Interactive Virtual Hands-on Manufacturing

Martin Jun¹ and Patrick Lee²

¹Associate Professor, Purdue University, West Lafayette, IN
²Assistant Professor, University of Vermont, Burlington, VM
Current CAD Software

• A series of features in sequence to represent a desired solid model

• Geometry based design
Current Design and Manufacturing

• Current design and manufacturing approach for part generation
• Well established CAD/CAM and verification software products
Need for Manufacturing Integration

- CAD software does not take manufacturing into consideration
- Difficult to learn design for manufacturing
- No environment for interactive manufacturing (not just touch capability)
Manufacturing Perspective

• CAD software essentially uses a series of Boolean operations

Can a part be generated using only Subtract Boolean operations?

Can such Subtract Boolean operations be performed interactively by user?
Proposed Approach

- Interactive virtual hands-on manufacturing
- Part design process is similar to manual machining process

![Diagram showing initial stock, tool trajectory by user, and final design with NC code generation.](image)
Software Interface Example

Interactive Virtual Hands-on Manufacturing for Students

Simulation  Order

Cylinder shape

Square shape
Software Interface Example

Interactive Virtual Hands-on Manufacturing for Students

Adjust part size (spread)
Software Interface Example

Interactive Virtual Hands-on Manufacturing for Students

Simulation

Order

Motion

Shape

Position
X: 09.30
Y: 12.70
Z: 01.05

Motion

Subtract
(Boolean)

- path 1
- path 2
- path 3
- path 4
(example)

Modify

X: 09.30
Y: 12.70
Z: 01.50

Ref. axis

X

Y

Z
Software Interface Example

Interactive Virtual Hands-on Manufacturing for Students

Simulation  Order

Motion

Shape

Position
X: 00.00
Z: 00.30

Subtract (Boolean)
- path 1
- path 2
- path 3
- path 4
(example)

Modify

- path 1
- path 2
- path 3
- path 4
(example)
Operation Example: Straight Line

Position
X: 09.30
Y: 12.70
Z: 01.05
Operation Example: Straight Line

Position
X: 09.30
Y: 12.70
Z: -1.10
Operation Example: Straight Line

Position
X: 09.30
Y: 12.70
Z: -1.10

Subtract (Boolean)
- Path 1

Modify
Operation Example: Straight Line

- Stock Tool
- Select a tool
- Rotate
- Subtract (Boolean)
- Path 1
- Modify

Position
X: 09.30
Y: 16.70
Z: -1.10
Operation Example: Curved Line

Simulation

Order

Motion

Shape

Position
X: 5.30
Y: 9.70
Z: 2.10

Subtract
(Boolean)

Modify
Operation Example: Curved Line
Operation Example: Curved Line

Position

X: 5.50
Y: 9.90
Z: -1.50

Simulation Order
Operation Example: Curved Line

Position
X: 5.90
Y: 11.90
Z: -1.50

Subtract (Boolean)
- Path 1

Modify
Operation Example: Curved Line
Operation Example: Curved Line

Simulate Virtual Hands-on Manufacturing for Students

Motion

Position
X: 9.40
Y: 17.90
Z: -1.50

Shape

Subtract (Boolean)
- Path 1

Modify
Operation Example: Curved Line

Position
X: 9.40
Y: 17.90
Z: 0.50
Operation Example: Freeform
Operation Example: Freeform

Interactive Virtual Hands-on Manufacturing for Students

Simulation
Order

Motion
Position
X: 3.40
Y: -3.90
Z: -0.50

Shape

Subtract (Boolean)
-

Modify
Operation Example: Freeform
Operation Example: Freeform
Operation Example: Freeform
Operation Example: Freeform
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning
Part Generation Example
Operation Example: Turning

Interactive Virtual Hands-on Manufacturing for Students

Simulation Order #1. Rough contouring

Motion

Shape

Subtract (Boolean)
- Path 1
- Path 2
- Path 3

Modify
Operation Example: Turning
Operation Example: Turning
Operation Example: Turning

Interactive Virtual Hands-on Manufacturing for Students

#4. Freeform contouring

1. Select tool paths
2. Subtract (Boolean)
   - Path 8
   - Path 9
   - Path 10
   - Path 11
   - Path 12
   - Path 13
   - Path 14
   - Path 15
   - Path 16
   - Path 17
   - Path 18
   - Path 19

3. Modify tool diameter (Φ3/4→1 in.)
Operation Example: Turning
New Approach for CAD/CAM
Manufacturing Workflow

Conventional Design-to-Manufacture Workflow

Customer → CAD Drawing → CAM Software → Part Program → CNC Machine → Cut Part

Streamlined Virtual Manufacturing Workflow

Customer → Interactive CAD → CNC Machine → Cut Part
Cybermanufacturing

Customer

Virtual Manufacturing
- Final Design
- Machine Configuration
- Tool and Workpiece
- Quantity Information

Upload

Data Server

Shop A

Shop B

Shop C

Shop D

CNC Machine

Cut Part

Provider Check

Delivery
Good Manufacturing Designer

Idea for parts

Target Part

- ???
- !
- !!
Good Manufacturing Designer

Virtual Manufacturing

Target Part
Good Manufacturing Designer

Virtual Manufacturing Results

Machining time: 39.0 sec
Part shape: Good

Machining time: 42.3 sec
Part shape: Normal

Machining time: 25.7 sec
Part shape: Good
Conclusion

• If the design process is similar to manufacturing, manufacturable parts can be readily designed

• Learning of manufacturing processes can be naturally obtained

• It provides a platform that allows innovative human inputs to manufacturing during the design process

• It can be a great tool for education and cybermanufacturing