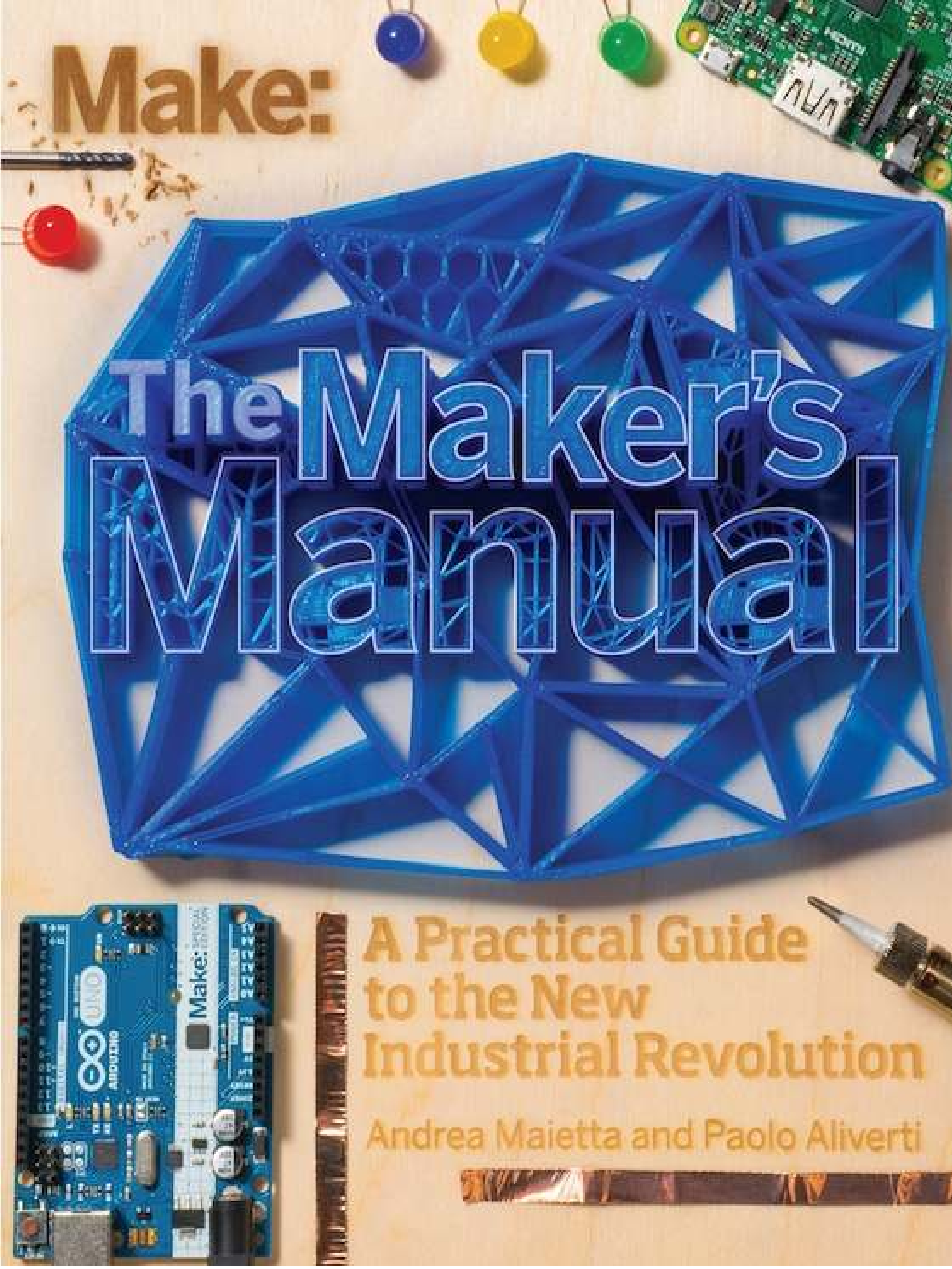
Make:
The Maker's Manual
A Practical Guide to the New Industrial Revolution
Andrea Maietta and Paolo Aliverti

The Maker’s Manual

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by Andrea Maietta and Paolo Aliverti

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Preface

A revolution is happening: the manufacture of objects is shifting from big companies—where your only choice might be the color black—to individuals, producing a previously unseen variety in things we make.

Today, thanks to versatile, powerful, and convenient tools such as Arduino and 3D printers, anyone can easily build, customize, fix, or improve objects. Tools and technologies have changed, but the passion for the process of creation hasn't.

A *maker* is not necessarily someone who works in design and manufacturing in her day job, but rathe someone who always finds a way to turn her passion into an actual source of personal and economic rewards. She may get down to work to solve a personal challenge and then realize there are other people with the same problem. How can these garage inventors turn their passion first into a startup and then into a sustainable business, especially in this period of economic crisis? Even manufacturin and selling are changing—the old criteria do not work anymore—and people who have difficulties with change see their situation worsen day by day.

The new entrepreneurs have an utterly different approach: it is based on scientific techniques that were born within the industry field, reached the software world, and finally arrived in the business system. Just as the open source phenomenon influenced software in the 1990s, today open hardware and open design influence the production of physical objects; new startups create open source products, including both software and hardware. The enterprise philosophy itself is open. It is beneficial to cooperate and collaborate: people share ideas, and the more those ideas spread, the mor the people and companies that are part of that community realize the profits. Anyone can contribute t projects and products and even create his own version, exchanging projects, ideas, and techniques to make (almost) anything. Such a model comes from the software world, where a worldwide communi of developers works with a spirit of collaboration and sharing. Everyone benefits.

To become a maker there are many things to learn, many of which were familiar to our grandparents, although those skills have largely been forgotten now. A maker, like a modern Leonardo da Vinci, must apply a great variety of skills and knowledge, not only technical expertise.

This manual is an overview of the indispensable tools you'll need to become a maker: the starting point for a truly rewarding path.

Born from the actual experience of Frankenstein Garage, which has been active with courses, workshops, and events for makers for years, this book explains complex concepts in a simple and intuitive way, anticipating the questions of those who wish to start or who still haven't managed to find their own way. The informal style helps you understand intimidating ideas, and takes you by the hand to help you create your personal toolbox, both physical and mental, in order to make the project of your dreams a reality.

The manual consists of four parts:

- Part I discusses the makers, explaining the origins of the movement and its potential impact on th economic system.

- Part II proposes an easy yet structured approach to generate or perfect your own ideas (creative techniques, design processes) and make them grow in a favorable environment. It explains what a startup is, how to run a project, what innovation and business models are, how to find reliable collaborators, and how to raise financial resources.
- Part III is the more practical section, and briefly introduces the tools you'll need to collaborate. After that, you will learn how to physically create products starting from a model and using technologies such as milling, 3D printing, and laser cutting.
- Part IV explains how to give life to your creations, thanks to electronics and microcontrollers. We will also show you how to generate visual interactions, and will give you an overview of the Internet of Things (IoT), the new manufacturing frontier.

Have fun!

Book Site

We have created a website where you can find further information, resources, links, references, and anything else that we couldn't include in the book. You can also download all the sample code listed in the book from this website.

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The following typographical conventions are used in this book:

Italic

Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`

Shows commands or other text that should be typed literally by the user.

`Constant width italic`

Shows text that should be replaced with user-supplied values or by values determined by context.

> This element signifies a tip, suggestion, or general note.

> This element indicates a warning or caution.

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Part I. The World of the Maker

…people who hack hardware, business-models, and living arrangements to discover ways of staying alive and happy even when the economy is falling down the toilet.

Cory Doctorow

Chapter 1. Who Are the Makers?

Today we live in a world many of us define as “advanced,” filled with technological wonders like smartphones and the World Wide Web. But these gadgets are just the fruit of an entire civilization based on the application of science and technology to our daily lives. Thanks to that civilization, we can live in a warm place, store our food without it spoiling, have light even when it is dark outside, communicate with the people we love anywhere in the world, or travel faster than our legs can carry us.

At the same time, many of these changes—the same ones that have improved our way of living—hav limited our lives. Most people may say they cannot live without computers, telecommunications, electricity, and synthetic chemicals. If those technologies were to suddenly disappear, a large portion of the earth’s seven billion people would start to die very quickly.

We are bombarded by media that do everything they can to encourage us to consume in an uncontrolled way—to queue in front of an Apple Store every six months, or to buy a new car every two years. And the same media make us feel “out of place” if we do not adjust to all the things advertising intends to inflict on us.

Within this context, products are no longer made to meet the consumers’ needs, but to create a viciou circle: objects are designed to last shorter and shorter amounts of time, to break soon after their warranty expiration date (accurately calculated by statistics) so that we have to go out and buy new objects, thus artificially creating a market whose only aim is to support production.

Today governments are concerned only about GDP growth (in Italy, for example, the decreasing curv of the yield spread is, at the time of this writing, a further common concern). Even so, the GDP is a somewhat poor indicator of national contentment, because it also grows during events such as disasters or wars.

But has it always been like this?

The Culture of Reuse

For our grandparents and their parents, everything was different. Those born around, say, 1925, grew up during the Great Depression—a period of high unemployment, job insecurity, homelessness, and even starvation in some of the most advanced countries in the world. They learned themselves—and imbued their children with the spirit—to make do with what they had, which was almost nothing.

This shortage of resources led to a culture of recycling, respect, and reuse. Nothing was thrown away instead, everything was ingeniously transformed using whatever tools were at hand. Our grandparent used to build what they needed themselves, and they were happy because they had something we ofte lack today: the sense of personal reward for having built something with their own hands, seeing thei creation evolve from a conceptual idea to reality—from cutting boards, knives, barrels, and sickles t more technological tools (see Figure 1-1).

It was a question of culture: when something was needed or had to be solved, people tried multiple approaches, starting from what was available and often recycling it in previously inconceivable ways until they found a solution. Then, as now, practice was the only way to actually learn.

Figure 1-1. The pleasure of building something with your own hands

We Are All Designers

As children, many, if not all of us, dismantled some toys to understand how they worked. Some of us even managed to assemble them again. All the toys we dismantled taught us something, allowing us t modify them according to our tastes or to create new ones. In the past, this kind of activity was very widespread among adults too, practiced by so-called tinkerers: people who took abandoned objects and dismantled, modified, and redesigned them into something new and absolutely wonderful.

Today, technology allows us to do the same thing digitally. The necessary tools are at our disposal, free of charge or at reasonable costs. We can design very different objects following very similar processes. Thanks to our access to all information and to the community’s support, learning is very simple, and we can become productive with different tools in a very short time.

Not Only Digital

In the 1990s everyone seemed to suddenly become a web designer: the spread of the Internet and the World Wide Web created a small factory of bits and bytes in many people's homes. With simple editing software, people could create websites. We believe that the immediacy of results and the low cost of entry have contributed to distancing today's young people, the so-called digital natives, from the traditional do-it-yourselfers who are still linked to the physical world.

What has changed recently is a sort of democratization in access to tools like 3D printers and other rapid prototyping machines, which has marked a return from bits (digital components) back to atoms (physical components) easier. These technologies have already been in existence for a long time, but they have usually been inaccessible to most people because of their extremely high costs. Today, a 3I printer can be had for as little as $500, much less than the original laser printer ($3,000). Even if othe tools like laser *cutters* and computerized milling machines are still somewhat expensive, there are different services that allow you to use such tools at very low costs. It is like renting a factory withou bearing all the startup costs: you only have to pay the manufacturing costs of what you need (plus, obviously, the supplier's mark-up).

This increased access to tools—as well as access to information on how to use the tools—has triggered the return to a culture of making and the spread of the maker movement.

The Maker

The maker is an enthusiastic hobbyist who gradually becomes part of a community of people who share the same interests. More and more he moves out of his field of competence, learning new skills thanks to the knowledge shared among the maker community. Once upon a time people had to apprentice with a carpenter if they wanted to create beautiful wood carvings, or with a blacksmith to forge metal. Today, those people can simply design objects with different shapes and have them created by computer-controlled woodworking machines or laser sintering machines.

Such hobbies are not only an occasion to meet new people, but they also might offer the makers the opportunity to earn some money or to found small companies, and in some cases they even lead to th birth of real phenomena in both cultural and economic terms.

Innovation—which, according to some economists, is the only way to increase a country's productivity—is a constant element for makers, as they always try to outdo themselves and go beyon what is at their disposal. The maker is like a new tinkerer, an inventor with a great deal of possibiliti that, until recently, were inconceivable.

With this great power comes great social responsibility. We're fortunate that most makers tend to share the results of their work, and to collaborate with different people from all over the world, no matter their position or professional background.

Our grandparents were all makers. But what about us? Are we ready to be makers?

Chapter 2. The Origins of the Movement

Humans have been makers since the dawn of our history. In fact, you could say human history began *because* we were such prodigious makers. Today, we are experiencing a renaissance in Do It Yoursel (DIY) technology: the old maker tools of hammers, chisels, pliers, and tongs are being augmented by tablet computers, collaborative software, crowdsourcing, and desktop manufacturing. Sometimes the act of “making” is more digital, and all of these tools are replaced by a small portable computer.

The last 10 years have seen the growth of hackerspaces, makerspaces, and Fab Labs: workshops wher lovers and creators of technology, mechanics, interaction, and art can meet, share their knowledge, and collaborate to create diverse objects (see Figure 2-1). In these places, it is possible to find—and use—equipment that is typically not available to individuals due to its high cost: drill presses, weldi equipment, laser cutters, 3D printers, and more. With a reasonably priced gym-like subscription, anyone can access the equipment, which democratizes production.

In the beginning, the high initial cost needed to set up these spaces limited the expansion of this phenomenon, since only a few big institutions were able to finance this kind of workshop.

Figure 2-1. A hackerspace plate in a picture by Vargson

Today, however, there are thousands of such places. Even though they are typically found in universities and other institutions, commercial hackerspaces/makerspaces are growing. The most famous is TechShop, which, as of this writing, has eight locations open in the United States.

The Culture of Sharing

The spread of digital technologies in the maker community and makerspaces has allowed the *early adopters* to be active in open source software projects, or at least to be familiar with them and share their philosophy. Sharing and collaborating are at the basis of the early communities that were taking shape within these spaces, which—thanks to the Internet—allowed them to expand and reach the remotest areas of the globe.

Many technologies that are adopted within these spaces can be dangerous if not used properly. Therefore, before accessing the equipment, beginners often attend training courses normally given by other enthusiasts. Training helps you understand a topic thoroughly, and is even important with activities without inherent danger, such as programming a microcontroller. Many makerspaces and hackerspaces have a culture based on a virtuous circle where mentors and students exchange roles, being a teacher of one topic and a student of another.

The Triumph of Technology

The easy access to digital technologies has fostered the spread of a new culture of making: sharing information—through the Internet—brings the manufacture of artifacts, even complex ones, within anybody's reach. Today we have the opportunity to turn our ideas into objects, transforming bits to atoms with a click of the mouse. We can access the power of a factory from our room, from a train, from the park.

The quick manufacturing offered by these new technologies reduces production time and cost, giving people with little experience and capital the opportunity to get quick feedback on various prototypes, thus fostering the incremental development process that is typical of a good project.

See, for example, the Gossamer Condor in "The Value of Quick Iteration".

The Fab Labs

In the late 1990s, Neil Gershenfeld, professor at the Massachusetts Institute of Technology (MIT), realized that his students were well prepared on theory, yet didn't know how to actually *make* objects. So in 1998, he created a course called "How to Make (Almost) Anything".

In that course, Gershenfeld taught his students how to make small electronic circuits, how to program microcontrollers, and how to use Computer Numerical Control (CNC) milling machines, laser cutters, and other tools. The "almost" in the course title relates to, on one hand, the limits of the tools and materials, and on the other, to a number of shared values. Throughout the course, Gershenfeld realized that his students were using the equipment for their own purposes, rather than for their assigned projects. The creativity of those young students came as an extremely nice surprise: one student raised the curiosity of his fellow students by making a bicycle with traditional works and a frame made of laser-cut Plexiglas; another student, who used to feel discomfort when people invaded her personal space, created a smart dress that would raise spikes whenever someone got too close to her back.

Another student even created a cartoon-like soundproof backpack, in which she could scream and ver without anyone noticing, and then later release the recorded scream once she was out of the room.

From this experience, in 2002 the first Fab Lab was born. Fab Lab is short for “fabrication laboratory,” a workshop where things are manufactured, but also for “fabulous laboratory.” Gershenfeld has taken the Fab Lab culture around the world, helping local populations solve the issu of their communities: from the Norwegian shepherd who can locate his sheep on the mountains at the end of the grazing season thanks to a short-range radio transmission system, to the Indian farmers’ village that doesn’t have enough money to buy a tractor and makes do by adapting a motorbike, to th African farmer who pumps water out of a well by means of solar power. All these stories are collecte in Gershenfeld’s book, *FAB: The Coming Revolution on Your Desktop—from Personal Computers to Personal Fabrication* (Basic Books).

The Spread in the Media

In 2005, O’Reilly Media published the first issue of MAKE, a magazine that today is the point of reference for the entire community of makers. Each issue includes articles and explanations, books and tools reviews, and, most of all, lots of projects, from the most basic to the most complex: a speaker in a cereal box, a rocket, a device that can throw the dog its ball when you’re tired. The typic project can be carried out over a weekend, even though some can take much longer: for example, a makers’ laboratory made from scratch has taken three issues. Most issues have their own theme: games, robotics, space, 3D printing, remote controls, and many others. Moreover, there are often articles for beginners that explain, step by step, the basics of different techniques as well as impossible challenges where, with a few (very few!) objects, the reader has to cope with the most absurd situations, nearly like being the ground crew on the *Apollo 13* mission, minus the pressure of actually being there.

One of the strong points of the magazine is its social aspect: many articles describe parent-child projects that can be easily carried out in a garage. Here, creating something together can bond a relationship that is crucial for the child’s growth; other articles explain team projects.

To stress this social aspect even more, at the end of 2005, after publishing the first four issues of MAKE, on a late evening in the office, Dale Dougherty—one of the founders of the magazine—aske “Wouldn’t it be cool if we could get all these makers together in one place to share what they make?” It was a brilliant idea, and in 2006 the first Maker Faire took place in San Mateo. There, over 100 makers exhibited their creations. Since then, the Faire has grown every year (with over 1,100 makers and 130,000 attendees) and mini Maker Faires have popped up all over the world. In 2013, the first European Maker Faire landed in Rome, and worldwide there were 100 Maker Faires that year (see Figures 2-2 and 2-3 for photos from the 2013 Maker Faire Bay Area).

Figure 2-2. Visitors at the Maker Faire Bay Area in 2013 (Alfredo Morresi)

Figure 2-3. There are all sort of things at the Maker Faire Bay Area (Alfredo Morresi)

Chapter 3. A New Revolution?

The first Industrial Revolution, which straddled the 18th and 19th centuries, was brought about by the introduction of machines into the production cycle—in particular the flying shuttle, which mechanized weaving, and steam power, which replaced human and animal muscle with a tireless engine.

This revolution changed everything. Living standards and education rose for millions of people. Global empires not only became possible but also, for the first time, practical. The earth’s atmospher saw its highest carbon dioxide levels in 800,000 years. Language changed, as words like *job* and *work* acquired their current-day meanings. Even the way we viewed time changed: before the Industrial Revolution the average person usually needed to know the time to an accuracy no finer than morning afternoon, or evening. (Clerics needed to know the time a bit more accurately, to correctly perform th Liturgy of the Hours, the eight times a day a good Christian must pray; for that reason the best timepiece in a village was usually the clock on the church steeple.) But after work began being regulated by machines, people needed to know the exact hour—sometimes the minute—they had to arrive at work, the church clock was replaced by the factory whistle, and life became frantic.

The second Industrial Revolution dates back to the end of the 19th century—when electricity, oil, and chemicals led to the introduction of the assembly line in factories—and lasted well into the last third of the 20th century. Less well understood is the third Industrial Revolution, which we’re in right now It most likely began around the mid-20th century with the development of the computer, continued through the development of electronics, nuclear power, biotechnologies, nanotechnologies, and information technology, and it may very well be culminating with the development of desktop manufacturing machines.

The Introduction of Computers

When the Germans began using the electromechanical Enigma machine to encrypt their secret messages during World War II, the Allies needed a high-speed computation machine to decipher thos messages. At first they used high-function mechanical adding machines operated by “computers,” which were people, usually women, who punched the buttons. Unfortunately, this solution had some weaknesses: these computers, while proficient, were still performing calculations by hand, and, like all humans, needed time to eat, drink, and have a rest. Since the Allies were intercepting thousands o Enigma messages each day, this was not an easy strategy to pursue. So, the next step was the construction of the electromechanical calculator, which helped cryptographers to decipher the Enigm messages in less time. Toward the end of the war, the British developed the first all-electronic computer to decipher messages encrypted on a different German machine, the Lorenz SZ 40/42.

However, the first electronic computers had defects, too: they were large enough to fill entire rooms, extremely expensive, and very, very delicate, being made primarily of old-fashioned glass vacuum tubes. The Mean Time Between Failures (MTBF) for ENIAC, one of the first electronic computers (see Figure 3-1), was measured in hours in its early days. When it crashed, workers would walk *insid* the computer (which was room-sized, remember), and hunt for which of the machine’s 17,468 vacuu tubes had burned out.

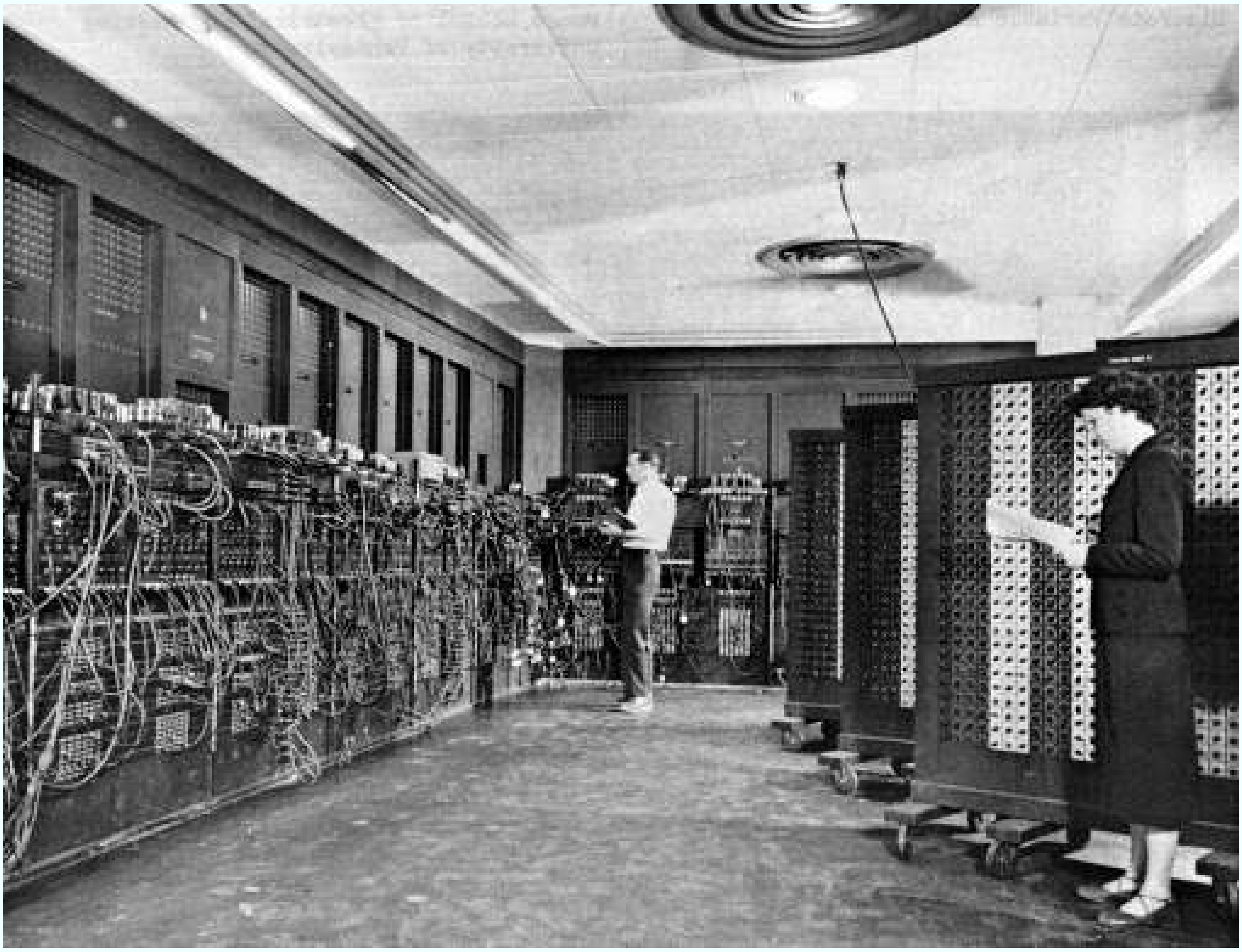

Figure 3-1. ENIAC, one of the very first computers (US Army photo from Wikimedia Commons)

Since these early times, computers have progressed in an impressive way: their calculation power ha doubled almost every 18 months, so that today, any kind of smartphone is far more powerful than on of the first data processors.

The Power of Information

Great innovations often come from military projects, and the Internet is no exception. It started as a project called ARPANET, funded by DARPA (Defense Advanced Research Projects Agency, one of the agencies under the US Department of Defense) in the 1960s as a way to link the computers in fou universities: Stanford Research Institute, University of California Santa Barbara, University of Utah, and University of California Los Angeles.

From that moment on, more and more computers have been connected with one another into network first locally, then at regional and national levels, and finally globally. We call this global network the Internet, the Net of the nets, which, thanks to its numerous services, has completely changed the management of information, and—with the development of the World Wide Web in the early 1990s—the way people and companies interact with one another.

It is easy to understand how the access to information remarkably enhances the power of all players involved. The consumer has a wider range of choices, the producer can deal with more markets and suppliers, and it is far easier to create new contacts and to collect information (via user feedback) regarding the quality of products and services. The computer and the Net can intervene at any point o the supply chain, improving it at all levels.

From Bits to Atoms

Today, thanks to the 3D printer, you can create a three-dimensional object just by downloading a ready-to-use file from sites such as Thingiverse or YouMagine and printing it with a specialized device, just like we do with any paper document through a traditional printer. The concept is nothing new: the 3D printer was born long ago, but, until recently, the machines and materials were too expensive for an individual to own. Within the past few years, however, the cost of such devices has dropped so much that now it is possible to buy a desktop 3D printer (see Figure 3-2) practically at th same price as a laser printer.

Figure 3-2. A personal 3D printer working

In recent years, 3D printing and the maker phenomenon have captured the world's attention. They've had a strong impact on people's imagination: what would happen to the current economic system, some pundits wonder, if each of us could build a perfectly functioning object for any need? What would become of the system of industrial production and economies of scale if everyone could make the things they need? Some have even wondered what this means for the capitalistic system as a whole.

It is true that these changes in production processes as a whole will certainly influence the market an the global economy, but such an impact doesn’t necessarily have to be bad. Certainly, targeted microproduction may help reduce the uncontrolled consumerism we have always been exposed to through the media, because it would enable us to start repairing things again just like our grandparen used to, instead of throwing them away. Distributed small-scale making will also lead to creating objects just where they are needed (for example, spare parts), instead of transporting goods all over the world.

Personal manufacturing must not necessarily be regarded as a threat to the economy and to industrial production, because it is often a component of them. The fact that it is possible to build something by yourself does not mean that everyone wants to do it.

On the other hand, many people are more likely to buy a ready-made object, available in the market, and then customize it according to their own needs, both in terms of function and/or of look. A quick look at models on Thingiverse or YouMagine turns up a lot of accessories for existing products.

The options for customization are endless—from turning a computer into a steampunk piece of art to engraving patterns on closet doors—yet these options do not hinder the mass-market production cycl at all. On the contrary, personal manufacturing can pave the way to a series of aftermarket services, thus allowing the makers—organized independently or in a network of new, specialized, digital technological craftspeople—to offer a customization service to those who can’t or don’t want to mak the desired modifications personally.

The Rebirth of the Economy

The world is currently going through a serious period of crisis, especially here in Italy where, in 2013 youth unemployment exceeded 40%. In the face of this lack of jobs, a lot of people have started new companies, typically linked to web applications. Thanks to the Internet, the economic barrier to onlir entry has practically disappeared (even if the same can’t be said about the Italian red tape and taxatio system). Personal manufacturing may be a very important tool to help these young people—and not only them. Today, anyone may start their adventure as a maker and micro-entrepreneur from their home or garage, and the Internet can help them be global from the very beginning.

As it often happens, a maker may create an object for herself or another person and then realize that others might also want that object, perhaps with a few simple customizations. In such cases, personal manufacture is perfect because the setup costs of the machines are marginal, so the maker can carry out all those tiny modifications at a reasonable price. Customization of everything, from Ferraris to colored T-shirts bearing the image of a favorite singer, is a big business. What consumers are paying for is not just the cost of the modifications, but a special price for the opportunity to be different.

As soon as makers reach the point where a great many people are interested in their wares, personal manufacturing ceases to be sustainable and they must use industrial factories with mass production to exploit far more convenient economies of scale. A mold for injection molding can easily cost thousands of dollars, but at that scale the manufacture of a single item will not cost a few dollars (as might with desktop manufacturing tools) but rather a few cents. This will enable the maker, collaborating with a contract manufacturer, to develop and grow without problems and without enormous startup investments.

Therefore, a maker following a sustainable business model can turn something conceived as a niche object into a mass-market product. Moreover, if a few of his products or services are successful, the maker can become an accomplished entrepreneur and create a solid company, thus bringing homemade competencies—with their shorter turnaround times and lower costs allowed by digital technologies—to more people’s attention. Consequently, such a system can generate new jobs, help the local economy to restart from the bottom up, and maybe even cause a chain reaction in which more and more new companies are created and are able to generate, in turn, new jobs themselves.

Part II. Realizing an Idea

“Would you tell me, please, which way I ought to go from here?”

“That depends a good deal on where you want to get to.”

Lewis Carroll, Alice’s Adventures in Wonderland

Chapter 4. Can Creativity Be Learned?

Many of us have several ideas that we'd like to make real. Some of these ideas might have come to u after we worked on specific projects, or might be based on some research that we have carried out. Some ideas might have been a sudden spark inspired by an apple falling from a tree (hopefully not a MacBook Air!). Many people think that being an innovator and generating new ideas are natural gifts or talents: you either have it or you don't. The truth is, even if you think you're not creative, you can learn how to be.

Some people say that in order to innovate we don't need new ideas, we just need to stop thinking of the old ones. But where do "new" ideas come from? How can we be creative? Sitting under a tree, waiting for an apple to fall on our head, is of little use—even though, according to legend, we know about at least one distinguished precedent. To find an answer, we can turn to neurophysiology, the study of the functions of the brain and nervous system.

Neurophysiology for the Uninitiated

Just as asking someone "How do you feel about that?" doesn't make you a psychologist, reading this chapter on the brain will not make you a neurophysiologist. We're about to talk about an extremely complex field in an extremely simplified way. Nevertheless, it might help us understand our behavio a bit better.

Our brain is a wonderful machine, the most fascinating part of the entire human body. Sir Charles Sherrington, the "grandfather" of neurophysiology and a poet, used to say:

> *It is as if the Milky Way entered upon some cosmic dance. Swiftly the head mass becomes an enchanted loom where millions of flashing shuttles weave a dissolving pattern, always a meaningful pattern though never an abiding one; a shifting harmony of subpatterns.*

Our entire nervous system consists of nearly 100 billion neurons, the specialized, electrically excitable cells that process and transmit information. While there are many different types of neuron they typically consist of three sections: a *soma*, or cell body; the soma's tentacle-like *dendrites*, whic receive messages from other neurons; and a long-branched *axon*, which ultimately passes those signals to other neurons. While the signals within each neuron are electrical, communication betwee neurons is wireless, in the form of dozens of different chemicals that represent the messengers of thinking.

Every time a thought is born in our mind, thousands of these neurons trigger a very articulated sequence of actions and electric discharges: each neuron acts as a tiny yet extremely powerful data processing and transmission center that can manage a wide and complex flow of information. The pa each thought takes through the brain creates a series of memory tracks—actual maps of our mind.

The Learning Process