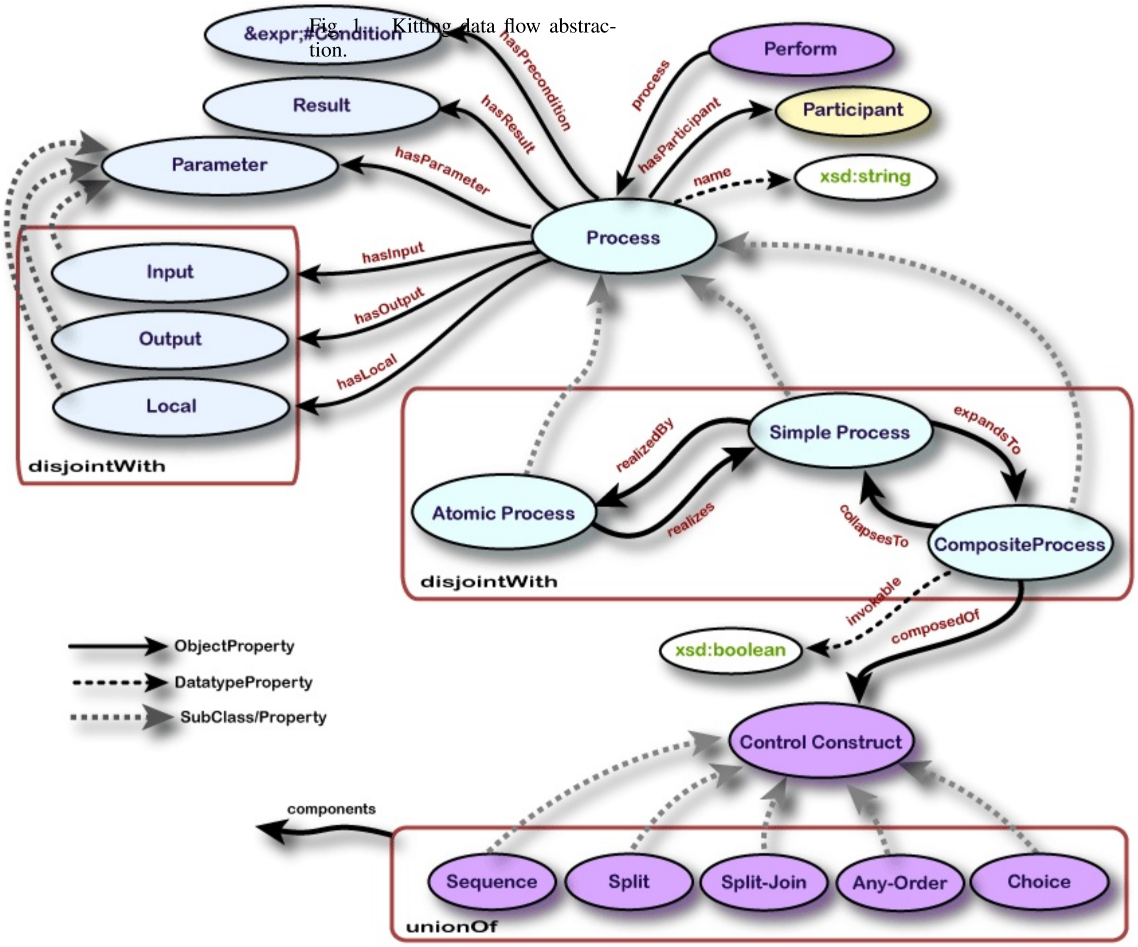


Fig. 1. Kitting data flow abstraction.

## III. Metrics

### A. Plan Metrics

Blah, Blah, Blah

### B. Execution Metrics

Blah, Blah, Blah

## IV. Assumptions

Blah, Blah, Blah

## V. CONCLUSIONS AND FUTURE WORK

## References


[1] Y. A. Bozer and L. F. McGinnis. Kitting versus line stocking: A conceptual framework and descriptive model. *International Journal of Production Economics*, 28:1–19, 1992.

[2] O. Carlsson and B. Hensvold. Kitting in a High Variation Assembly Line. Master's thesis, Luleå University of Technology, 2008.

[3] J. Jiao, M. M. Tseng, Q. Ma, and Y. Zou. Generic Bill-of-Materials-and-Operations for High-Variety Production Management. *Concurrent Engineering: Research and Applications*, 8(4):297–321, December 2000.

[4] L. Medbo. Assembly Work Execution and Materials Kit Functionality in Parallel Flow Assembly Systems. *International Journal of Production Economics Journal of Industrial Ergonomics*, 31:263–281, 2003.

[5] G.F. Schwind. How Storage Systems Keep Kits Moving. *Material Handling Engineering*, 47(12):43–45, 1992.