RAPID MANUFACTURING – A BUSINESS CASE FOR DEVELOPING REUSABLE MULTIMEDIA FOR ENGINEERING EDUCATION

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ABSTRACT
Rapid Manufacturing (RM) is the name given to the production of 'series' or 'end-use' component parts made using 'Additive Layer Manufacturing' (ALM) processes. ALM processes take three dimensional Computer Aided Design (3D-CAD) data and directly 'print' or 'grow' parts in a variety of materials.

Although RM remains in its infancy, with up-take restricted almost exclusively to large scale OEM's and technology focused research firms, the technology has been cited as leading towards a 'second industrial revolution for the digital age', where it could have a significant impact on business, society, the economy and the environment.

Because RM has the potential to change the paradigm of global manufacturing, it is undoubtedly of increasing importance in both further and higher education. To-date however, RM focused learning tools have been restricted to printed materials, static web based resources and on-line multimedia content produced by technology vendors to stimulate sales.

This paper discusses the development of a commercial business model, "RM-Media", which is dedicated to the brokerage of reusable learning resources focused on RM, including digital video, audio, process animations and digital photographs. The paper addresses the development of educational content within the RM-Media product offer, in addition to global market segmentation, data and content brokerage mechanism and web based procurement.

INTRODUCTION
Rapid Manufacturing (RM) is one of a number of applications for component parts made using 'Additive Layer Manufacturing' (ALM) processes [1]. Other commercial applications for ALM within industry, include the manufacture of prototypes, know as rapid prototyping [2], tool cores and cavities, know as rapid tooling [3], and in the manufacture of patterns for a range of casting processes, known as rapid casting [4].

In recent years however, there has been an increase in the number of additive layer manufactured parts used for end use applications or RM. Examples of RM applications include aerospace components [5], automotive applications [6], medical applications [7], motor sport parts [8], and consumer products, such as light shades [9], furniture and football boots [10]. However, although RM has been identified as the possible catalyst for a 'new industrial revolution for the digital age' [11], wide spread knowledge of RM remains limited within both academia and industry.

The potential impact of RM on industry, and therefore academia is however unquestionable. Many business benefits can be attributed to the adoption of RM. These include the reduction or elimination of fixed assets such as mould tooling, jigs, fixtures and cutting tools. RM can also reduce or eliminate many stages of the traditional supply chain, reducing lead times, inventory and supply chain transaction and logistics costs. RM allows for the manufacture of topologically optimized components, producing parts that are 'manufactured-for-design', as opposed to 'designed-for-manufacture'. Because RM parts are made using additive manufacturing technologies, as opposed to subtractive machining or formative molding processes, little if any waste material is generated. Moreover, additive manufacturing allows for almost unlimited geometric complexity, providing new design freedoms and significant parts consolidation. The impact of RM on the future engineering and manufacturing teaching curriculum will undoubtedly be widespread.

Moreover, the market place for RM within industry and therefore graduate employment should not be underestimated. Based on current growth rates, it is estimated that by 2010 the RM market should be worth in excess of $270-million per annum, compared to little over $100-million today [12] [13]. However, given on the flexibility of ALM technologies, RM could facilitate production within the much wider $1.3-trillion marketplace that represents general production engineering [14]. To this end, the European Commission has forecast that RM could replace between 5% and 15% of conventional production processes within the next 5 to 10-years [15]. Based on this figure alone, we could assume that by 2017, RM activities within the EU could account for $44,283-million of added production value. Much of which will be generated through the direct engagement of high value added, knowledge driven workers at both a graduate and technician level.

To achieve this exponential growth, research funding has been allocated by both national and EU governments for the development of ALM technologies for RM applications. Research funding is being used to improve the accuracy and repeatability of processes, the functionality of materials and the production throughput of systems. However, it is questionable whether technology developments alone will be enough to stimulate the predicted transition from traditional production technologies to ALM technologies over the coming decade.

It is suggested by the author that in addition to the development of new and improved ALM technologies, a number of 'softer' management and education tools must also be developed and adopted, if RM is to maximize its potential impact. One such 'soft tool' is the development of globally accessible learning resources focused on ALM processes and RM applications.

THE NEED FOR RM LEARNING RESOURCES

Traditional manufacturing processes are either subtractive such as machining, or formative such as molding, casting or stamping. Secondary fabrication processes such as welding are also used to consolidate formative and subtractive manufactured parts. RM can be differentiated from these traditional process in that it is additive, with parts being generated particle by particle, layer by layer. The basic principle of additive manufacturing therefore differs considerably from traditional manufacturing processes. From an educational perspective, a number of questions must therefore be answered if students and industrialists are to fully understand the capabilities and subsequent applications of this technology. These questions include:

- How are 3D solid models transferred into the additive manufacturing environment
- How are 3D solid models generated (CAD / Point Cloud / Vector / MRI / CT / Math's)
- How do additive layer manufacturing systems deposit or consolidate material into layer?
- How do additive layer manufacturing systems consolidate 2D layers into 3D objects?
- How will RM effect existing business models and supply chains
- How will RM effect the design of products and the engagement of customers
- What are the capabilities and constraints of different additive manufacturing processes in terms of materials, accuracy, repeatability, build capacity, machine throughput and resolution

THE SCALE OF THE MARKET PLACE

Initial consultation undertaken in the summer of 2006 with both higher education lecturing staff and further education teaching staff, suggests that although such material would be highly and increasingly relevant across a range of technical education, flexible and reusable learning materials are not readily available in this area. Further market analysis has subsequently identified over 30,000 courses globally in which RM will undoubtedly be taught either now or in the future, delivered by over 250,000 different lecturing staff. A project was therefore initiated in October 2006, by UK based Rapid Manufacturing technology consultancy Econolyst Ltd, to respond to this market opportunity.

SEGMENTATION OF ADDITIVE LAYER MANUFACTURING TECHNOLOGIES

Within the global additive manufacturing market place, there are over 40 different technologies, marketed by over 30 vendors. However, these technologies can be segmented into just 12 mechanisms that use either thermal or chemical layering processes, as shown in Figure 1.

Because this market segmentation is based on generic layer manufacturing mechanisms, as opposed to specific and available commercial technologies, the initial educational solution was to produce detailed animations showing how each mechanism generates both an individual layer and how subsequent layers are 'stacked' to generate a solid 3D object.

To then compliment each animation and to show product differentiation, digital video footage of each individual commercial ALM process was then shot at locations around the world over a 9-month period. This was then complimented with an archive of both video and stills images of resulting parts.

Having developed both animations and process footage, interviews will over 90% of the worlds ALM technology vendors were then undertaken to camera, to provide voice-over, narrative and subjective comment. Additional interviews were then conducted with technology users, where process capabilities and constrains were discussed in addition to Rapid Manufacturing applications and case studies. Further interviews and process filming is currently scheduled through to Q1 of 2008.

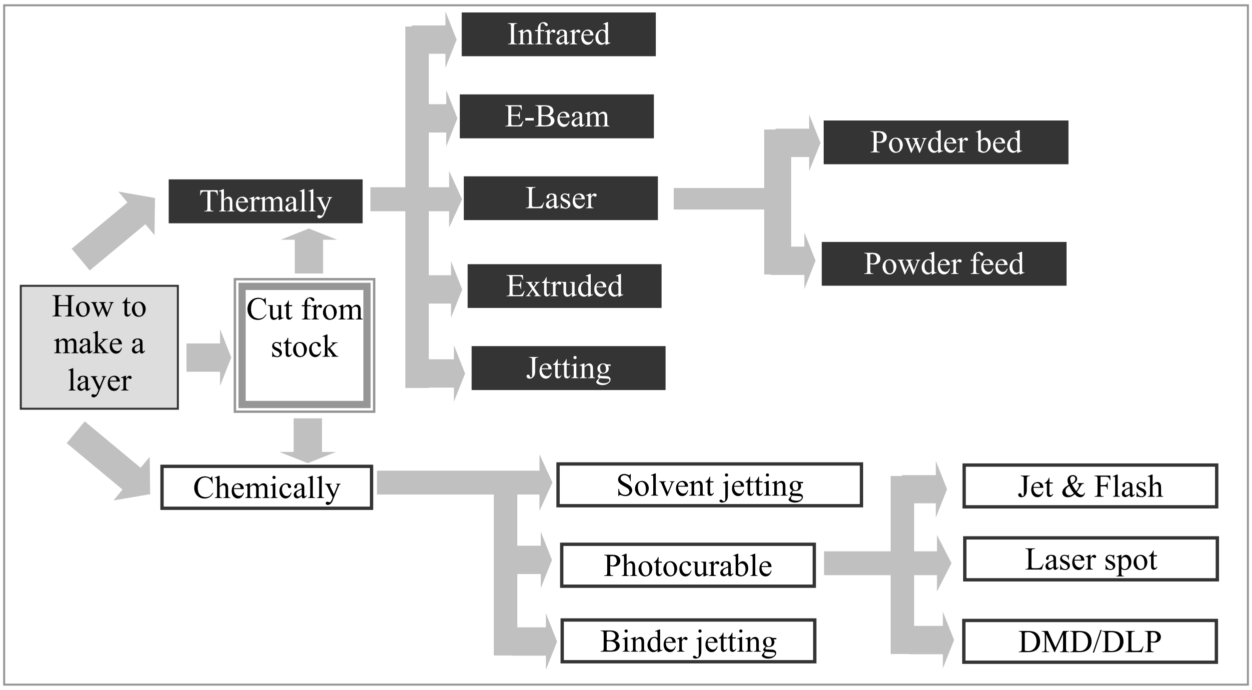

Figure 1: Additive layer manufacturing mechanisms

Having developed what is arguably the world's largest archive of RM focused multimedia, as shown in Figure 2, Econolyst has now engaged in the development of a web based brokerage solution aimed at making these media assets assessable to a global market place.

RM-MULTIMEDIA DELIVERY

Through consultation with the academic market place, it has become apparent that no one multimedia solution will fit all requirements. Hence a flexible delivery approach is required to maximize the market opportunity. The key considerations for flexibly delivery include:

- Flexible content duration, where material can be used either in blocks during a lecture, or to support individual lectures throughout a module.
- Variable resolution files for different applications
  - High resolution formats for presentations
  - Low resolution formats for e-learning, web delivery or I Pod's
  - Mpeg, AVI or codex formats for different operating systems
- Variable cost options based on duration, resolution and content
- Packaged DVD options with bespoke and branded menus
- Digital photo archives to support handouts and printed materials
- Power Point embedded slide shows, with institutional branding
- Optional voiceovers, sound and narrative
- Assigned copyright for use in presentations, websites and literature

MANUFACTURER	TECHNOLOGY	ANIMATIONS		VIDEO FOOTAGE							DIGITIAL IMAGES				
		Generation of a single layer	Staking of layers into 3D object	Machine	Machine during build	Part following build	Part removal and clean up	Finished Parts	Interview with vendor	User Interview	Machine design	Part during build	Part following build	Part removal and clean up	Finished Parts
ARCAM	EBM	●	●	●	x	x	x	●	●	●	●	x	x	x	●
Concept Laser	Laser Cusing	●	●	●	-	-	-	●	●	-	●	-	-	-	●
EnvisionTEC	Profactory	●	●	●	+	+	+	+	●	+	●	+	+	+	●
EnvisionTEC	Vanquish	●	●	●	●	+	+	●	●	-	●	●	●	+	●
EOS	EOSINT P	●	●	●	●	●	●	●	●	●	●	●	●	●	●
EOS	EOSINT M	●	●	●	●	●	+	●	●	●	●	●	●	+	●
MCP	Realizer	●	●	●	●	●	x	●	●	x	●	●	●	X	●
Nextfactory	Digiwax	●	●	●	●	●	+	●	●	+	●	●	●	+	●
Objet	Eden	●	●	●	●	●	+	●	●	●	●	●	●	●	●
ProMetal	Direct Metal	●	●	●	●			●		●	●	●			●
ProMetal	Sand	●	●	●	●			●							
Solidscape	T-bench top	x	x	x	x	x	x	x	x	x	x	x	x	x	X
Speedpart	RP3							●	●						●
Stratasys	FDM	●	●	●	●	●	●	●	●	●	●	●	●	●	●
3D Systems	SLA	●	●	●	●	●	●	●	●	●	●	●	●	●	●
3D Systems	SLS	●	●	●	●	●	●	●	●	●	●	●	●	●	●
3D Systems	Thermojet	●	●	●	●	●		●	●	●	●	●		●	●
3D Systems	InVision HR	●	●	●	●	●	●	●	●	●	●	●	●	●	●
3D Systems	InVision LD	●	●	●				●	●		●				●
Trumpf/POM	Powder feed	●	●	●	●	●			●		●	●	●	●	●
Voxel Jet	VX800	●	●	●							●				●
Z-Corp	Z510	●	●	●	●	●	+	●	●	+	●	●	●	●	●

KEY

Current footage	●
Planned Q3 2007	+
Planned Q4 2007	x
Planned 2008	-

Figure 2: Econolyst RM Multimedia asset archive

ONLINE DELIVERY MECHANISMS

Online systems such as IStockPhoto [16] and IStockvideo [17] allow users to purchase credits in advance, and then to download variable resolution media in real time. Other systems such as Apple I-tunes [18] allow users to download either singular or batches of files at a set resolution (or quality) for a fixed cost. As yet the author has been unable to source a commercial software solution that allows the online and real time delivery of video content, where the end user is also able to specify attributes such as resolution, duration, file format or sound content. It should also be noted that a 5-minute duration high resolution AVI file, will equate to 1GB of data. Hence, although it is possible to exchange high quality multimedia files online; these will not always be viewable in real time.

Moreover, consultation with the academic market place, suggests that the real time online purchasing of digital teaching materials remains some way off, as such a business model would require either the use of institutional credit cards, institutional online money transaction services such as PayPal, or the use of personal credit cards by staff.

Given the technological challenges of delivering flexible multimedia to institutional buyers, a decision has been made to launch the Econolyst RM-Multimedia service using a partial web based procurement model.

THE ECONOLYST RM-MEDIA PROCUREMENT MODEL

The solution currently under development for launch in November 2007 will use an on-line specification process, where the media buyer will select from a matrix of available media assets. These assets will be viewable in low resolution online prior to purchase. Having selected the required assets, the buyer will then be given a number of selection options, such as the required resolution and file format and whether voiceovers or narratives are required. A series of cost options will then be presented in real time back to the buyer, based on the delivery of data as either raw media files, data encoded onto DVD with a menu system, or data pre-embedded into an MS-Power Point slideshow. At this stage the buyer will also be given the lead-time for the supply of their chosen media, as this will be dependent on the chosen delivery format.

Only on acceptance of the chosen delivery format will the buyer be prompted for payment details which will include both credit card and invoice options.

FUTURE DEVELOPMENTS

A number of long-term future developments are currently under consideration at Econolyst, including the development of a bespoke 'automated' materials delivery solution and the possible development of an open-source e-learning module on Rapid Manufacturing using RM Media content.

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