Evolutionary Process Planning
Presented By
Dr. Prof. Hoda ElMaraghy
FCIRP, FME, FCIMNE
Intelligent Manufacturing Systems (IMS) Centre
Industrial & Manufacturing Systems Engineering Department
University of Windsor

Presented at
STC "O" – WG – SPECIES Meeting
56th CIRP General Assembly Kobe, Japan, August 25, 2006

Outline:
- Challenges In Manufacturing
- New Environment
- Evolution Notions:
  - Product/Process
  - Families
  - Manufacturing Systems
- Evolution Aspects
- Sample Research
- Challenges In Process Planning for Co-Evolution

CHALLENGES FACING MANUFACTURING ENTERPRISES AT PRESENT
- Global competition and frequent market changes.
- Increasingly customized products.
- Responsiveness, agility and high performance of manufacturing systems call for new approaches to achieve cost-effective responsiveness at all levels.

It is becoming increasingly important that the manufacturing system and all its support functions, both at the physical and logical levels:
- Can accommodate these changes, and
- Are usable across several generations of products and product families.

Challenges (cont.)
- Modern manufacturing paradigms (e.g. FMS & RMS) aim to achieve these multi-objectives.
- Many enablers are required for the successful implementation of these paradigms and achieving the desired adaptability:
  - Flexibility, Changeability and Reconfigurability of hardware components, and
  - The soft or logical support functions, such as product/process modeling, process planning, process and production control strategies and logistics present a formidable challenge,
- These must not only be in place but also be adaptive and well integrated for any successful and economical responsiveness to changes in manufacturing to materialize.

Challenges (cont.)
- The process plans and planning functions are important links between the features of generations of products/product families and the features, capabilities and configurations of manufacturing systems and components throughout their respective life cycles.
- Process plans have a symbiotic relationship with both products and systems and their effective generation can be an important enabler for changeable and responsive manufacturing systems.

New Environment for Process Planning
- Families of manufactured parts are changeable.
- Manufacturing resources and functionality are reconfigurable.
- Products variations are increasing in scope and frequency.

Well-defined relationships between parts, processes and systems can help facilitate the automatic evolution of Process Plans as a link and enabler of effective changeability.
**Product-Process Evolution**

Driven by:
- Customer
- Innovation
- Cost
- Regulations

Driven by:
- Knowledge
- Technology
- Material
- Cost

Evolvable Process Plans are required in this dynamic multi-directional environment.

---

**Product Evolution Example**

- CFM56 is a high bypass ratio turbine fan engine, under development since 1970s.
- Family consists of six series (sub-sets): 2, 3, 5A, 5B, 5C, 7, ordered chronologically.
- Four fan sizes, ranging from 60 to 72 inches.
- Produced thrust ranging from 18,500 to 34,000 pounds

---

**Product Evolution Example (cont.)**

- Family of fans produced in four sizes: 60", 61", 68", and 72"
- Variation of fan form is in response to changes in functional requirements (thrust, fuel efficiency, noise attenuation, maintainability, etc.)

---

**Machine Evolution Example**

Multi-Tasking, Multi-Spindle (All in One)
- Multi-tasking / parallel processing (less time)
- Less fixtures, less tools, special tools (less expenses)
- Less load, set-up and unload (less operators, less accumulated errors), etc.

Process Plan elements are very different
Process planning objectives are more complex (min. cycle time, synchronization, workspace and interference considerations, cutting forces, …)

Parts are produced in minutes – Process Plans and programs take weeks and are not optimal.

---

**Evolution in Product Families**

**Families:**
- Evolve
- Overlap
- Mutate
- Form New Species

---

**It is All In The Family**

Who belongs to the “Family”
- Product variants
- Components variants within a product
- Configuration variants of components within same product

Derivatives and Variations in Function, Form and Configuration lead to Classes including:
- Series of Products (Function)
- Series of Components (Configuration)
- Series of Features (Dimensional and Time Versions)
Chronological Evolution of Products Species

Example: Automobile Engine

- Natural
- Progressive
- Gradual
- Uni-directional

Cylinder height range has been changing over time, based on research, for optimum engine performance.

Functional Evolution of Products Species

- Forced
- Selective
- Discrete
- Bi/Multi-directional

Cylinder height is changed within its optimum range, for obtaining desired engine capacity.

Three-Way Process planning

Product – Process - System

Generating Machine Structure

Process Plan Reconfiguration

- Parts or product change
- Change in Machine configuration
- Change in Process Plan

Reconfigurable Process Planning

Mapping between the possessing capabilities of machines and parts features

Generation of kinematics like machine structure aids process planning

Amr Shabaka and Hoda ElMaraghy, CARV '05, Munich

Challenges of Multi-Directional Evolution of P.P. for pre-planned and evolutionary changes:

Define:
- Features, Characteristics & Mechanisms
- Prerequisites, Drivers & Enablers
- Modeling methods: classes, hierarchies, co-evolution rationale, rules, associativity relationships (rules, functions, constraints, tables, etc.)
- Solution approaches and mapping transformations
- Many-to-Many relationships between products, processes and systems must be developed for effective co-evolution

Thank you,