
Abstract

The current approach for many manufacturing enterprises is to centralize product development, product production, and product distribution in a relatively few physical locations. These locations can decrease even further when companies off-shore product development, production, and/or distribution to other countries/companies to take advantage of lower resource, labor or overhead costs. The resulting concentration of employment leads to regions of disproportionately high underemployment and/or unemployment. As a result, nations can have regions of underpopulation with consequent national problems such as infrastructure being underutilized, and long-term territorial integrity being compromised (Beale, *Rural Cond Trends* 11(2):27–31, 2000).

20.1 Introduction

The current approach for many manufacturing enterprises is to centralize product development, product production, and product distribution in a relatively few physical locations. These locations can decrease even further when companies offshore product development, production, and/or distribution to other countries/companies to take advantage of lower resource, labor or overhead costs. The resulting concentration of employment leads to regions of disproportionately high underemployment and/or unemployment. As a result, nations can have regions of underpopulation with consequent national problems such as infrastructure being underutilized, and long-term territorial integrity being compromised [1].

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This chapter is based on VTT Working Paper 113 Digiproneurship: New types of physical products and sustainable employment from digital product entrepreneurship, by Stephen Fox & Brent Stucker. The terms “Digiproneurship” and “Factory 2.0” were first introduced in this paper, which is archived at <http://www.vtt.fi/inf/pdf/workingpapers/2009/W113.pdf>

Because of recent developments in additive manufacturing, as described in this book, there is no fundamental reason for products to be brought to markets through centralized development, production, and distribution. Instead, products can be brought to markets through product conceptualization, product creation, and product propagation being carried out by individuals and communities in any geographical region.

In this chapter, *conceptualization* means the forming and relating of ideas, including the formation of digital versions of these ideas (e.g., CAD); *creation* means bringing an idea into physical existence (e.g., by manufacturing a component); and *propagation* means multiplying by reproduction through digital means (e.g., through digital social networks) or through physical means (e.g., by distributed AM production).

Many companies already use the Internet to collect product ideas from ordinary people from diverse locations. However, these companies are feeding these ideas into the centralized physical locations of their existing business operations for detailed design and creation. Distributed conceptualization, creation, and propagation can supersede concentrated development, production, and distribution by combining AM with novel human/digital interfaces which, for instance, enable non-experts to create and modify shapes. Additionally, body/place/part scanning can be used to collect data about physical features for input into digitally enabled design software and onward to AM.

Web 2.0 is considered as the second generation of the Internet, where users can interact with and *transform* web content. The advent of the Internet allowed any organization, such as a newspaper publisher, to deliver information and content to anyone in the world. More recently, however, social networking sites such as Facebook, or auction web sites such as eBay, enable consumers of web content to also be content creators. These, and most new web sites today, fall within the scope of Web 2.0.

AM makes it possible for digital designs to be transformed into physical products at that same location or any other location in the world (i.e., “design anywhere, build anywhere”). Moreover, the web tools associated with Web 2.0 are perfect for the propagation of product ideas and component designs that can be created through AM. The combination of Web 2.0 with AM can lead to new models of entrepreneurship.

Distributed conceptualization and propagation of digital content is known as digital entrepreneurship. However, the exploitation of AM to enable distributed creation of physical products goes beyond just digital entrepreneurship. Accordingly, the term, *digipreneurship* was coined to distinguish distributed conceptualization, propagation, and creation of *physical* products from distributed conceptualization and propagation of just digital content. Thus digipreneurship is focused on transforming *digital* data into physical *products* using an *entrepreneurship* business model. Short definitions of the terms introduced in this section are summarized in Fig. 20.1.

Web 2.0 + AM has the potential to generate distributed, sustainable employment that is not vulnerable to off-shoring. This form of employment is not vulnerable to



Fig. 20.1 Definition of terms

off-shoring because it is based on distributed networks in which resource costs are not a major proportion of total costs. Employment that is generated is environmentally friendly because, for example, it involves much lower energy consumption than the established concentration of product development, production, and distribution, which often involves shipping of products worldwide from centralized locations.

As discussed throughout this book (particularly in Chaps. 17, 18 and 20), developments in AM offer possibilities for new types of products. Thus, there are many potential markets for the outputs of digiproneurship.

20.2 What Could Be New?

20.2.1 New Types of Products

Developments in AM, together with developments in advanced Information and Communication Technologies (aICT), such as more intuitive human interfaces for design, Web 2.0, and digital scanning, are making it possible for person-specific/location-specific and/or event-specific products to be created much more quickly and at much lower cost. These products can have superior characteristics compared to products created through conventional methods. In particular, AM can enable previously intractable trade-offs to be overcome. For example, design trade-offs such as manufacturing complexity versus assembly costs can be overcome (e.g., geometrically complex products can now be produced as one piece rather than having to be assembled from several pieces); material selection trade-offs such as performance requirements versus microstructures can be overcome (e.g., turbine blades can now have both high strength and high thermal performance in different locations); economic trade-offs such as person-specific fit and/or functionality versus production time and/or cost can be overcome (e.g., customized prosthetics, such as hearing aids with person-specific fit, can be produced rapidly).

When utilizing an additive approach to production, the consumption of non-value adding resources can be radically reduced during the creation of physical goods. Further, the amount of factory equipment needed and, therefore, factory

Table 20.1 Radical reductions in the consumption of non-value adding resources

Example	First order effect	Second order effect
No need for molds/dies	Less material consumption	Lower start-up costs
Fewer parts to join	Less joining equipment	Less capital tied up in infrastructure
Fewer parts to assemble	Less labor and less assembly equipment	No need to off-shore production to low labor cost markets
No spare parts are stocked	Less storage space	Reduced factory and warehousing size

space needed is reduced. As a result, opportunities for smaller, distributed (even mobile) production facilities increase. Some examples are provided in Table 20.1. Perhaps most importantly, the potential for radically reducing the size of production facilities enables production at point-of-demand.

Although digiproneurship is probably best enabled by AM, any digitally driven technology which directly transforms digital information into a physical good can fall within the scope of digiproneurship. This can include the fabrication of structures which enclose space (such as for housing) whereby each individual piece could be created using a digitally driven cutting operation and then assembled at the point of need into a usable dwelling.

It is very important to note that the limitations of manufacturing equipment and the need for expert knowledge of microstructures and material performance have previously restricted the value of direct consumer control over content. Thus, most examples of consumer-produced content are for nonphysical products [2]. For example, a person who reads a newspaper (consumer of the newspaper) walks down a street and sees something newsworthy. The person takes a photograph of it. The person sends the image to the newspaper. The photograph is included in the newspaper, and hence the person becomes a partial producer of what they consume. While such forms of consumer input are established, it is only recently that developments in aICT and AM make possible consumer input into a wide range of physical goods.

From an engineering and design standpoint, AM technologies are becoming more accurate, they can directly build small products (micron-sized) and very large products (building-sized). New materials have been developed for these processes, and new approaches to AM are being introduced into the marketplace. From a business-strategies standpoint, AM technologies are becoming faster, cheaper, safer, more reliable, and environmentally friendly. As each of these advancements becomes available within the marketplace, new categories of physical goods become competitive for production using AM versus conventional manufacturing. Combination of aICT with AM thus offers a wide range of opportunities for innovation in products and product services. Opportunities exist for individuals (e.g., at home), B2B (Business to Business), and B2C (Business to Consumer). Further, opportunities exist for creation of designs or creation of physical components. Thus a digiproneur could be someone who: (1) creates digital tools

for use by consumers or other digiproneurs; (2) creates designs which are bought by consumers or businesses; (3) creates physical products from digital data; or (4) licenses or operates enabling software or machinery in support of digiproneurship.

By replacing concentrated product development, production, and distribution with distributed product conceptualization, creation, and propagation it is possible for individuals or communities to bring products to different types of consumers without needing to make large investment in market research, design facilities, production facilities, or distribution networks. The reasons for this are further explained in the following subsection.

20.2.2 New Types of Organizations

Web 2.0 technologies have spawned a convergence of traditional craft with technologies. One need only attend a local Maker Faire to see the gamut of entrepreneurs offering products made traditionally, with lots of electronics, and with AM content. To support the emerging communities of craftsmen and women, online portals, blogs, and repositories have proliferated. For example, some portals have been established to focus on 3D Printing (www.3ders.org) or more broadly on making (www.instructables.com). The number of blogs focused on 3D Printing, AM, and making is too numerous to do justice by listing only one or two. Since the creation of 3D digital content can be challenging several repositories of 3D content have been created, the most well-known being Thingiverse (www.thingiverse.com). Even traditional craft-based media have changed with, for example, Make Magazine adopting a synergistic combination of traditional paper distribution with online content and interaction. Each of these examples represents a business entity that was created by an entrepreneur who wanted to leverage Web 2.0 and add value to AM users, companies, or communities.

In traditional manufacturing industries, companies such as MFG.com have become very success as industry matchmakers, finding suppliers or customers for companies around the world. They provide services for establishing supply chains and handling logistics for companies. Their expansion into the AM field seems inevitable and may already have begun. This may cause existing service bureaus adapt their business models. They can join existing networks of parts suppliers or possibly try to build their own networks. They could choose to concentrate on their technology (within AM) or become more consumer focused, possibly becoming a supplier to a virtual storefront company.

From a different perspective, companies can utilize Web 2.0 technologies to engage with their customers to a much greater extent. Customer co-design and crowdsourcing are new terms that relate to this customer focus. Some consumer companies, such as Nike, Dell, and Home Depot, have been pioneers in providing web-based tools that enable customers to configure their own products. We can expect this trend to continue to grow exponentially. New opportunities will emerge for unprecedented levels of customer engagement. We are seeing new companies

created to provide customer-designed products, for example sunglasses, that are fabricated locally using AM. One could image kiosks at local shopping malls that are equipped with 3D printers for near real-time fabrication.

The Local Motors crowdsourcing example has been mentioned in earlier chapters. They have been an early adopter of crowdsourcing for automotive vehicles. Many other organizations and companies are experimenting with crowdsourcing technologies and practices for the development of products. It will be interesting to see how a highly technical and integrated product (such as a car) can be developed by hundreds of geographically dispersed individuals who are contributing informally on irregular schedules. From marketing and decision-making perspectives, however, having all of these individuals critique and vote on design alternatives and become invested in the outcome of the group activity can have tremendous benefits in terms of sales. Products may become successful simply because they “went viral” due to high levels of involvement from vocal online communities.

Going beyond Web 2.0 technologies, the area of cloud computing has enabled the emergence of cloud-based design and manufacturing (CBDM) concepts. We are already seeing mechanical CAD companies, such as Dassault Systemes and AutoDesk, offer cloud-based CAD and engineering systems. Some companies are talking about cloud-based AM part fabrication services. CBDM represents a natural evolution of this trend. One challenge for cloud-based manufacturing is the need for hard tooling for part manufacture and product assembly. It is difficult to provide flexible, scalable, “produce anywhere” services if one has to first fabricate a lot of tooling. On the other hand, AM offers a flexible, scalable, “produce anywhere” solution for CBDM. It is likely that we will see CBD products and services incorporate some CBM aspects. Perhaps an obvious first step is a “3D Print” button in cloud-based CAD systems. A longer term possibility is a convergence between cloud-based CAD and supply chain service providers (e.g., MFG.com) so that engineering designers can include manufacturing, vendor, and supply chain consequences of design decisions quickly in a seamless online environment.

20.2.3 New Types of Employment

As summarized in Table 20.1, innovative combinations of AM and aICT help eliminate non-value adding consumption of resources and reduce energy consumption arising from transportation of finished goods. Creation of physical products at point-of-demand can overturn current comparative disadvantages in the creation of physical products for global markets. As an example, today Finland has the comparative *disadvantages* of limited natural resources, far distance from mass markets, and relatively high labor costs. However, aICT + AM has the potential to make Finland’s comparative disadvantages become *unimportant* in global value networks. This is because centralized models of physical production can be replaced by distributed models of value creation. In distributed models, design can take place anywhere in the world, and production can take place anywhere else

in the world. As a result, there are opportunities for many jobs to be created in Finland by meeting “derived demand” for the software, hardware, and consultancy needed by creation organizations in other parts of the world. This is in addition to the jobs that can be created in Finland by meeting “primary demand” for physical goods which are used in Finland, Russia, Nordic regions, and beyond; or unique designs which can be electronically delivered to consumers worldwide for their creation. Thus, the resources that become important in digiproneurship are creativity, technological savvy, and access to digiproneurship networks.

Innovative combinations of AM and aICT make it possible for creation of diverse product types by people without prior knowledge of design and/or production. Regions of persistent unemployment could be reduced by enabling a dynamic network of aICT + AM micro-businesses and Small and Medium-sized Enterprises (SMEs). These could be distributed among local individuals working from their homes, from their garages, from their small workshops, or from light industrial premises. They could be distributed among families and communities that have a generational investment and an abiding commitment to the regions in which they live. Accordingly, the jobs generated by digiproneurship are resistant to concentration and outsourcing.

The labor cost component of aICT + AM products is relatively low. Thus, these combinations of high technology and low labor input mean that there is little incentive to outsource to low labor cost economies. A summary is provided in Table 20.2 of the factors that can enable overturning of regional disadvantages which might occur in the creation of physical products for global markets.

A diverse range of people and businesses could offer products via digiproneurship. Some examples of these people and business are:

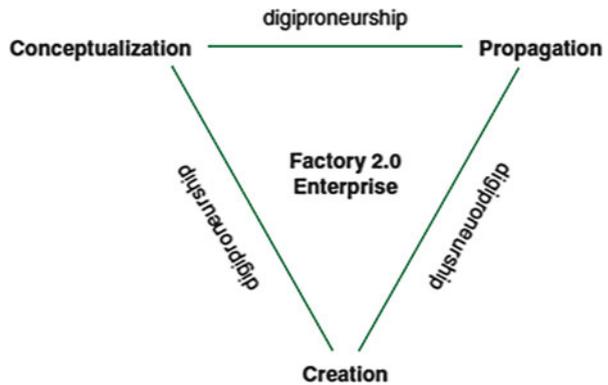
- Artistic individuals who want to create unique physical goods
- Hobby enthusiasts who understand niche market needs
- IT savvy people who are interested in developing novel aICT software tools
- Farmers wanting to diversify beyond offering B&B to the occasional tourist
- Under-employed persons looking to provide supplemental income for their families
- Unemployed people who are reluctant to uproot to major cities to look for work
- Machine shops wanting to diversify and/or better utilize their skilled workforce
- SMEs that want to introduce more customer-specific versions of their product offerings
- Multinational corporations seeking to streamline the design and supply of goods which will be integrated into their products

Thus, digiproneurship represents the intersection of conceptualization, creation, and propagation, as illustrated in Fig. 20.2.

Table 20.2 Overturning regional disadvantages in the creation of physical products

Typical location-based disadvantages	aICT + AM potential
Lack of natural resources	Products make use of relatively small quantities of high-quality engineered materials procurable worldwide
High labor costs	Labor content is smaller, but networking and technology integration content is higher
Distance from markets	aICT + AM products can be designed anywhere, propagated digitally and produced at the point-of-need. Shipping costs are minimized

Fig. 20.2 Digiproneurship involves the creation of a business enterprise by connecting conceptualization, propagation, and/or creation



20.3 Digiproneurship

Entrepreneurship involves individuals starting new enterprises or breathing new energy into mature enterprises through the introduction of new ideas. Entrepreneurship is associated with uncertainty because it involves introducing a new idea [3]. Well-known examples of digital entrepreneurship include Facebook, Google, and YouTube. By taking digital entrepreneurship one step further, into the creation of physical goods, digiproneurship represents the next logical step.

Distributed conceptualization and propagation can reduce the risks traditionally associated with entrepreneurship. In particular, digitally enabled conceptualization and propagation of new concepts and designs for physical products can eliminate the need for costly conventional market research. Further, digitally enabled propagation of product designs to point-of-demand AM facilities can eliminate the need for physical distribution facilities such as large warehouses, costly tooling such as injection molds, and difficult to manage distribution networks. Together, digitally enabled conceptualization, propagation, and creation can eliminate many of the uncertainties and up-front expenses that have traditionally caused many entrepreneurial ventures to fail.

Digiproneurship transcends traditional design paradigms by facilitating the emergence of enterprise through the self-expression of personal feelings and opinions. New digital interfaces which enable non-experts to capture their design intent as physically producible designs could radically transform the way products are conceived and produced.

One of the earliest enterprises that could be considered a digiproneurship enterprise was Freedom of Creation (www.freedomofcreation.com), as discussed in Chap. 20. Subsequently to Freedom of Creation, numerous other digiproneurship activities have been started, including FigurePrints (www.figureprints.com) for creation of World of Warcraft figures and virtual storefronts such as Shapeways (www.shapeways.com) and Ponoko (www.ponoko.com), which are online communities where digiproneurs can sell designs, services, and products.

Digiproneurship opportunities are now being considered early in the conceptualization stage for new products. The Spore game and Spore Creature Creator (www.spore.com) were designed such that Spore creatures, created by the game players, are represented by 3D digital data that can be transferred to an AM machine for direct printing using a color binder jetting process. This is unlike the original World of Warcraft figures, which appear 3D on-screen but are not 3D solid models; and thus require data manipulation in order to prepare the figure for AM. Spore Sculptor (sporesculptor.com) has been set up as a portal for Spore game users to purchase physical representations of their Spore creatures.

In the future, inexpensive, intuitive solid modeling tools, such as Google SketchUp (sketchup.google.com), may be used widely by consumers to design their own products. For many products, safety or intellectual property concerns will likely lead to software which will enable consumers to modify products within expert-defined constraints so that consumers can directly make meaningful changes to products while maintaining safety or other features that are necessary in the end-product.

The success of digiproneurship enterprises is due to their recognition of market needs which can be fulfilled by imaginative product offerings enabled through innovative combinations of aICT and AM. Although pioneers have demonstrated that successful enterprises can be established, the potential for digiproneurship extends significantly beyond the scope of today's technological capabilities and business networks. In particular, as aICT and AM progress, and new business networks are established, the opportunities for successful digiproneurship will expand.

Several research and development priorities for aICT and AM are crucial for further realization of digiproneurship:

Digiproneurship-related research and development priorities for aICT

- Development of geometric manipulation tools with intuitively understandable interfaces which can be used readily by non-experts.
- Application of expert-defined constraints (such as through shape grammars and computational semantics) to enable experts to create versatile parameters for digiproneurship products. These parameters conform to criteria for, e.g., safety

and brand, but facilitate the creation of person-specific, location-specific, and/or event-specific versions by non-experts.

- Web-based digiproneurship tools which can enable non-experts to set up and operate their own digitally driven enterprise. These web-based tools encompass market opportunities and business issues; as well as technology characteristics and material properties.
- Additional web-based digiproneurship tools to assist in setting up virtual enterprises that integrate supplier identification, supply chain configuration, marketing, and product delivery.

Digiproneurship research and development priorities for AM

- Continuing the current trend to lower-cost equipment and materials
- Automating and minimizing post-processing of products after production, so that parts can go directly from a machine to the end customer with little or no human interaction
- Continuing the current trend to increasing diversification of machine sizes, speeds and accuracies
- Interfaces to automatically convert multimaterial and multicolor user-specified requirements directly into digital manufacturing instructions without human intervention

As digiproneurship matures, there will be a need for an increasing number of creation facilities that enable digiproneurs to reach customers irrespective of their location. Some of these creation facilities will be the 3D corollary to today's local copy centers. As such, they may even offer AM alongside 2D printers. Further, companies in all sectors may lease AM equipment in the same way that they lease document printers today. AM creation facilities could be located within department stores (e.g., for customer-specific exclusive goods such as jewelry); large hospitals (e.g., for patient-specific prosthetics); home improvement stores (e.g., for family-specific furnishings); and/or industrial wholesalers (e.g., for plant-specific upgrade fittings). Competition and cooperation among creation facilities that provide services to digiproneurs will be enabled by aICT. Those who establish these creation facilities will themselves be digiproneurs and aid other digiproneurs in creating physical products. Development of digiproneurship infrastructure will lead to an increasing ability by digiproneurs to conceptualize, create, and propagate competitive new products, resulting in a sustainable model for distributed employment wherever digiproneurship is embraced. This, then, will be "Factory 2.0." As Web 2.0 has seen the move from static web pages to dynamic and shareable content; Factory 2.0 will see the move from static factories to dynamic and shareable creation. To make this possible, Factory 2.0 will draw upon Web 2.0 and the distributed conceptualization and propagation which it and AM enables.

Since the advent of the industrial revolution, the creation of physical goods has become an ever more specialized domain requiring extensive knowledge and investment. This type of highly concentrated and meticulously planned factory

production will continue. However, Factory 2.0 will likely flourish alongside it. This will enable production by consumers, as envisioned 40 years ago [4]. Thus, the innate potential of people to create physical goods will be realized by fulfilling the latent potential of Web 2.0 combined with AM in ever more imaginative ways. Additionally, for the first time since the industrial revolution began, the trends towards increasing urbanization to support increasingly centralized production may begin to reverse when the opportunities afforded by Factory 2.0 are fully realized.

Conclusions

There is no longer any fundamental reason for products to be brought to markets through centralized product development, production, and distribution. Instead, products can be brought to markets through product conceptualization, creation, and propagation in any geographical region. This form of digiproneurship is built around combinations of aICT and advanced manufacturing technologies.

Digiproneurship offers many opportunities for a reduction in the consumption of non-value adding resources during the creation of physical goods. Further, the amount of factory equipment needed and, therefore, factory space is reduced. As a result, opportunities for smaller, distributed, and mobile production facilities will increase. Digiproneurship can eliminate the need for costly conventional market research, large warehouses, distribution centers, and large capital investments in infrastructure and tooling.

Creation of physical products at point-of-demand can make regional disadvantages unimportant. A wide range of people and businesses could offer digiproneurship products, including artists, hobby enthusiasts, IT savvy programmers, underemployed and unemployed people who are reluctant to uproot to major cities to look for work, and others.

Novel combinations of aICT and AM have already made it possible for enterprises to be established based on digitally driven conceptualization, creation, and/or propagation. The success of these existing enterprises is due to their recognition of market needs which can be fulfilled by imaginative, digitally enabled product offerings. As aICT and AM progress, and new creation networks are established, CBDM will become a reality, the opportunities for successful digiproneurship will expand and Factory 2.0 will come into being.

As digiproneurship expands and Factory 2.0 becomes a reality, AM could come to have a substantial impact on the way society is structured and interacts. In much the same way that the proliferation of digital content since the advent of the Internet has affected the way that people work, recreate, and communicate around the world, AM could 1 day affect the distribution of employment, resources, and opportunities worldwide.

20.4 Exercises

1. Do you think AM has the potential to change the world significantly? If so, how? If not, why not?
2. In what ways could AM's future development mirror the development of the Internet?
3. Find and describe three examples of digipreneurship enterprises which are not mentioned in this book.
4. How would you define Factory 2.0?
5. Based upon your interests, hobbies, or background, describe one type of digipreneurship opportunity that is not discussed in this chapter.

References

1. Beale CL (2000) Nonmetro population growth rate recedes in a time of unprecedented national prosperity. *Rural Cond Trends* 11(2):27–31
2. Fox S (2003) Recognizing materials power: how manufacturing materials constrain marketing strategies. *Manuf Eng* 81(3):36–39
3. Drucker PF (1993) *Innovation and entrepreneurship: practice and principles*. HarperCollins, New York
4. Toffler A (1970) *Future shock*. Bantam Books, New York