Instructional Webinar:
What, how, and where to enter the RAMP Competition

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National Institute of Standards & Technology

Mohan Krishnamoorthy
PhD Candidate
Department of Computer Science
George Mason University
Visit challenge on-line!


RAMP: Reusable Abstractions of Manufacturing Processes

About the Challenge

Ramp up the use of manufacturing standards!

Posted By: National Institute of Standards and Technology
Category: Scientific/Engineering
Skill: Engineering
Interest: Manufacturing

Submission Dates: 9 a.m. ET, Dec 19, 2016 - 5 p.m. ET, Mar 20, 2017
Judging Dates: Mar 27, 2017 - Jun 08, 2017
Winners Announced: Jun 08, 2017

In the future, manufacturing will be planned out in the virtual world. How can we do this if we don’t even have models for the basic processes such as welding, drilling, and forging? Sewing, assembly, or distillation? No, we don’t even have models for those either! At least, not the types of models really needed for our high-tech world.

Manufacturers need models to improve operations, to protect the environment, to share information, and to compose them into systems.

Official Rules

First Place
$1,000.00
Second Place
$750.00
Third Place
$500.00
Runners Up
$1,000.00

Up to five runners up will receive $200 each
If you have questions….

- Live participants: use the Q&A chat bar
- After the webinar, send any other questions to
  - Swee Leong, swee.leong@nist.gov
  - Bill Bernstein, wzb@nist.gov
ASTM International: Committee E60 on Sustainability

Scope:

The acquisition, promotion, and dissemination of knowledge, stimulation of research and the development of standards relating to sustainability and sustainable development.

http://www.astm.org/COMMITTEE/E60.htm

Subcommittee E60.13 on Sustainable Manufacturing
ASTM E2986-15:
Standard Guide for Evaluation of Environmental Aspects of Sustainability of Manufacturing Processes

• Designed to complement:
  – ISO 14000 (environmental management)
  – ISO 50000 (energy management)

• Provides guidelines for the collection and analysis (e.g. decision making processes) of manufacturing data

• New Appendix (up for ballot) demonstrates its use through a machining case study.

https://www.astm.org/Standards/E2986.htm
ASTM E3012-16:
Standard Guide for Characterizing Environmental Aspects of Manufacturing Processes

• Designed to complement ASTM E2986-15

• Provides guidelines for the formal characterization and representation of unit manufacturing process (UMP) models

• Fundamental foundation for the idea of a repository of reusable UMP models

https://www.astm.org/Standards/E3012.htm
Goals of ASTM E3012-16

- Consistently characterizing manufacturing process models
- Sharing and re-using manufacturing process information
- Promoting integration of tools for manufacturing-related decision-making
- Aiding environmental sustainability assessment
Goals of RAMP Competition

• Model any unit manufacturing process of interest

• Demonstrate ASTM E3012-16 on a variety of unit manufacturing processes (UMPs)

• Demonstrate the use of a reusable standard format leading to models suitable for system analysis, such as
  – simulation modeling or
  – as an optimization program.
The “When” - Important Dates

Submission Deadline: March 20, 2017
@ 5pm ET

Announcement of Finalists: April 17, 2017
(by e-mail)

Announcement of Winners: June 4-8, 2017

ASME 2017 MSEC
Los Angeles, CA
The “Who”

- Can be teams or individuals
- Person accepting prize must be US citizen or permanent resident
What to submit?

1. Graphical Representation
2. Transformation Function(s)
3. Description of Nomenclature
4. Description of Information Sources
5. README Section
6. Written Narrative
1) Graphical Representation

**Product/Process Information**
- Equipment and material specifications
- Process Specifications
  - Setup-operation-teardown instructions
  - Control Programs and process control
- Product and engineering specifications
  - Part geometries

**Resources**
- Equipment
- Tooling
- Fixtures
- Human
- Software

**Transformation**
- Energy
- Material
- Information

**Input**
- Energy
- Material & consumables
- Outside factors
- Disturbance

**Output**
- Product
- By-Product
- Waste
  - Solid, liquid, emission
  - Thermal, noise
- Feedback

*Figure based on ASTM E3012-16. Standard available for competition participants.*
**Product & Process Information**

**Job Information**
- **Part Description:** Heat Sink Test Part
- **Geometry:** Complex, see CAD file (file.stp)
- **Material:** Al6061
- **Operations:** Mill thicknesses, bosses and counter bores, deburr, mill chamfers, radii, mill fins
- **Required Tools:** End mills, chamfer mills, rounding mills

**Transformation Equations**

\[
V = N \times D \times 1000\pi \\
p_i = p_s + p_c + p_a \\
t_a = 60 \times \frac{t_m + L_c}{f_r} \\
t_a = 60 \times \frac{t_{a,o} + d_o}{f_r} \\
p_m = \frac{VRR \times V}{1000} \\
t_h = t_{a,o} + t_r \\
t_i = t_h + t_m \\
e_i = e_m + e_t + e_b \\
e_c = e_i + e_t \\
Yield = n_c \\
C = E \times C_{kwh} \\
CO2 = E \times CO2_{kwh} \\
E = e_c \times n_c \times 2.78e^{-4}
\]

**Inputs**
- Electrical energy, kWh
- Workpiece material (e.g. aluminum, steel)

**Outputs**
- Finished part, qty
- Waste
  - Heat, BTU
- Material, kg

**Resources**
- **Operator:** John Doe
- **Machine:** GF Agile HP600U
- **Fixture Details:** Mill Clearance, Drill, Ream and Tap Mounting
- **Software:** See MasterCam for fixture and tooling specifics

**Tool List:**
1. 1/4" Dia. 2 Flute Stubby Fullerton E.M.
2. 3/16" Dia. 2 Flute Stubby Fullerton E.M.
3. 3" Face Mill
4. 1/2" Dia. 2 Flute Stubby Fullerton E.M.
5. 1/4" x 45° Chamfer Mill
6. 1/4" x .020" x 45° Chamfers
7. 1/4" x .093” Corner Rounding E.M.
1) Graphical Representation - Example

**Product & Process Information**

**Job Information**

**Part Description:** Heat Sink Test Part

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**Variable definitions for transformation equations (short list)**

- $V_p$ – Specific Cutting Energy (W/mm$^3$)
- $V_i$ – volume of input (mm$^3$)
- $V$ – Cutting Speed (m/min)
- $t_{a,o}$ – Approach and Overtravel time (sec)
- $t_r$ – Retract time (sec)
- $t_h$ – Handling Time (sec)
- $t_i$ – Milling Idle time (sec)
- $p_i$ – Milling Idle power (kW)
- $e_i$ – Milling Idle Energy (kJ)
- $e_c$ – Energy Consumed per cycle (kJ/cycle)
- $t_c$ – Total time per cycle (sec)

- $p_m$ – Milling Power (kW)
- $e_m$ – Milling Energy (kJ)
- $f_t$ – Feed per tooth (mm/tooth)
- $VRR$ – Volume Material Removal Rate (mm$^3$/min)
- $L_c$ – Extent of the first contact (mm)
- $t_m$ – Milling Time (sec/cut)
- $E$ – Total energy consumed (kWh/cycle)
- $C$ – Total cost for energy ($)
- $CO_2$ – Total CO$$_2$$ for energy (kg)
- $t_i$ – Total time for all cycles (sec)
- $Yield$ – Items produced in all cycles (qty)

**Transformation Equations**

For centered milling:

- $t_m = 60 * l_m + L_c / f_r$
- $L_c = \sqrt{d * (D - d)}$

For peripheral milling:

- $t_m = 60 * l_m + L_c / f_r$
- $L_c = \sqrt{d * (D - d)}$

For face milling:

- $t_m = 60 * l_m + 2 * L_c / f_r$
- $L_c = \sqrt{w_m * (D - w_m)}$

- $V = N * D * 1000\pi$
- $p_i = p_s + p_c + p_a$
- $t_c = t_i + t_c + t_u + t_i$
- $V_i = l_m * w_m * h_m * n_c$
- $t_{a,o} = 60 * \frac{d_a + d_o}{f_r}$
- $p_m = \frac{VRR * V_p}{1000}$
- $t_h = t_{a,o} + t_r$
- $t_i = t_h + t_m$
- $e_m = p_m * t_m$
- $e_i = p_i + t_i$
- $e_c = e_m + e_i + e_b$
- $t_i = t_c * n_c$
- $Yield = n_c$
- $C = E * C_{kwh}$
- $CO_2 = E * CO_2_{kwh}$
- $E = e_c * n_c * 2.78e^{-4}$

**Inputs**

- Electrical energy, kWh
- Workpiece material (e.g. aluminum, steel)

**Outputs**

- Finished part, qty
- Waste
  - Heat, BTU
  - Material, kg

**Resources**

- **Operator:** John Doe
- **Machine:** GF Agile HP600U
- **Fixture Details:** Mill Clearance, Drill, Ream and Tap Mounting
  - Holes Orientation, Origin $\rightarrow (0.100, 0.720, 0.168)$
- **Software:** See MasterCam for fixture and tooling specifics

**Tool List:**

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5. 1/4” x 45° Chamfer Mill
6. 1/4” x .020” x 45° Chamfers
7. 1/4” x .093” Corner Rounding E.M.
2) Transformation Function(s)

Include equations that compute metrics from control parameters in any readable mathematical format, such as

- MS Word,
- LaTeX,
- ASCII text,
- JSONiq
- Matlab

Submissions only acceptable in PDFs
3) Description of Nomenclature

- Include all variable names and types in the structured form (like a table)

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
<th>Type</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>machine</td>
<td>Name of the machine</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>material_type</td>
<td>Work piece Type (material)</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>material_length</td>
<td>Work piece length</td>
<td>Parameter</td>
<td>mm</td>
</tr>
<tr>
<td>material_width</td>
<td>Work piece width</td>
<td>Parameter</td>
<td>mm</td>
</tr>
<tr>
<td>material_height</td>
<td>Work piece height</td>
<td>Parameter</td>
<td>mm</td>
</tr>
<tr>
<td>millType</td>
<td>Milling Type</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>centered</td>
<td>Tool cornered or centered (yes or no)</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Diameter of the cutter</td>
<td>Parameter</td>
<td>mm</td>
</tr>
<tr>
<td>N</td>
<td>Spindle Speed</td>
<td>Variable</td>
<td>rpm</td>
</tr>
<tr>
<td>f_r</td>
<td>Feed Rate</td>
<td>Variable</td>
<td>mm/min</td>
</tr>
<tr>
<td>n_t</td>
<td>Number of tooth</td>
<td>Parameter</td>
<td>integer unit</td>
</tr>
<tr>
<td>depth</td>
<td>Depth of cut</td>
<td>Parameter</td>
<td>mm</td>
</tr>
</tbody>
</table>

... ... ... ... ... ...

16
4) Description of Information Sources

- Sources used to define UMP models, such as existing literature, case studies, and textbooks.

<table>
<thead>
<tr>
<th>MODEL SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UMP Name:</strong> Milling</td>
</tr>
<tr>
<td><strong>Source Name:</strong> Unit Process Life Cycle Inventory Dr. Devi Kalla, Dr. Janet Twomey, and Dr. Michael Overcash 08/19/2009</td>
</tr>
<tr>
<td><strong>Where on the web:</strong> <a href="http://cratel.wichita.edu/uplci/milling/">http://cratel.wichita.edu/uplci/milling/</a></td>
</tr>
<tr>
<td><strong>@date:</strong> 07/26/2016</td>
</tr>
<tr>
<td><strong>@author:</strong> Mohan Krishnamoorthy, Alex Brodsky</td>
</tr>
</tbody>
</table>
5) README Section

- Nature and location of files, i.e. folder structure
- Might include a URL to your submission’s video
- Source code files are optional but can be included if you feel that they will better clarify your work.
- PDF only. We will not run the code.
6) Written Narrative (750 words max)

- **Validation**: explain how the model is validated.
  - Examples include: case study, literature review, traditional cross-validation techniques, or others

- **Novelty of UMP analysis**: show off your ideas!
  - Knowledge/understanding of UMP modeling
  - Standards supporting reusable models
  - Techniques for development & validation of UMP models
Summary: Information for UMP & its instantiation

Product/Process Information

**Material Properties**
Type: Aluminum 6061
Brinell hardness: 30-150
Specific cutting energy $U_p$: 0.98 W/(s*mm^3)
Cutting speed: 120-140 m/min
Feed per tooth: 0.28-0.56 mm/tooth
Density: 2712 kg/m^3

**Machine Instructions (G-code)**
N1418 T3
N1419 G91 G28 Z0 M06
N1420 T1 M01
G90 G10 L2 P#501 X[#510]
M8
...

Transformations

- http://cratel.wichita.edu/uplci/milling/
- http://cratel.wichita.edu/uplci/drilling-2/

Resources

**Set-up Sheets**

<table>
<thead>
<tr>
<th>Num</th>
<th>Dia.</th>
<th>Len.</th>
<th>CRC</th>
<th>Tool Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.2500</td>
<td>3</td>
<td>3</td>
<td>1/4&quot; Dia. 2 Flute Stubby Fullerton E.M.</td>
</tr>
<tr>
<td>RELIEF:</td>
<td>OUT OF HOLDER: 1.03</td>
<td>REACH:</td>
<td>HOLDER: C4007-0016</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>0.1250</td>
<td>17</td>
<td>17</td>
<td>1/8&quot; Dia. 2 Flute Stubby Fullerton E.M.</td>
</tr>
<tr>
<td>RELIEF:</td>
<td>OUT OF HOLDER: 0.86</td>
<td>REACH:</td>
<td>HOLDER: C4007-0016</td>
<td></td>
</tr>
</tbody>
</table>

**Tool List**

- 2 0.2500 3 1/4" Dia. 2 Flute Stubby Fullerton E.M.
- RELIEF: OUT OF HOLDER: 0.85 REACH: HOLDER: C4007-0016
- 17 0.1250 17 1/8" Dia. 2 Flute Stubby Fullerton E.M.
- RELIEF: OUT OF HOLDER: 0.84 REACH: HOLDER: C4007-0016
- 18 0.2500 18 1/4" Dia. 2 Flute Stubby Fullerton E.M.
- RELIEF: OUT OF HOLDER: 0.85 REACH: HOLDER: C4007-0016
- 10 0.2264 10 3/16" Dia. 2 Flute Stubby Fullerton E.M.
- RELIEF: OUT OF HOLDER: 0.85 REACH: HOLDER: C4007-0016
- 20 0.2500 20 1/4" Dia. 2 Flute Stubby Fullerton E.M.
- RELIEF: OUT OF HOLDER: 0.85 REACH: HOLDER: C4007-0016

**Inputs**
- http://cratel.wichita.edu/uplci/milling/
- http://cratel.wichita.edu/uplci/drilling-2/

**Outputs**
- http://cratel.wichita.edu/uplci/milling/
- http://cratel.wichita.edu/uplci/drilling-2/

**UPLCI Database**
http://cratel.wichita.edu/uplci/

**NIST SMS Testbed**
http://smstestbed.nist.gov

Review Criteria for Selecting Finalists

- **Completeness:** Submission follows the guidelines and includes all necessary components.
- **Complexity:** Model reflects the complexities of the manufacturing process, especially those which influence sustainability indicators such as energy and material consumption.
- **Clarity:** Model is clear in describing the process and the process-related information.
- **Accuracy:** Submission accurately models the process as shown through validation.
- **Novelty:** Approach taken develops new techniques to advance model reusability or reliability.
Awards and travel stipends

- First Place Prize: $1,000
- Second Place Prize: $750
- Third Place Prize: $500
- Runners Up Prizes (up to five): $200 each

All finalists and other participants can also apply for a travel stipend to Los Angeles of up to $1500

MSEC Workshop URL: https://www.nist.gov/news-events/events/2017/06/workshop-formalizing-manufacturing-processes-structured-sustainability
Live Judging Criteria

• **Complexity – 10%**: Model reflects complexities of the manufacturing process, especially those which influence eco-indicators, e.g. energy/material consumption.

• **Clarity – 10%**: Model is clear in describing the process and the process-related information.

• **Accuracy – 35%**: Submission accurately models the process as shown through validation.

• **Novelty – 35%**: Approach taken develops new techniques to advance model reusability or reliability.

• **Presentation – 10%**: Quality and content conveyed in a brief in-person presentation at 2017 MSEC.
Pause to check Q&A board...

Demo: Using JSONiq to formally represent UMP transformation functions

Mohan Krishnamoorthy,
George Mason University
Product & Process Information

Job Information
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Variable definitions for transformation equations (short list)

- \( U_p \) — Specific Cutting Energy (W/mm³)
- \( V_i \) — Volume of input (mm³)
- \( V \) — Cutting Speed (m/min)
- \( t_{a,o} \) — Approach and Overtravel time (sec)
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- \( e_i \) — Milling Idle Energy (kJ)
- \( e_c \) — Energy Consumed per cycle (kJ/cycle)
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- \( E \) — Total energy consumed (kWh/cycle)
- \( C \) — Total cost for energy ($) 
- \( CO_2 \) — Total CO₂ for energy (kg)
- \( t_c \) — Total time for all cycles (sec)
- \( Yield \) — Items produced in all cycles (qty)

Transformation Equations

- \( f_t = f_r/(N * n_z) \)
- \( VRR = w_m * d * f_r \)

For centered milling:
- \( L_c = D/2 \)

For peripheral milling:
- \( t_m = 60 * \frac{l_m + L_c}{f_r} \)
- \( L_c = \sqrt{d * (D - d)} \)

For face milling:
- \( t_m = 60 * \frac{l_m + 2*L_c}{f_r} \)
- \( L_c = \sqrt{w_m * (D - w_m)} \)

- \( V = N * D * 1000\pi \)
- \( p_i = p_s + p_c + p_a \)
- \( t_c = t_i + t_c + t_u + t_i \)
- \( V_i = l_m * w_m * h_m * n_c \)
- \( t_{a,o} = 60 * \frac{a_o + d_o}{f_r} \)
- \( p_m = \frac{VRR*V_i}{1000} \)
- \( t_h = t_{a,o} + t_r \)
- \( t_i = t_h + t_m \)
- \( e_m = p_m * t_m \)
- \( e_i = p_i + t_i \)
- \( e_c = e_m + e_i + e_b \)
- \( t_c = t_c * n_c \)
- \( Yield = n_c \)
- \( C = E * C_{E, kWh} \)
- \( CO_2 = E * CO_2_{E, kWh} \)
- \( E = e_c * n_c * 2.78e^{-4} \)

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JSON Structure

- Lightweight data-interchange format
- An open standard like XML
- Represent hierarchical and heterogeneous data
- Example JSON Object:

```json
{
    "scalar": value,
    "JSON Object": {...},
    "JSON Array": [...],
    ...
}
```
JSONiq – the JSON query language

- Query and functional programming language
- Analogous to SQL
- Write transformation equations as executable code
- Lends to reusable models
Atom – a “hackable” text editor

• Code and text editor
• Fully Customizable
• Provides many packages and plugins
• Easy to setup and use
• Intuitive Interface
Demo time!
Atom Studio & Zorba Resources

- Detailed Instructions (Go here first!):
  http://mason.gmu.edu/~mnachawa/resources/jsoniq-environment.html

- Zorba XQuery/JSONiq Processor
  - (http://www.zorba.io/download)

- Atom Studio
  - (https://atom.io/)

- Atom Binding to Zorba
  - (linter, language-jsoniq, atom-runner)