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New Analogue – Design In The Post Digital Age

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I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

A handwritten signature in blue ink, appearing to read 'A. Mathewson', with a long horizontal stroke extending to the right.

Dr Alan Mathewson

January 2020
Thessaloniki - Greece

Abstract

This dissertation was written as part of the MSc in Strategic Product Design at the International Hellenic University.

The aim of this project has been to develop a technological artefact that will address the brief of being a product which imparts some of the analogue experience we used to be exposed to before the emergence of digital technology. However, it must also be a product for the post-digital age. This has required the development of an understanding of how digital technology affects us in our daily lives and the places where we would like to see more human interactions and contact.

The biggest challenge for me in this project was to think like a product designer. The course in IHU has provided the tools for this and I now understand the interfaces between art and design and science and design. I have been an engineer for a long time, and I think that the rigor and discipline that is required for engineering, can in some ways stifle innovation and creativity. This project has been a refreshing change and it is really liberating once you embrace it.

This thesis reviews the ideas in design that have arisen since the turn of the 20th century. It provides information on contrasting design approaches and it also provides a background, (in an appendix) for the growth of the electronics industry from the invention of the transistor to the current post-digital era.

A product concept which I believe has the potential to create a market in tourism and electronics has been designed and the necessary skills to turn it into a real product have been elaborated. The product, a portable inkjet printer for creating and sending postcards which are personalized to your experiences, has been proposed. This device will create more tangible memories of your vacation and will let people at home know that you are thinking about them.

I would like to thank Professor Liamadis for his great ideas and support and I would like to thank Kim Roberts, Rania Emmanouilidou and Olga Simoni for their technical support and proofreading efforts. I would also like to thank Cian O'Murchu for helping me to find many of the books I have read in the course of this work.

This course has not been without its interesting and challenging moments, but I have really enjoyed participating in it. **A Big - Thank You** to all the staff and students on the course who helped me and talked to me in English on those long hot summer weekends.

Keywords: New Analogue, Post Digital Design, Design Thinking, Digital Technology, Postcards from the Cloud

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20, January 2020

Contents

Chapter One - Introduction.....	8
Introduction	8
Post Digital Technologies	9
Dissertation Outline	10
Chapter Two - Creativity and Design	11
Introduction	11
Background to Product Design	12
The Bauhaus.....	12
Product Design	15
Human Centred Design	16
Design Thinking	17
Design and Politics	19
Summary	19
Chapter Three - New Analogue.....	21
Introduction	21
The Analogue World.	23
Analogue Publishing and Journalism	24
Analogue Music.....	26
Analogue and Retail Sales	30
Board Games and Instant Photography.....	31
Discussion.	33
Summary	34
Chapter Four - Design In The Post Digital Age	35
Introduction	35
Design Thinking In the Post Digital World	35
Mobile Phones	36
Alarm Clocks.....	40
Photography.....	41
Miscellaneous Post Digital Devices	43
Discussion.....	45
Chapter Five - Potential Design Projects for the Post Digital Age.	47
Introduction	47
Possible Design Projects.....	47

Veracity Indicator.....	47
Facial Recognition Obscuration System.....	48
The Do Not Disturb Table.....	48
Postcards from The Cloud.....	49
Design Proposal.....	51
Prototyping and Test.....	51
Competitive Analysis.....	52
Design Proposal One.....	52
Dimensions.....	53
Summary of Feedback on First Design.....	56
Design Proposal Two - The Revised Printer.....	58
Chapter Six - Discussion and Conclusions.....	61
Discussion.....	61
Summary and Conclusions.....	63
Appendix - The Evolution Of Digital Technologies 1949-2020.....	66
Introduction.....	66
Early Days.....	66
George Boole.....	66
The First Computers.....	68
Boolean Algebra.....	69
The First Transistor.....	71
Integrated Circuits.....	72
Moore's Law.....	74
The Internet.....	76
The World Wide Web.....	77
The Internet of Things.....	78
Smart Phones.....	80
Social Networking.....	83
Digital Platforms.....	89
Social Media.....	90
The Cloud.....	91
Analytics and Artificial Intelligence.....	93
The Post Digital Era.....	94
Artificial Intelligence.....	94
Extended Reality.....	97
Challenges of Extended Reality (XR).....	99

Quantum Computing	100
Secure Financial Transactions (Block Chain)	101
Summary and Conclusions	103
Bibliography	104
Books.....	104
Articles	107
Journals	107
Conference Proceedings	108
Miscellaneous	109
Internet References	109

Chapter One - Introduction

Introduction

The title of this dissertation is ‘New Analogue – Design in the Post Digital Age’. This topic was proposed as an area that would be informative and interesting to investigate in terms of how digital technologies will impact our lives over the next ten-year period and beyond. The main questions to be answered are what will the post digital world look like? and what, exactly, is New Analogue?

The concept of analogue circuit design is a complex area in electronic circuits and systems. This is an area which requires considerable skill and a detailed understanding of where currents flow in circuits and how to optimise their flow. This process cannot be automated, and it requires exceptional design expertise because it concerns itself with current flow in individual transistors. Current is a very big function of the structure and geometry of the device and no two transistors behave in exactly the same way, even if they are drawn to be identical. This happens because process variations conspire to change dimensions minutely and those minute geometrical differences impact directly on the current passing through the device. Analogue Circuit Design primarily involves the layout of individual transistors in a circuit, so that these non-uniformities cancel each other out.^{1,2}

All the stimuli around us are analogue in nature and we interact with them in real time. However, computers are unable to do this directly, they must respond to the real world by converting all the signals that they encounter into a digital format before they can be processed in a computer. Once processed, the signal is reconverted into analogue to be fed back into the real world. At both steps in this process the real-world signal is approximated into or from the digital domain and something is lost. This is normally a very small amount of the signal and good designers can almost eliminate it. However, this deficit or mismatch is still there in all our interactions with the digital world³.

New Analogue is an analogy of this concept and illustrates what is happening when people use digital devices and digital media in their everyday lives. They use the tools but do not really understand how they work, and this leads to a certain distrust and the feeling that something is being slowly removed

¹ Optimizing MOS Transistor Mismatch, Simon J. Lovett, Marco Welten, Alan Mathewson, and Barry Mason, IEEE Journal of Solid-State Circuits, VOL. 33, NO. 1, January 1998 pp 147-150

² Matching Properties of Deep Sub-Micron MOS Transistors, Jeroen A. Croon, Willy M Sansen, Herman E. Maes, Springer 2005

³ Hertzian Tales Electronic Products, Aesthetic Experience and Critical Design, Anthony Dunne, MIT Press, 2008

from the user experience, but they don't really know what it is⁴. There is just a lack of full and complete satisfaction from the experience. This is creating some disquiet in users of digital devices and media.

Post Digital Technologies

Digital technologies have become all pervasive in our lives now and the next generation of technologies, based on them are starting to emerge⁵. Some of these technologies will be used to extract information and patterns from our interactions with media, which may compromise our personal space⁶. Some will cause us to further engage us with our various screens in ways that are deleterious to our emotional health and relationships⁷⁸ and this will further diminish the experience we get from them⁹.

Take the act of reading a book for example. A text can be read in an e-reader which has many useful features. You can read it in the dark without disturbing your partner, you can choose the font and its size and you can change the page by pressing buttons or swiping the screen. Reading an actual book, magazine or newspaper is a more traditional activity. However, it is one in which all the senses are invoked. You can feel the weight of it, tell the quality of the publication by the size and density of the font and the paper quality, by feel and smell as well as by eye.

'Turning a page' is a step in the journey, and you can tell how far you have been and how far there is to go just by looking at where you are physically. You can bookmark pages and annotate the margins as you proceed, and while these things are also possible in an e-reader it is not as easy, and the experience is not the same. The other item of significance is that you either own the book or borrowed it from somebody who owns it. What passes for ownership of downloaded texts is predominantly a licence to read it and it is not easy to share it with others without accusations of piracy arising¹⁰.

Alternatively, according to Florian Cramer ¹¹

'The term 'post-digital' can be used to describe either a contemporary disenchantment with digital information systems and media gadgets, or a period in which our fascination with these systems and gadgets has become historical.....

⁴ New Dark Age - Technology and the End of The Future, James Bindle. Verso Books 2019

⁵ The Shallows, What The internet Is Doing to Our Brains, Nicholas Carr, W. W. Norton 2010

⁶ The Filter Bubble: What The Internet Is Hiding From You, Eli Pariser, Penguin 2012

⁷ Reclaiming Conversation - The Power of Talk in the Digital Age'. Sherry Turkle Penguin Press 2015

⁸ Networked Living, P. Papadimitraki, Proceedings of the 7th Conference on Computation, Communication and Aesthetics Milan 2019

⁹ Digital Minimisation, Cal Newport, Portfolio/Penguin/Random House publishers. 2019

¹⁰ 'The Digital Continuum: The Influence of Ownership, Access, Control, and Cocreation on Digital Offerings' K.S Micken, S.D. Roberts, J.D. Oliver, AMS Rev (2019). PP 1-18

¹¹ 'Florian Cramer What Is Post Digital ?' APRJA Volume 3 , Issue 1 2014. pp-11-24

....After Edward Snowden's disclosures of the NSA's all-pervasive digital surveillance systems, this disenchantment has quickly grown from a niche 'hipster' phenomenon to a mainstream position — one which is likely to have a serious impact on all cultural and business practices based on networked electronic devices and Internet services'.

Dissertation Outline

This thesis concerns this disquiet and describes the motivation for the need of an analogue experience even when surrounded by digital applications. Chapter Two provides a recent history of Design and Chapter Three describes this perceived need for an analogue experience in much more detail and provides some examples of industries where the implementation of digital approaches is not as successful as people imagined that it would be. Explanations for this, based on the analogue experience deficit, are provided and based on this information. Chapter Four describes some current design case studies which demonstrate a trend towards the desire for an analogue experience in the post digital era. Chapter 5 provides some suggestions for possible design projects and an example of an analogue system which is enmeshed in the digital world. Chapter Six summarises the work in the dissertation and establishes some conclusions. There is also an Appendix which describes the evolution and development of the digital era and indicates what is to come in the Post Digital Age.

Chapter Two - Creativity and Design

Introduction

Design is the process of envisaging and planning the creation of all objects, interactive systems, buildings and vehicles. The purpose of design concerns creating solutions for problems that people are having. These can be physical items or more abstract systems that address a need or an issue.

Design is a broad concept and its meaning can vary substantially from one field to another. It permeates every aspect of our day to day lives and branches out into many different subgenres. However, all of these involve understanding, creativity and vision. In every case, the item or service that has been designed becomes a product to be sold which someone will purchase as the solution to a need. Indeed, everything that is around us today has been designed by somebody.

The design of a cup which does not burn the user when they are holding it, and, which keeps the liquid inside hot for an extended period, is an example of a simple design issue. The structure and balance of the cup in use needs to be taken into consideration as well as its aesthetics. It is impossible to 'just make a cup' from scratch successfully. An understanding of the materials and the way that they behave over temperature is essential, and equally the physics and balance of the cup when it is full or empty need to be considered. Once the physical structure of the cup has been resolved; it needs to be made aesthetically pleasing in order to make it attractive for purchase.

Making it attractive is important because, if there is a choice from a hundred different cups, which all work appropriately, the user will choose the most attractive one. However, while important, the aesthetics of a product are not the only aspect of its design that need to be considered. Aesthetics help to sell it, but it also must be functional. There is a common misconception that design is simply the adornment of an object and that it is an art form. This could not be further from the case. Design is about making the user's interaction with the environment more natural and complete.

While not exactly an art nor a science, design takes elements from both. Art is primarily about creating something that expresses vision, ideas and feelings while Engineering requires the problem-solving aspect of science. Design exists primarily to address a need. To quote Steve Jobs:

"Most people make the mistake of thinking design is what it looks like. People think it's this veneer – that the designers are handed this box and told, "Make

it look good!" That's not what we think design is. It's not just what it looks like and feels like. Design is how it works"

Background to Product Design

The phrase "form follows function" was coined by architect Louis H. Sullivan in his 1896 essay "The Tall Office Building Artistically Considered"¹². The statement refers to the idea that a skyscraper's exterior design should reflect the different interior functions.

" That these shapes "express the inner life" of the thing is a law of nature, which should be followed in any organic architecture. Furthermore, that the exterior "shell" of the skyscraper should change in appearance to reflect interior functions. If this new organic architectural form was to be part of natural beauty, the building's facade should change as each interior function changes"¹³.

The architect Frank Lloyd Wright¹⁴ transformed this credo and stated that;

"Less is only more where more is no good," and "'form follows function' is mere dogma until you realize the higher truth that form, and function are one."

This philosophical approach has evolved into a universal truth for the design community and one of its many exponents can be found in the Bauhaus movement which commenced at the start of the 20th century.

The Bauhaus

Steve Jobs¹⁵ and Apple's Chief Designer Jonathan Ive¹⁶ were ultimately inspired by the Bauhaus movement¹⁷ and the work of Dieter Rams in the design of their products. The Bauhaus was a counterpoint to the claustrophobic and dark living spaces inhabited by people at the turn of the century¹⁸. It was also one of the schools of thought about Architecture, Design and Craft that has had a massive impact on the products that we purchase and the way that we live our lives today¹⁹. The

¹² https://ocw.mit.edu/courses/architecture/4-205-analysis-of-contemporary-architecture-fall-2009/readings/MIT4_205F09_Sullivan.pdf Accessed 09/01/2020

¹³ 'The Meaning of 'Form Follows Function'', Jackie Craven, <https://www.thoughtco.com/form-follows-function-177237>. Accessed 9/01/2020

¹⁴ 'The Architecture of Frank Lloyd Wright, Fourth Edition: A Complete Catalog', William Allin Storrer, University of Chicago Press. 2017

¹⁵ 'Steve Jobs', Walter Isaacson, Simon & Schuster. 2011

¹⁶ 'Jony Ive: The Genius Behind Apple's Greatest Products', Leander Kahney, Portfolio. 2013

¹⁷ 'Bauhaus 1919-1933: Workshops for Modernity', Barry Bergdoll, Leah Dickerman, Museum of Modern Art. 2009

¹⁸ 'Bauhaus', Magdalena Droste. Taschen. 2018

¹⁹ 'Bauhaus' Jeannine Fiedler, Peter Feierabend, H.F. Ullmann Publishing. 2013

Bauhaus had its roots in the German Arts and Crafts movement²⁰ and was founded by Walter Gropius in 1919. It was created with the aim of repairing the damage that was done to the concept of design and creation by the utilisation of advanced modes of production²¹. The most significant aspect of the movement was that the Bauhaus brought together art and technology to develop a modern way of thinking about how products are designed and created. This was also in line with the thoughts of Friedrich Nietzsche²² who influenced Gropius and his colleagues and whose writings built the core philosophy of Bauhaus movement²³.

Apart From Gropius²⁴ who was an architect inspired by the work of Frank Lloyd Wright and William Morris, the Bauhaus was host to a faculty of celebrated contemporary artists like Paul Klee(Design Theory)²⁵ and Wassily Kandinsky(Colour and Form)²⁶ as well as Joseph Albers(Glass Painting)²⁷, Anni Albers(Textiles)²⁸, Marcel Breuer(Furniture)²⁹, Marianne Brandt(Metalwork)³⁰ and Laszlo Moholy-Nagy(Photography)³¹. Some Examples of Bauhaus Design and Creativity are shown in Figures 1-4.

The Foundation Course at the Bauhaus was the corner stone of their philosophy. It provided a very structured learning experience which involved the development of creativity through experimentation as well as a theoretical and practical course on design and design theory. Figure 5 illustrates the structure and the understandings that were developed over the duration of the course³². A general design theory was developed from the analysis of experiments and the conclusions that were drawn from them. The aim of the design activities at the Bauhaus was to develop affordable products for the general population, while retaining a high degree of functionality and taking the concept of mass production as a major aspect of the design brief^{33 34}.

²⁰ 'The Arts and Crafts Movement (World of Art)' Elizabeth Cumming, Wendy Kaplan, Thames and Hudson. 1991

²¹ 'The German Genius: Europe's Third Renaissance, the Second Scientific Revolution, and the Twentieth Century', Peter Watson, Harper Perennial. 2011

²² 'I Am Dynamite! A Life of Friedrich Nietzsche' Sue Prideaux, Faber and Faber. 2018

²³ 'Will to Power. An Attempted Transvaluation of All Values', Friedrich Nietzsche: trans. Anthony M. Ludovici Obscure Press. 2013

²⁴ 'The Life of Walter Gropius: Visionary Founder of the Bauhaus' Fiona McCarthy, Faber and Faber. 2019

²⁵ 'Paul Klee: Life and Work', Boris Friedewald, Prestel. 2019

²⁶ 'Vasily Kandinsky' Edited by Helmut Friedel, Annegret Hoberg, Prestel. 2016

²⁷ 'Josef Albers: Life and Work', Charles Darwent, Thames & Hudson Ltd. 2018

²⁸ 'On Weaving: New Expanded Edition', Anni Albers, Princeton University Press. 2017

²⁹ 'Breuer', Robert McCarter, Phaidon Press. 2016

³⁰ 'Tempo, Tempo! The Bauhaus Photomontages of Marianne Brandt' Elizabeth Otto, Jovis. 2005

³¹ 'Design and Visual Culture from the Bauhaus to Contemporary Art', Edit Tóth Routledge. 2018

³² <https://www.lomography.com/magazine/189352-the-bauhaus-wheel-diagram> accessed 29/12/2019

³³ 'History of Modern Art', H. H. Arnason, Elizabeth C. Mansfield, Pearson. 2012

³⁴ 'The Art and Craft Divide –On the Exigency of Margins' Agnieszka Ługowska, Recherches sur les Arts, vol. XVI SSN 1641-9278, 2014



Figure 1 Teapot -Marianne Brandt



Figure 2 The Wassily Chair - Marcel Breuer

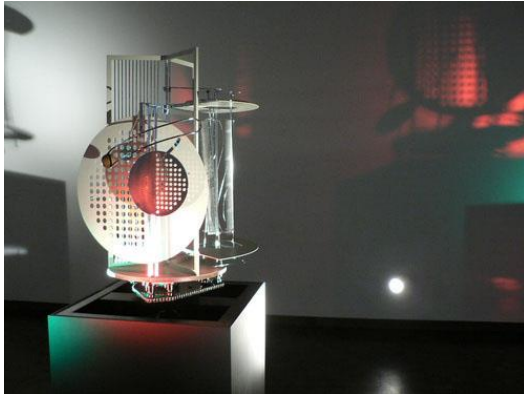


Figure 3 Light Space Modulator- Mohly-Nagy



Figure 4 The Bauhaus Building In Dessau –Gropius

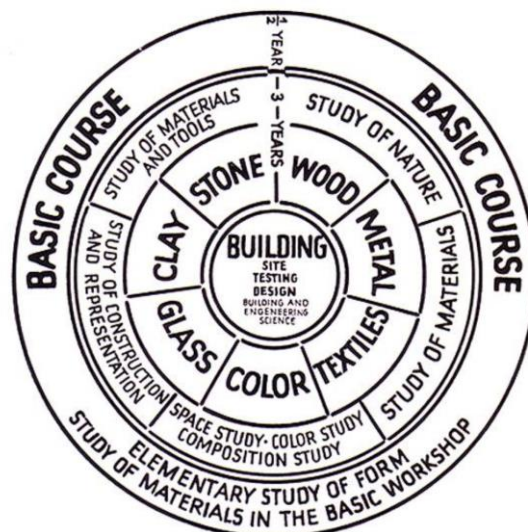


Figure 5 The Bauhaus Design Training Wheel / Syllabus

Product Design

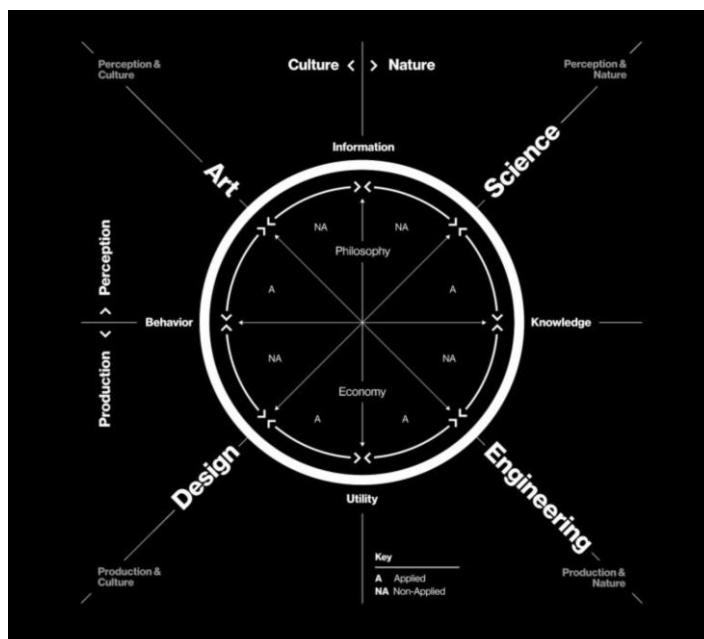


Figure 6 The Different Components Of Design³⁵

Design problems are best solved when approached in a comprehensive and systemic fashion. The goal of the design process is to organize the work and turn ideas into concrete solutions. Designers perform research and collect information about the problem they are trying to solve. They endeavour to develop an understanding of who has a requirement for the product and why they need it; What materials they should use; How easy it would be to manufacture and how much it

should cost. They must also consider how other people are trying to solve this problem, and how their approach differs from their competition. From this study, they make a design plan and identify the significant features that contribute to their solution.

Design is a process that requires a very broad spectrum of skills (Gold 2007)³⁶ and Figure 6 contains an image which illustrates the interactions in a design process and the skills required to achieve a coherent and appropriate design. Each skill or competence in the matrix provides input to the next. This has been labelled the Krebs Cycle of Creativity (Oxman 2016)³⁷. Here, Science provides basic *Knowledge* of materials and structural properties to Engineering. Engineering develops this knowledge and creates *Utility*, which Design takes as input and converts it into *Meaning, Behaviour and Societal Value*. Art then takes these important parameters and converts them into *Social Perception* which, ideally, informs the Science into which directions to pursue, and the cycle then repeats itself³⁸. All four disciplines need to work seamlessly together to express the creative process in the best way possible.

³⁵ 'Age of Entanglement' Neri Oxman, Journal Of Design and Science, 13 January, 2016

³⁶ 'The Plenitude. Creativity, Innovation, and Making Stuff', Rich Gold, MIT Press. 2007

³⁷ 'Age of Entanglement' Neri Oxman, Journal Of Design and Science, 2016

³⁸ 'Postproduction – Culture as Screenplay: How Art Reprograms the World', Nicolas Bourriaud, Sternberg Press. 2005

All designs are human centred because, by definition, they address a specific perceived need. Dieter Rams³⁹, the head designer for Braun over the period 1961-1995, (and inspiration for Jonathan Ive of Apple), provided some very important and inspirational guidelines or rules for design⁴⁰. Rams was a graduate of The Ulm School of Design which has the Bauhaus in its antecedents⁴¹. Rams approach inspires me, I appreciate simplicity and elegance in a product and one of my most treasured possessions is the Travel Alarm Clock. I was not aware of its significance as a design icon when I bought it. However, I saw it as a functional and completely self-explanatory product with clean lines and a certain stripped back elegance.



Figure 7 The Braun BC02XB Travel Alarm Clock

Dieter Rams Rules for Good Design⁴²:

- Good Design is Innovative
- Good Design Makes a Product Useful
- Good design Is Aesthetic
- Good Design Makes the Product Understandable
- Good design is Unobtrusive
- Good Design Is Honest
- Good Design Is Long Lasting
- Good Design Is Thorough Down to the Last Detail
- Good Design is Environmentally Friendly
- Good Design is as Little Design as Possible

These rules epitomise everything that is distinctive about German design and what it has stood for since the sixties. This aesthetic is still present in much of the output from German factories from industrial machinery to cars and clothing.

The sixties also saw the emergence of the radical Anti-Design movement that took a stance against everything this kind of modernism stood for^{43 44}. This movement reacted against the emphasis that was placed on the style and the aesthetics of form and espoused exaggerated and expressive qualities

³⁹ 'Dieter Rams: As Little Design As Possible', Jonathan Ive, Klaus Klemp, Sophie Lovell, Phaidon Press. 2011

⁴⁰ 'Why Designer Dieter Rams Is Having a New Moment'. Elizabeth Fazzare Architectural Digest, November 20, 2018

⁴¹ 'After the Bauhaus, the Lesser-Known Ulm School Had a Seismic Impact on Design', Claudia Martinez Visual Culture Sep 11, 2019.

⁴² 'Less and More: The Design Ethos of Dieter Rams', Klaus Klemp Gestalten. 2015

⁴³ 'Superdesign: Italian Radical Design 1965-75', Maria Cristina Didero, Evan Snyderman, Monacelli Press. 2017

⁴⁴ 'Made in Italy: Rethinking a Century of Italian Design' Grace Lees-Maffei, Kjetil Fallan, Bloomsbury Academic. 2014

such as vibrant striking colours⁴⁵. The key proponent of this movement was Ettore Sottsass⁴⁶, but it also involved designers such as Paolo Lomazzi⁴⁷, Alessandro Mendini⁴⁸ and Piero Gilardi⁴⁹. This *Radical Movement* created unique furniture that was functional and cheap, and aesthetics were not considered to be important as indicated in Figure 8.



Figure 8 The 'Blow' Chair (Paolo Lomazzi)



Figure 9 A 'Carlton' Bookcase by the Memphis Group, Ettore Sottsass 1980⁵⁰

By the second half of the seventies, the movement had dis-banded and Sottsass had formed the Memphis Group⁵¹ which created pieces that did not follow any known trends at the time but dominated the early 1980 design scene. The work of Memphis was the antithesis of Rams formal approach to design. An example of this style in the form of a bookcase designed by Sottsass is presented in Figure 9⁵².

Design Thinking

Many of the designs described above involved designs by a designer working in isolation with their vision of what they wanted to create. In the last twenty years the world of design has transformed radically. Design has become a more focused profession in which multi-disciplinary teams create products which address the requirements of society. Design is now based on previously underutilised market research and customer needs surveys^{53, 54, 55}. In theory, the design of a product is more about

⁴⁵ 'Crafting Design in Italy: From Post-war to Postmodernism', Catharine Rossi, Manchester University Press. 2015

⁴⁶ 'Ettore Sottsass and the Poetry of Things' Deyan Sudjic, Phaidon Press –2015

⁴⁷ 'De Pas D'Urbino Lomazzi. Opere e Progetti' Maria Teresa Feraboli, Libraccio Editore. 2015

⁴⁸ 'Mondo Mendini: The World of Alessandro Mendini' Alessandro Mendini, Ruud Schenk, et al. Groninger Museum. 2019

⁴⁹ 'Piero Gilardi' Maurizio Sciacaluga, Galleria Il Torchio. 2003

⁵⁰ <https://www.bukowskis.com/en/auctions/611/7-ettore-sottsass-a-carlton-bookcase-by-memphis-italy-1980-s> Accessed 22.12.2019

⁵¹ More is More: Memphis, Maximalism and New Wave Design Claire Bingham, te Neues Media GmbH & Co. 2019

⁵² 'Ettore Sottsass' Phillipe Thome, Francesca Picchi, Emily King, Phaidon. 2017

⁵³ 'The Design of Everyday Things' Don Norman, Basic Books. 2013

⁵⁴ 'Product Design and Development' Karl T Ulrich and Stephen D. Eppinger, McGraw Hill. 2012

⁵⁵ 'The New Design-Why Design Is Too Important to be Left to the Designers', A.S Wasserman, Index Magazine - The New Design Thinking 2004 pp 4-6

the market intelligence than the actual design. Information on markets now informs the strategies of companies and these enable product decisions to be made in advance of the ability of the engineering aspects to deliver them⁵⁶. Table One shows the difference in philosophy from the old approach to design to the more current 'Design Thinking' based version.

It is clear from this table that considerable transformation of the design process has taken place. Individual 'charismatic' designers have been replaced with flexible, multidisciplinary teams. They now have global targets and are constrained by requirements to understand and respond to customer needs.

Old Design	New Design
Product Driven	Process Driven
Product Function	User Experience
Technology Driven Function	Human Centred Innovation
Producer Centric	Customer Centric
We Know What You Should Want	What Do You Really Need and Want?
Think From Inside The Company	Think From Outside In The World
Experience Based Judgement	Research Based Insight / Foresight
Specification Culture	Prototyping Culture
Maximise Shareholder Wealth	Maximise Human Benefit
Think From The Present Forward	Think From The Future Back
Limited Production and Mass Manufacturing	Flexible Manufacturing and Mass Customisation
Serial Functional Hand Off Product Development	Iterative Parallel Interdisciplinary Team Product Development
Professional Experts Only	Co- Design Co-Development With Users
Resource and Energy Intensive	Green Re-Cyclable, Sustainable
Big, Slow, Heavy	Small, Fast, Light
Only Designers Design	Everybody Can Use Design Methods and Tools
Only Design Students Should Learn	Everybody Should Learn Design as a General Knowledge Subject K-12

Table 1 The Differences between Traditional and Design Thinking Based Approaches
(Wasserman 2004)

For sure, the general public do not necessarily know what they want from advanced products, because they do not have the background to understand what is possible in the technology. However, they can announce their needs clearly, and it is up to the technology providers to satisfy them. It is the role of market research to identify these needs and to provide market intelligence for new product development and innovation. However, market research needs to be used and interpreted appropriately for market intelligence to function properly. To paraphrase David Ogilvy⁵⁷

⁵⁶ 'The New Design-Why Design Is Too Important to be Left to the Designers', A.S Wasserman, Index Magazine - The New Design Thinking 2004 pp 4-6

⁵⁷ "Design Between The Lines", P. Le Quement, Merrell, London New York. 2019

'I notice increasing reluctance on the part of marketing and design executives to use judgment; they are coming to rely too much on research, and they use it as a drunkard uses a lamp post for support, rather than for illumination'

My interpretation of this statement is that it is necessary to look closely at implicit and unstated needs to get significant benefit from market intelligence. It is not good enough to just use the market research to retrospectively justify pre-existing positions.

Feedback on how things work in the field when exposed to a sample user community can raise all sorts of issues that had not been considered before. Iterative testing in product development is required to eliminate as many user issues as possible before the product can be released. This is crucial because any malfunctions can result in people thinking it does not reflect their needs. Everything needs to be tested exhaustively before it can be exposed to the general public. As Will Rodgers said⁵⁸

'You never get a second chance to make a first Impression'

Design and Politics

Design is the activity of producing artefacts, but it is not necessarily considered as a political activity. However, the design of an artefact, is also a political decision and it is a statement about how people should live, communicate or behave. Furthermore, design can be used as a political instrument in the form of activism, or as a medium for discussing and dreaming about possible or better futures. Politics itself can also be understood as a form of design, since it involves planning, making decisions and devising laws.

Summary

In the past, design was the domain of creative individuals who had a vision and implemented it. The success or failure of their product was a function of how their ideas resonated with the general public. Product designers like Dieter Rams and Ettore Sottsass had different visions of what was the correct way to design products for the public and both had very clear brand identities⁵⁹. The Bauhaus which inspired Rams, took quite a 'stripped back' approach. Whereas, Alessi which evolved from the Radical movement were more playful and more full of *joie de vivre*. A reflection on the two styles is provided

⁵⁸ <https://www.forbes.com/quotes/9717/> Accessed 14/01/2020

⁵⁹ 'New Design In The Post Industrial Era' G. Liamadis International Hellenic University Lecture Series 2019

in Figures 10 and 11 which contrasts Tea and Coffee services from Alessi (Alessi and Mendini) and Bauhaus (Marianne Brant).



Figure 10 Alessi Tea and Coffee Service (Mendini & Alessi)



Figure 11 Bauhaus Tea and Coffee Service (Brandt)

Nowadays, design is a profession that requires multiple skills to obtain optimum performance. The creative tools that are adopted require the involvement of multi-disciplinary teams in order to achieve a more user centric outcome. Potential users must be consulted on what they want and need, and sometimes these are not necessarily the same thing^{60,61}. Once a statement of user needs has been established, design solutions must be considered and prioritised. The highest priority ideas need to be prototyped and tested against the market. User feedback is required based on the prototypes and incremental enhancements need to be made to address the market concerns.

Design thinking is an iterative process and using it to build products is not always fully adopted because it is risky. It may ultimately get to the ideal solution, but it will take time and a lot of money to get it right. The use of *Design Thinking* is an ideal situation which is not always replicated in the industrial world because it is too time consuming and expensive to be universally adopted. The market window for new products is finite and if you spend too much time on development and ‘feature creep’ you lose the opportunity that you may have had when you started. Hi-tech start-ups are victims of this particularly, everything is run on a tight budget because the technology is so expensive to develop. This means that the longer you wait to get your product to market, the faster your working capital burns in staff salaries and the less likely you are to have a successful venture.

⁶⁰ ‘The Design Of Everyday Things’, Don Norman, Basic Books. 2013

⁶¹ ‘Product Design and Development’, Karl T. Ulrich, Steven D. Eppinger, McGraw Hill. 2011

Chapter Three - New Analogue

Introduction

There is nothing in the human experience that is intrinsically digital, and every human experience is an analogue transaction. As briefly stated in Chapter 1, the whole world is analogue and everything that happens in it changes seamlessly as a function of time. Figure 12 shows the difference between a true analogue signal (Green) and the same signal regenerated by sampling the analogue signal and rebuilding it to make a digital representation of the original (Blue). Clearly, there are some disparities between the original and the re-constituted signals, these differences define the fidelity of the reproduction.

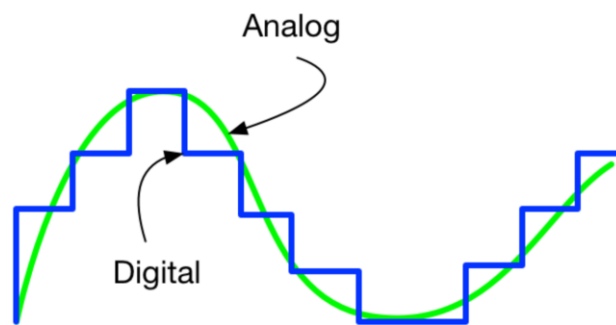


Figure 12 The Digital Representation of an Analogue Signal⁶²

In order to be used in a computer, every analogue signal must be converted to digital before an operation can be performed^{63,64}.

In the early part of the 20 century, equipment used to perform scientific experiments were shown to have an abundance of dials which read out the current status of the experiment. These dials were analogue monitors of what was happening in the experiment, and scientists had to take notes of the readings in order to understand what was taking place.

The needle in the dial moves in real time as a direct function of the electromechanical signals flowing through the sensor. Each mark on the circumference of the dial is an analogue indication of the parameter being measured. Clearly, the scale chosen could provide different amounts of precision depending upon how granular the sensor was. Scientists at the time were not able to monitor the

⁶² <https://www.androidguys.com/news/the-lg-v20-has-a-quad-dac-for-audiophile-level-sound/> Accessed 27/11/2019

⁶³ <https://www.analog.com/en/index.html#> Accessed 28/11/2019

⁶⁴ https://www.eetimes.com/document.asp?doc_id=1334680# Accessed 28/11/2019

signal on the dials constantly, so they inspected their dials periodically. They were sampling⁶⁵ the data at specific times and writing the measurement on the dial in their notebooks.



Figure 14 An Analogue Pressure Gauge

In this chapter a discussion of how the impact of the digital revolution, which has swamped almost every aspect of the analogue world is provided⁶⁶. People still use their smartphones and laptops, but some are rejecting parts of the digital aspects of their lives. There are areas such as music, journalism and the retail industry where digital technologies were expected to completely eclipse the technology preceding them in a process called Creative Destruction⁶⁷. Although This has not come to pass as imagined.

Creative Destruction is a term used to describe the impact that disruptive technologies can have on an existing industrial base, and the quality of life of the people working in it. This takes place when an existing way of working must completely transform to reflect new industrial paradigms. For example, the automotive industry was transformed by the adoption of Henry Ford's production line⁶⁸ and the destruction of the print and typesetting industries arose because more modern methods for publishing newsprint⁶⁹ became available.

⁶⁵ 'Analog-to-Digital Conversion', Marcel Pelgrom, Springer 2013

⁶⁶ 'The Revenge of Analog – Real Things and Why They Matter' David Sax Public Affairs- Perseus Books 2016

⁶⁷ 'Creative Destruction: Why Companies That Are Built to Last Underperform the Market--And How to Successfully Transform Them', Richard Foster, Sarah Kaplan Random House 2001

⁶⁸ 'Henry Ford and the Assembly Line (Unlocking the Secrets of Science)', John Bankston, Mitchel Lane Pub. 2003

⁶⁹ <http://whattheythink.com/articles/55522-day-typesetting-industry-died/> Accessed 27/11/2019



Figure 15 An Early Digital Printing Press

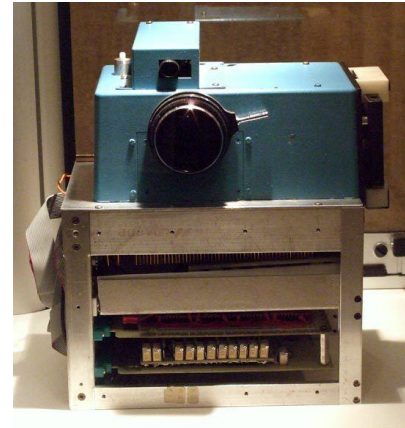


Figure 16 The First Digital Camera (Kodak 1975)⁷⁰

The internet is obviously the largest ever instance of creative destruction. It has transformed the world as we know it and its adoption has resulted in millions of people's jobs disappearing over a fairly short period of time. These jobs were replaced with considerably fewer positions e.g. at the height of its power, Kodak, which invented the first digital camera,^{71 72} employed about 1.5million people and was worth \$28 billion. Today Kodak has gone bankrupt and the new face of digital photography is Instagram. When Instagram was sold to Facebook for a billion dollars in 2012, it only employed thirteen people⁷³

Those displaced people have had to retrain to find other employment. This has meant that job flexibility, professional training and further broader education have become an essential part of life and education and training has become a growth market in the economy^{74,75,76}

The Analogue World.

As previously stated, the world and every human experience in it is analogue. It is time varying and physical. Digital technologies are simply an approximation of the real world and they lose something intangible in terms of user experience when they are deployed. In some ways digital technologies are disconnecting people from the real analogue world. Every human experience has within it, the deployment of all our senses to make a lasting memory of an event. Digital technologies transform that experience into a reduced experience set⁷⁷. For example, it is possible to tell that you are reading

⁷⁰ 'Camera: A History of Photography from Daguerreotype to Digital', Todd Gustavson, George Eastman House. 2012

⁷¹ <https://www.cnet.com/news/photos-the-history-of-the-digital-camera/> accessed 27/11/2019

⁷² <https://lens.blogs.nytimes.com/2015/08/12/kodaks-first-digital-moment/> accessed 28/11/2019

⁷³ <https://www.businessinsider.com/instagram-employees-and-investors-2012-4> Accessed 28/11/2019

⁷⁴ <http://siteresources.worldbank.org/INTLL/Resources/Lifelong-Learning-in-the-Global-Knowledge-Economy/chapter1.pdf> accessed 28/11/2019

⁷⁵ <https://www.bloomberg.com/graphics/2019-new-economy-drivers-and-disrupters/> Accessed 28/11/2019

⁷⁶ 'The Economics of Offshoring', Winston Chang Chang, (Available at SSRN: <https://ssrn.com/abstract=2016984>) March 6, 2012

⁷⁷ <https://exepose.com/2017/05/10/finished-the-pen-is-mightier-than-the-screen/> Accessed 30/11/2019

a newspaper, a magazine or a book simply by the weight, smell, quality, the tactile nature of the paper that you are handling. If you are reading it on a kindle or a tablet, you must swipe a glass surface or push buttons to turn pages. These are not the same and while both have the same outcome, something has been lost in the translation from the analogue world to the digital one. This is what I would like to refer to as an *Experience Deficit*. Most digital technologies are efficient at transmitting information, but they are not suited to the full user experience that the analogue world has to offer.

There are many different fields of endeavour in which a product genre was initially seen as a potential victim to complete creative destruction. However, customer reaction has led to a resurgence in less fashionable technologies in niches which impart a different user experience to simply consumption. These are outlined in conjunction with the advantages that the analogue experience imparts to the product in the next sections.

Analogue Publishing and Journalism

Publishing is possibly the most surprising area where the digital revolution was supposed to decimate the industry. However, there is still a healthy presence of analogue artefacts in the marketplace but about seven years ago there was a very justifiable concern that the printed book was on the verge of obsolescence

However, the latest book sales figures and market research seem to indicate the opposite. For example, in Canada⁷⁸, e-books only accounted for 16.9% of total book sales in 2016, this was a reduction from 19% in 2015. However, over the same time period, paperbacks made up 54.2% of purchases with hardcovers accounting for another 23.9%. Furthermore, it was reported in 2013 that 62% of younger people (16-24 year olds) prefer to read paper books in preference to their e-versions⁷⁹ and, 65% of Americans admitted to reading a printed book in 2016, compared to only 28% who read an e-book⁸⁰.

There is obviously an attraction to using an e-reader because it is convenient and light weight and is ideal for travel, vacations etc. However, the experience is not the same as using a traditional book and e-readers do not lend themselves to annotations, note-taking or page markers easily. All these things are possible in an e-reader, but they are much more difficult to use than just writing in the margin of a book or bending a page over at an interesting point. The tactile nature of the book, the turning of pages and being able to see, at a glance, how much more of the book remains are also crucial to the

⁷⁸ <https://www.booknetcanada.ca/> Accessed 28/11/2019

⁷⁹ <https://www.theguardian.com/books/2013/nov/25/young-adult-readers-prefer-printed-ebooks> Accessed 28/11/2019

⁸⁰ <https://www.pewresearch.org/internet/2016/09/01/book-reading-2016/Accessed> Accessed 28/11/2019

user experience, which I do not get with an e-text. This is only my impression. However, I am not alone. Theo Stone from Exeter University wrote⁸¹;

‘Nowadays, the e-book simply looks old-tech, ancient, worn-out, and, factoring the combined price of reader and individual story, just as expensive. The book, meanwhile, has remained timeless because that is what it is. This is because it carries a design that has been with us for millennia. An old, worn Penguin carries a sense of prestige with it, a new Folio edition demands respect, but a Kindle is simply another purchase’.

Books are not the only area of publishing where e-readers are not really fulfilling their potential. Magazines and Specialist Journals are also at least as strong as they were when e-reading devices were announced, and they could be stronger in many cases ⁸². Clearly, there are advantages to the idea of being able to send a newsletter or a magazine to your whole distribution list in a matter of seconds, but the recipient could just delete it unopened.

Advertising revenue for e-Zines is limited by the fact that the adverts that are published are as transient and ephemeral as the magazine itself. Advertisers need a good chance of people being exposed to their advertising before they will pay for it. However, advertisers in high quality magazines are happy to invest heavily to be included in an edition of e.g. Vogue⁸³ or ‘Good Food’⁸⁴ or ‘Popular Mechanics’⁸⁵ because of the long lasting and high quality or specialist exposure they get. Whatever the journal, the advertising is ever-present, if the publication remains available. Consequently, magazine advertising has a much greater longevity than any that is placed in digital media.

A further advantage that magazine copies have over e-versions of the same thing is, that even if a subscription has been paid to get a copy, an e-zine is not a physical entity, and you do not actually own it. It is also not possible to leave a tablet around the house with an open version of ‘The Economist’ to demonstrate to your visitors that you are erudite and up to date. Our purchases and property define us to our friends and colleagues and when they are not visible, they do not convey the message that they need to, for their social impact⁸⁶. Simply reading the contents of the magazine

⁸¹ <https://exepose.com/2017/05/10/finished-the-pen-is-mightier-than-the-screen/> Accessed 28/11/2019

⁸² <https://whatsnewinpublishing.com/magazines-are-alive-and-well-publishers-refresh-their-strategies-for-the-print-format> Accessed 28/11/2019

⁸³ <https://www.vogue.com> Accessed 28/11/2019

⁸⁴ <https://www.bbcgoodfood.com> Accessed 28/11/2019

⁸⁵ <https://www.popularmechanics.com/> Accessed 28/11/2019

⁸⁶ ‘Society Of The Spectacle’ Guy Debord, Black and Red. 2002

is not enough for the full experience. One must have been seen to read it to get the best value out of it.

Analogue Music

The ability to hear music in your own home has always been a very attractive proposition for many listeners⁸⁷. Technologies for transporting people into the concert hall experience evolved from the use of different types of disk, cassette tapes and CDs. We are now experiencing wireless streaming services onto our phones or laptops through e.g. i-Tunes or Spotify cloud-based applications. The transition from what was effectively analogue music to digital music took place at the time of the introduction of the CD. This was when the analogue signal from microphones and music pick-ups were digitized to create a very high-quality reproduction of the music that was being created. The analogue signal that had been transcribed up to that point was either stored in the form of three-dimensional grooves, cut into a plastic disc^{88, 89} as shown in Figure 17 or as an arrangement of magnetic domains on a celluloid tape⁹⁰.

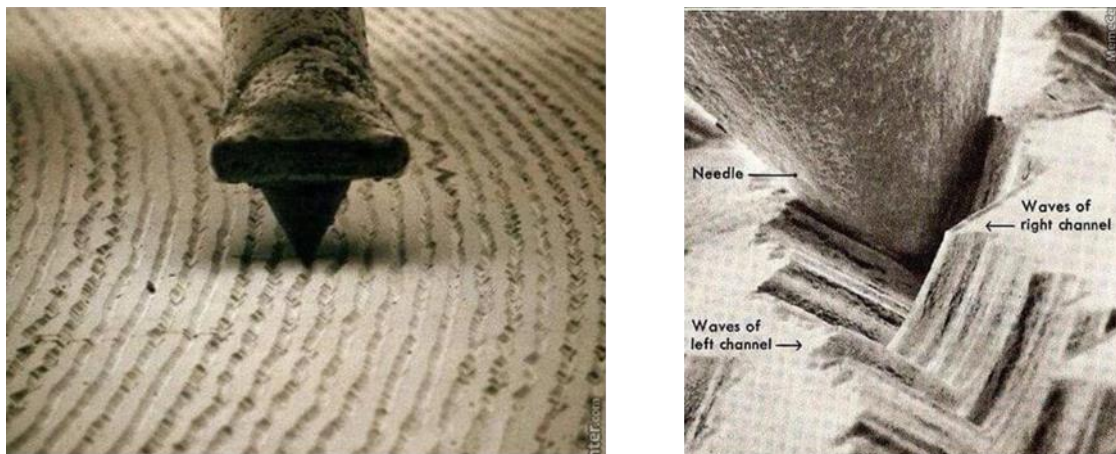


Figure 17 Images of the Grooves in a Vinyl Record⁹¹

In a CD, the music is stored in a series of microscopic slots arranged in a spiral towards the centre of the pressed plastic disc, which has been coated in Aluminium. An example of a CD surface is presented in Figure 18.

A CD has a similar reading process as a vinyl disk, but it is read by laser instead of a mechanical stylus. When the CD was announced, it was sold as having much better fidelity than vinyl, without the inherent delicacy of the vinyl listening experience. Being allegedly indestructible was as big an

⁸⁷ 'The New Analog – Listening and Reconnecting in A Digital World' Damon Krukowski, The New Press. 2017

⁸⁸ <https://www.whathifi.com/features/how-does-vinyl-record-make-sound> Accessed 29/11/2019

⁸⁹ <https://www.youtube.com/watch?v=bw4YmbAKocM> (How Do Vinyl Records Work) Accessed 29/11/2019

⁹⁰ <https://electronics.howstuffworks.com/gadgets/audio-music/cassette1.htm> Accessed 29/11/2019

⁹¹ <https://forums.stevehoffman.tv/threads/vinyl-needle-magnified-1000x.391696/> Accessed 29/11/2019

advantage as clarity and sound perfection when the CD was first introduced. However, scratches were seen to impact CDs as much as vinyl as time and use proceeded. The main difference being that the vinyl experience still let you hear the record, but the CD had to be thrown away because it became unplayable.

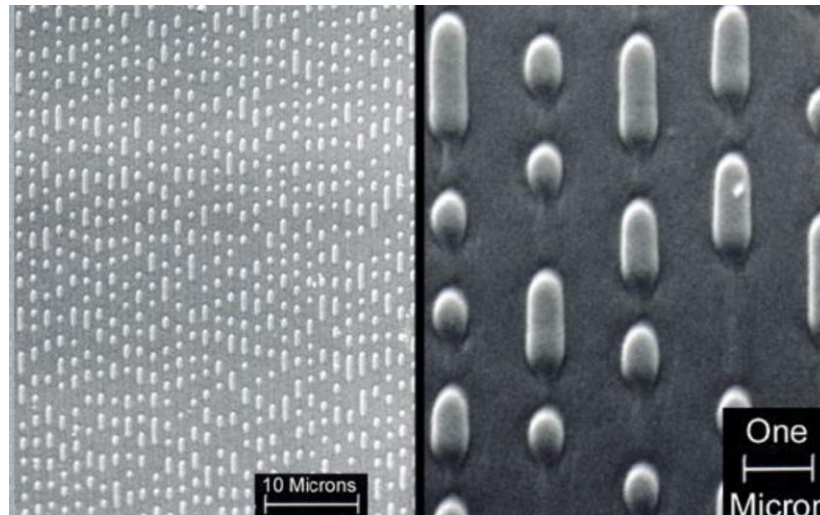


Figure 18 The Surface of a CD⁹²

The final death knell for vinyl apparently occurred in 2006 where sales of all vinyl formats reached their nadir⁹³. Furthermore, over the following years the infrastructure for playing vinyl and cassette formats disappeared from people's houses to be replaced with CD players and ultimately streaming technologies. Over the last ten years, both vinyl and cassette formats⁹⁴ have started to make a resurgence and vinyl has now overtaken CDs in the sales figures reported in late 2018 and early 2019⁹⁵. Sales of Turntables are up and growing rapidly⁹⁶ and interestingly these older formats are mainly being bought by people in their early 20's (millennials⁹⁷).

⁹² <http://federicocacciotti.altervista.org/projects/CDspectroscope/cdspectroscope.html> Accessed 30/11/2019

⁹³ <https://www.spin.com/2014/05/did-vinyl-really-die-in-the-90s-death-resurgence-sales/> Accessed 30/11/2019

⁹⁴ <https://www.latimes.com/business/story/2019-08-05/column-cassette-tapes-are-back-but-its-not-about-the-music> Accessed 29/11/2019

⁹⁵ <https://www.digitalmusicnews.com/2019/09/08/vinyl-overtake-cd-sales/> Accessed 30/11/2019

⁹⁶ <https://thevinylfactory.com/news/turntable-resurgence-240-spike-in-record-player-sales-at-john-lewis/> Accessed 30/11/2019

⁹⁷ <https://www.thesun.co.uk/fabulous/5505402/millennials-baby-boomers-generation-groups-z-y-x-explained/> Accessed 30/11/2019

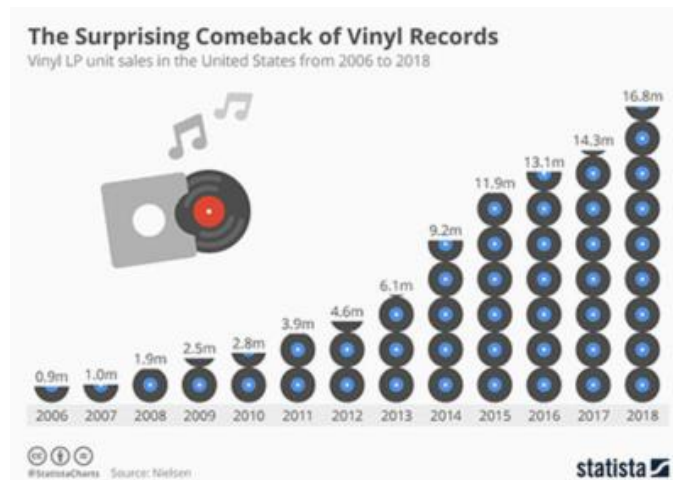


Figure 19 Sales of Vinyl Records Since 2006⁹⁸

There are several reasons for this: -

- **Sound Quality** The sound quality is described to be to cleaner and warmer on vinyl than it is in MP3 digital format. Vinyl has the best fidelity because the music we listen to now is broadcast in a format, where details are missed, and overall quality is diminished. This happens because audio files must be compressed to make them small enough be stored with thousands of others. Furthermore, vinyl is far more high-quality, and no audio data is lost when pressing a record.
- **The Ritual and The Experience.** Playing a record involves taking the disk out of its packaging, being careful not to touch the playing surface whilst loading it onto the turntable, dusting it and then putting the tone arm/ needle at the start of the record. Normally, people listen to at least one side of the whole album before changing the record. This enables people to become more familiar with the less well publicised songs on the album and leads to more familiarity with the artists whole output. It is also possible to read the lyrics while listening to the record. The artwork on the cover is often high impact, it can be tactile⁹⁹ or subtle¹⁰⁰ but it has a presence, as a function of its size, which is not possible to achieve in CD and certainly not in MP3 versions. In retrospect, all the perceived disadvantages of playing analogue music in the past are the benefits that people are availing of now. You cannot jump from artist to artist easily, you do not just listen to the one song you have heard of, you actually, deliberately, listen to the whole album, rather than it being 'just there in the background' . This is a true analogue experience

⁹⁸ https://www.cepro.com/news/nielsen_vinyl_sales_up_14-6_2018/ Accessed 30/12/2019

⁹⁹ <https://www.discogs.com/The-Rolling-Stones-Sticky-Fingers/master/23828> Accessed 30/11/2019

¹⁰⁰ <https://www.thebeatles.com/album/beatles-0> Accessed 30/11/2019

- **The Purchase.** Buying records is a magical experience and one that I spent many happy hours on when I was younger. This is the type of experience that is lost when accessing music, on a song by song basis from your phone. You take gambles, and you pay money for albums based on maybe one song with no idea whether they are worth it or not. You talk to people, ask their opinions and suggestions, and ultimately make friends. It is more of a social experience than any app or online music shop could ever be.
- **When You Buy It, You Own It.** When you buy music as an MP3 on iTunes, you don't really own it, you are only licensing it. When you buy an album in a shop you actually own the record and you can do anything you want to with it.
- **It Is Portable and Transferrable** If you change listening platform like your i-pod, pc or phone, it is often difficult to get back all the music that you used to have. When you acquire a vinyl record, you are not just buying some album, you are making an investment that you can later sell, swap or maybe pass down to your children, now that they probably have a turntable.

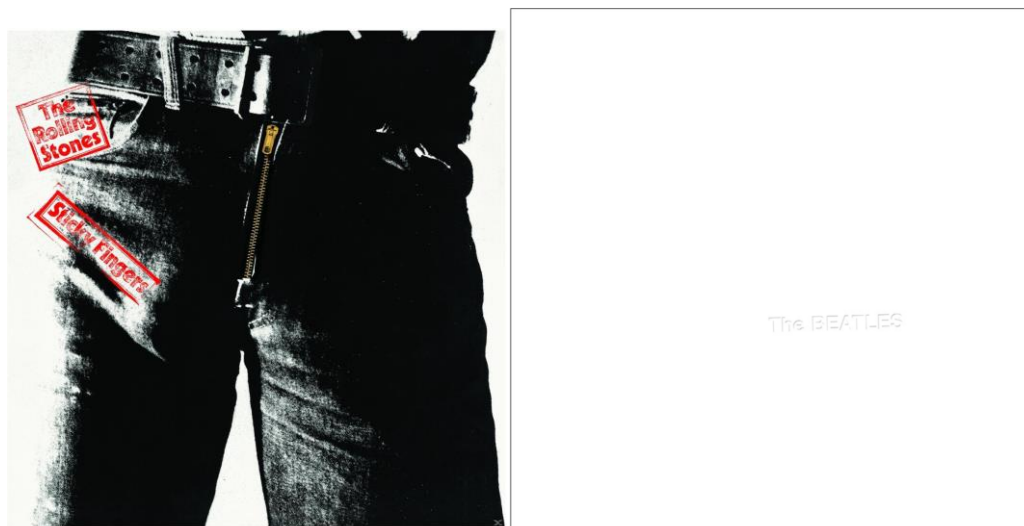


Figure 20 From The Sublime to The Ridiculous: The Rolling Stones 'Sticky Fingers' Album and The Beatles 'White Album'.

One would have thought that when Amazon started to sell books in 1994¹⁰¹ the local book shop would be phased out rapidly in the face of the competition. However, that has not been the experience to date. Bookshops lasted longer than anticipated in the onslaught of the on-line distributors. However, even though a large majority of them have been forced to close over the last decade they have not only demonstrated more resilience than anticipated, they are starting to make a comeback¹⁰². The advantage that Amazon has over the local book shop is that it offers an almost limitless selection of books as well as a multitude of other items to be rapidly distributed to anywhere in the world with no fuss. Being able to offer this range to the customer from its digital platform is a serious advantage but the fact that they do not completely dominate the market, and that shops still exist, indicates that there must be something missing in their offering.

Not everybody buys all their personal requirements on-line and there are reasons for this. Personally, the most important of these is that I am not comfortable paying for something by credit card and having to wait a week before it is delivered. In the last thirty years I have taken very little pleasure out of the shopping experience no matter what the medium is. However, if I do go shopping, almost all my purchases are impulse buys. That is what I used to like about record shops, browsing for new experiences and discussing a purchase with a person who would be sufficiently knowledgeable to provide the information I required. Buying a record by a new artist was always a transaction of a different kind where knowledge was exchanged and acted upon based on empathy.

In fairness, it is possible to get some feedback about the products on sale in the internet. However, you don't get to ask the respondents specific questions or why they bought it; and for sure you don't get to establish the quality, size or texture until it arrives at your door.

As mentioned earlier, the time taken from the transaction taking place, to the receipt of the item is much longer than 'a trip to the shops'. The delay that is induced into the purchase on-line removes the gratification that can come to the impulse shopper when making a purchase.

Amazon sell everything these days. However, every city has an enormous number of retail outlets all of which provide the possibility of seeing what interests you, and 'trying it on' as appropriate. You also get advice on how it works for you as an individual. The best example of a retail outlet which dominates the market but where its competitors do their selling on-line is the Apple Store. The Apple Store is a place where people go to hang out and see the latest Apple offerings. The Apple Store is also

¹⁰¹ 'The Everything Store: Jeff Bezos and the Age of Amazon' Brad Stone, Little, Brown and Company. 2013

¹⁰² 'The Revenge of Analog: Real Things and Why They Matter' David Sax, Public Affairs. 2016

the place where they stand in queues to buy the latest product after its release. It is also possible to bring purchases back directly to the store if they do not work. You can get expert advice on what to buy from a sales assistant who helps you to work out your personal requirements. Furthermore, you can get training on how to work their products from a real live person. People could buy exactly the same equipment on-line and it would be cheaper, but they go to the Apple Store for the experience and the personal contact.

None of this is possible in the digital shopping experience, although millions of people avail of it. When you decide what you want to purchase based on a photograph, buy it, and if you do not like it when it eventually arrives, you must return it. This is a process which can also be fraught with difficulty and expense. There is no pleasure or gratification in this process and there can be a lot of frustration. This could be the reason why the on-line shopping model hasn't been the all-conquering success that it may have been.

Board Games and Instant Photography.

There are many more examples of places where the on-line or digital world was thought to have the potential to take over the market for an existing service or industry. Gaming is another example. There is now another generation of people who enjoy gaming but would prefer to participate in face to face games than to interact over the internet. The games are different and there is still place for on-line exchanges but there is a massive growth in game playing cafes¹⁰³ and the resurgence of board games as an interactive entertainment and education medium¹⁰⁴. The global board games market is expected to exceed \$12 billion by 2023, with an annual growth rate of more than 9% per annum¹⁰⁵.

The return of the Polaroid or instant camera is providing another interesting development in terms of Analogue artefacts. Companies such as Polaroid, Fujifilm, Canon, and even Kodak have entered or re-entered the market over the past few years, to both critical and financial success. According to Polaroid President and CEO Scott W. Hardy¹⁰⁶;

'There's a nostalgia to instant photography for generations of consumers who grew up with it, and there's a novelty to it for generations of consumers who grew up in the digital age and have never held an actual photo in their hands until recently'.

¹⁰³ <https://www.grinandbeerit.co.uk/games-menu> Accessed 19/01/2020

¹⁰⁴ 'The Revenge of Analog: Real Things and Why They Matter', David Sax, PublicAffairs. 2017

¹⁰⁵ <https://www.prnewswire.com/news-releases/board-games-market---global-outlook-and-forecast-2018-2023-300763553.html> Accessed 30/12/2019

¹⁰⁶ <https://slate.com/technology/2017/12/instant-cameras-are-on-the-rise.html> Accessed 30/12/2019



Figure 21 Polaroid OneStep 2 Instant Camera



Figure 22 FujiFilm Mini 9 Instant Camera



Figure 23 Kodak Smile Instant Camera



Figure 24 Canon Zoemini S Instant Camera

There are also art movements which use Polaroid and instant cameras as their medium¹⁰⁷. Artists like Andy Warhol¹⁰⁸, Lucas Samaras¹⁰⁹, Anselm Adams¹¹⁰, David Hockney¹¹¹ and Robert Mapplethorpe¹¹² have all succeeded in bringing polaroid images to a special place in the world of contemporary art¹¹³.

¹⁰⁷ 'The Polaroid Years: Instant Photography and Experimentation'. Mary-Kay Lombino, Peter Buse, Prestel. 2013

¹⁰⁸ 'Andy Warhol: Polaroids XL', Richard B. Woodward, Taschen. 2015

¹⁰⁹ 'Unrepentant Ego: Self-Portraits of Lucas Samaras', Marla Prather, Whitney Museum. 2004

¹¹⁰ 'Polaroid Land Photography Manual: A Technical Handbook', Ansel Adams, Morgan & Morgan. 1963

¹¹¹ 'Cameraworks', Lawrence Weschler, David Hockney, Knopf. 1984

¹¹² Robert Mapplethorpe: Polaroids, Sylvia Wolf, Prestel. 2013

¹¹³ The Polaroid Project at the Intersection of Art and Technology, Edited by William A. Ewing, Barbara P. Hitchcock, University of California Press. 2016

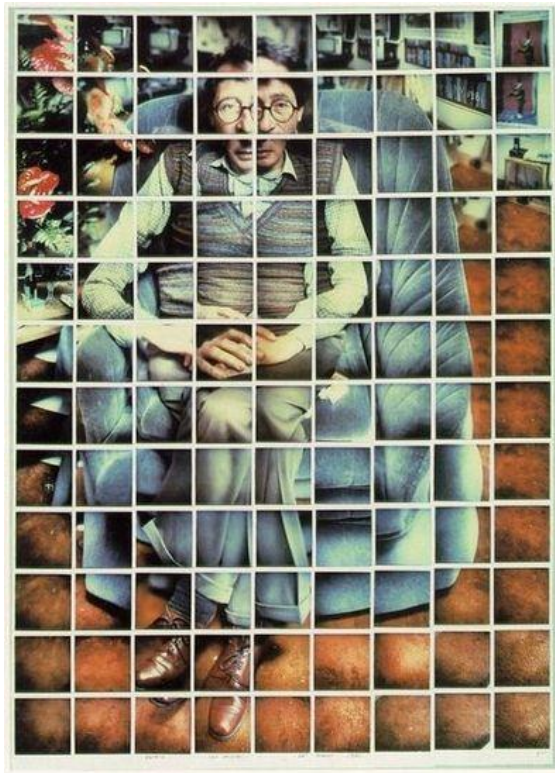


Figure 25 Polaroid Composite - David Hockney

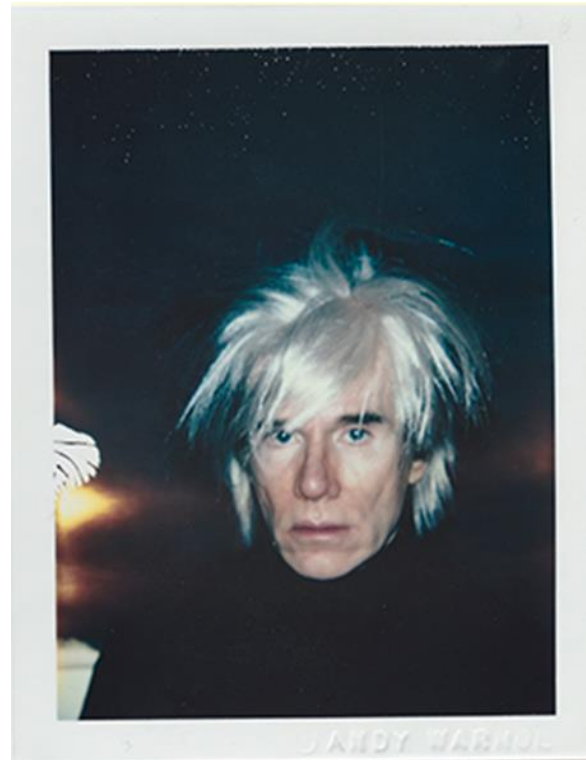


Figure 26 Self Polaroid - Andy Warhol

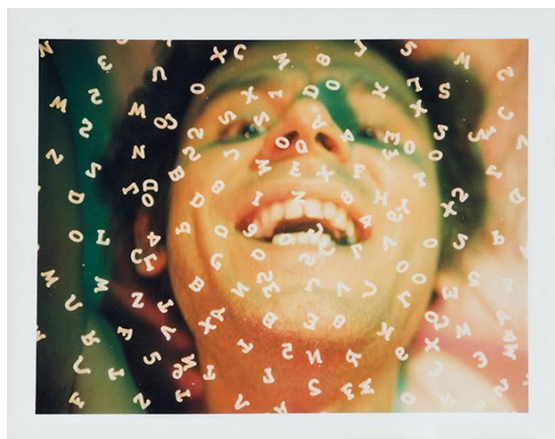


Figure 27 Self Portrait. Auto Polaroid - Lucas Samaras



Figure 28 Patti Smith - Robert Mapplethorpe

Discussion.

Digital technologies are not always better. Naturally, there are enormous benefits to working with media, files and devices in the digital domain, but after all, we are, still living in an analogue world. As human beings, we still touch things with our hands, engage with people, hear things with our ears and see things with our eyes. All of these are decidedly analogue reception devices.

Summary

The above sections were a snapshot of how different analogue worlds survived their first encounter with digital technologies and fought back against their dominance to create niches that people are comfortable with using and paying for. It is interesting that in addition to killing off millions of jobs in the industries that it encountered, digital technology created considerably less positions to replace them. The analogue niches discussed above are attempting to redress the balance by creating products that people want to have, and which stimulate employment and enhance quality rather than quantity of life. People may have to pay a bit more for most of them, but they are paying for the joy of purchase, ownership and utilisation which is sadly lacking in the digital experience.

Chapter Four - Design In The Post Digital Age

Introduction

Approximately four years ago I suffered my first ever reading injury. I was reading a book on my tablet, in bed, when I fell asleep and dropped the tablet. It hit me on the bridge of the nose and gave me a black eye. This was my first physical encounter with the post digital age. I had fallen asleep many times before whilst reading but on no other occasion did I hit myself with a book so hard that I caused an injury. As discussed previously, books, music and photography amongst other things have all been a part of the digital revolution that came about when computing and digital technology facilitated carrying incredibly large amounts of information around in very small form factor packages.

This convenience has not arrived without some cost. I believe that none of the experiences involved in downloading music or books or taking and viewing photographs instantaneously are as physically gratifying as a purchase from a knowledgeable shop keeper. The evolution of new technologies continues inexorably, but the purchase of 'entertainment products' is now a much less joyful and pleasurable experience. Spotify, Instagram and e-readers etc. all seem to have taken the joy of ownership, occasion and identity from the listening and reading experience and replaced them with simply being a consumer. Furthermore, there are many issues associated with the use of these new media which call into question, the issue of ownership and the power that you have over them and their disposal.

Design Thinking In the Post Digital World

As Discussed in Chapter 2 Design thinking is founded on consultation with the potential user and extensive market research on product desirability. However, as the history of the Ford Motor company can testify, basing new products solely on user feedback and market research can be catastrophic¹¹⁴.

The Edsel was a brand-new concept car from Ford which was a classic case of the wrong car for the wrong market at the wrong time. It was a prime example of the limitations of using market research to elaborate product strategies or at least of not taking the process seriously¹¹⁵. Based on their research, Ford made themselves an excellent case for a creation of a new medium-priced car, targeted at a broad spectrum of potential users. After spending \$250 million (\$2,4 billion today, assuming 3.5% inflation) on bringing the Edsel to the market, Ford discovered that the market for mid-price cars had been replaced by a boom in compact cars which was probably the one area that Ford had overlooked

¹¹⁴ <https://time.com/3586398/ford-edsel-history/> Accessed 17/01/2020

¹¹⁵ 'The Fate of the Edsel and Other Business Adventures', John Brooks, Harper & Row, 1963

in their research briefings. The failure of the Edsel is not necessarily an indictment of the use of *Design Thinking* especially since it is not clear that the Ford executives took any notice of the Market research, but it is a salutary tale¹¹⁶.

It is crucial to extract intelligence from the market information and identify trends in what people want that perhaps they are not aware of yet. I have identified a trend for people to eschew some of the irritating aspects of the Digital era with a view to having a more Analogue and human focused experience. The mobile phone market is a good example of where this digital minimalism is being manifested and there are numerous phones available now which are designed to act as simply communications devices.

Mobile Phones

I used to have a *Blackberry Bold 9000* phone (Figure 29) and it did everything that I expected. It facilitated calls, enabled SMS messages and I could read and send e-mails with a real, if physically small, QWERTY Keyboard. I took it everywhere and it was an excellent business tool. Blackberry provided mobile telecommunication technologies that enabled people to communicate quickly and securely and get things done. Furthermore, I had very few spelling errors /typos and the battery lasted a week! Blackberry phones were addictive to a certain extent, because they provided access to instant text-based communication in the palm of your hand, which had not previously been possible. In 2010 it was replaced with a modern smartphone (an HTC- Desire - Figure 30). This instrument only worked periodically as a phone, and I had very little confidence in it working when I needed it. Personally, I think many of Apps that can be installed on a phone are either useless and rarely used or they absorb far too much of your available time and attention. Many people are now feeling that this is too much of a price to pay and are starting to declutter their digital lives¹¹⁷.

Today's smartphones are significantly more addictive than BlackBerrys ever were, because they are specifically designed to capture and hold your attention so that data can be collected about you and monetized for the purposes of targeted advertising. They also focus on media consumption, which is another very lucrative revenue stream. You can communicate with a smartphone, but communication is not the primary purpose and it is not how they make money.

¹¹⁶ 'The Fate of the Edsel and Other Business Adventures', John Brooks, Harper & Row, 1963

¹¹⁷ 'Digital Minimalism: On Living Better with Less Technology', Cal Newport, Portfolio. 2019



Figure 13 Blackberry Bold 9000 (2006)



Figure 14 The HTC Desire (2010)

Apple, Facebook, Google, *et al*, utilise human behaviour and cognitive science to help their software to addict and manipulate people into compulsively using their products and services. A ‘need’ to enable people to escape from their digital addiction has been identified and a new generation of companies are targeting this market and providing ‘*stripped back*’ communications devices with different form factors. These devices are specifically designed for phone and text messaging and they use modern technologies like 4G to provide a high-quality phone signal. However, the ability to install Apps is either absent or using them drains performance to an unacceptable level. I have used a graphic from ‘*Light Phone*’ to illustrate this issue in Figure 31

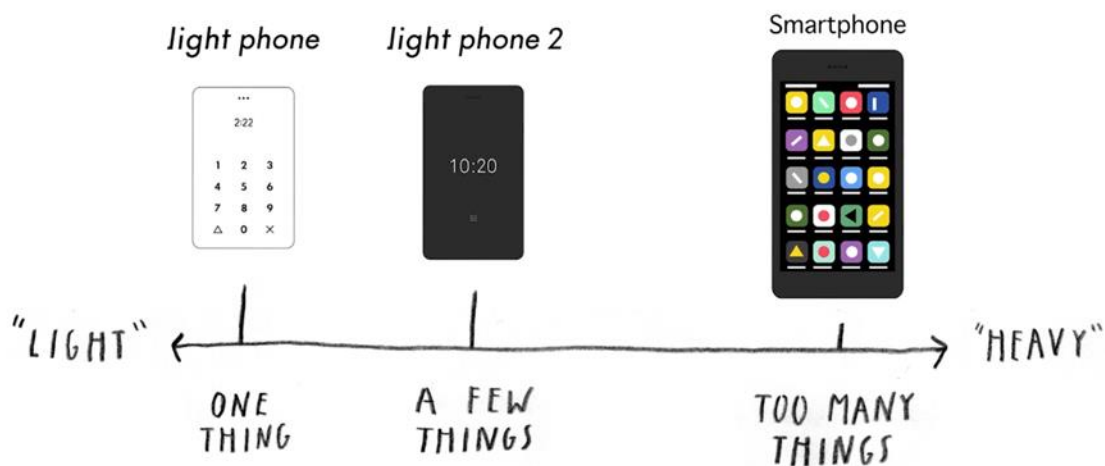


Figure 15 The Light Phone Model of Their Product Vision

The Unihertz-Jelly¹¹⁸, Runcible¹¹⁹, Punkt¹²⁰, Light-2¹²¹, Realphone¹²² KyoceraKY01L¹²³ and Mudita¹²⁴ are all phone concepts that exhibit communications capability, but which are deliberately ‘stripped-back’ in terms of functionality compared to a modern smart phone. They are invariably compact and espouse minimal user distraction as a major selling point. They are also much smaller than conventional smart phones. Technological enhancements such as high contrast e-ink (B&W) displays, reduced blue-light exposure and better antenna design for low emissions as well as long battery and call life are features of these phones. It becomes possible to adopt some of these technologies because of the reduced system performance requirements. However, all of them are a response to the concept of removing the user from the digital world and returning to a more analogue existence.



Figure 32 Punkt MP02 4G Phone



Figure 33 Mudita Pure 4G Phone



Figure 16 Runcible 4G Phone (Front)



Figure 35 The Runcible 4G Phone (Rear)

¹¹⁸ <https://www.unihertz.com/> Accessed 18/01/2020

¹¹⁹ <http://mono.hm/> Accessed 18/01/2020

¹²⁰ <https://www.punkt.ch/en/> Accessed 18/01/2020

¹²¹ <https://www.thelightphone.com/> Accessed 18/01/2020

¹²² [http://www.realphonecorp.com.](http://www.realphonecorp.com/) /Accessed 18/01/2020

¹²³ <https://www.engadget.com/2018/10/18/kyocera-releases-tiny-e-paper-companion-phone-in-japan/> Accessed 18/01/2020

¹²⁴ <https://mudita.com/> Accessed 18/01/2020



Figure 36 The Light-2 4G Phone



Figure 37 The Real Phone Corp. Logo/Sports Phone



Figure 17 Kyocera KL- 4G Phone



Figure 39 Unihertz Jelly 4G Phone

It is clear from these images that there has been a deliberate attempt to use nostalgia to create these devices. All of them hark back to a day when we knew that the battery would have enough charge to make the call, and that it would not annoy you with incessant notifications. Innovations such as the e-ink displays found in most of these products make them lower power and easier to read in bright sunlight. They also exhibit no blue light to keep you awake at night.

It is also interesting to see the most recent addition to the Unihertz product line which is a ruggedized smartphone called 'The Titan'. This exhibits a tactile QWERTY keyboard, another throwback to more Analogue days, and very reminiscent of a BlackBerry¹²⁵.

¹²⁵ <https://crackberry.com/unihertz-titan-looks-fulfill-your-desires-blackberry-passport-running-android>
accessed 18/01/2020



Figure 40 The Unihertz 'Titan' Smart Phone with QWERTY Display

Alarm Clocks

Nowadays, the mobile phone is a combination of functions that all used to be separate items that you had to carry around with you. Computer, Phone, Pager, Alarm Clock, Diary, GPS, Camera etc. were all individual devices at one time. Now they are all available in one convenient portable package. Unfortunately, all this functionality causes problems and as part of solution to these issues people are advised to buy themselves an alarm clock and a physical diary (both Analogue products). Companies like Modita and Punkt also provide sleep friendly alarm clocks, soft light displays, thermometers, environmental sensors and air fresheners as well as harmonious alarms, all for the digital detoxing market. Nendo¹²⁶ provide a similar range of their Kaklo Friends IoT range for domestic applications.



Figure 41 The Mudita 'Bell' Alarm Clock.



Figure 42 The Punkt-AC01 Alarm Clock

¹²⁶ <http://www.nendo.jp/en/works/kakao-friends-homekit/> accessed 20/01/2020



Figure 18 The Kaklo Friends Range of IoT Products for the Home (Nendo)

Photography

The phone camera is now completely built into our existence. We use it all the time to record special moments and it plays a massive role in our digital lives. However, although big strides are being made with the technology for cameras in high-end smart phones, they are all limited by the form factor of the phone and the quality of the lens that is possible to make to fit into it. No photographer who wants a high-quality image will use a phone camera to achieve it.¹²⁷

Digital cameras are evolving all the time and most of the innovation is placed in the development of sensors for different applications and photography modes. Design features of the camera body by all manufacturers had seemed to have saturated until the announcement of the Leica M Edition 60 camera. This is an expensive camera, costing in excess of \$6,000, without the lens, and it does not have an LCD display to show the outcome of the image taken. Figures 44 and 45 show images of the camera and in Figure 45 it is evident that where the display is normally found in conventional digital cameras has been replaced by a very large ISO selection dial.

The Analogue resonances in this design are very clear. It is not possible to see the image that you have taken so it is important to take more care with the framing, lighting, focus, film speed, depth of field etc. This harks back to older times when you had to wait until you got back to the studio to develop the photographs before you knew what you had taken. It also eliminates what is known as ‘chimping’ in the photography world¹²⁸.

¹²⁷ Product Photography Course. Mr. Orestis Kourakis, International Hellenic University, 2019

¹²⁸ <http://erichatheway.com/2017/05/23/chimping/> Accessed 18/01/2020



Figure 44 The Leica M Edition 60 Digital Camera (Front)



Figure 45 The Leica M Edition 60 Digital Camera (Rear)

‘Chimping’ is essentially looking at each image to see if you got it right so that you can decide whether you need to take another image or not. Professional photographers are just as guilty of this as the layman, but they should be able to frame and expose photographs properly without having to look at each image to see if it is correct. While this Leica camera would not be for many lay-men, it is interesting that Leica feel the need to remove this kind of feedback from the professional. I believe that the reason for this is an urge to recreate the mystery and anticipation of film photography and to stimulate the photographer to higher levels of achievement in the set-up of their images.



Figure 46 Chimping - Eric Hathaway

In complete contrast to the Leica ME 60, another photography genre has been established based on the use of what is essentially a toy camera, and which uses inexpensive photographic film for its images (Lomography). Despite the name, these cameras are always fully functional and capable of taking photographs, albeit with optical aberrations due to the limitations of their simple lenses. From the 1990s onward there has been interest in the artistic use of these cameras, both those designed

for children such as the Diana, and others originally intended as mass-market consumer cameras such as the Lomo LC-A, Lubitel, and Holga. Many professional photographers use Lomography cameras and exploit the vignetting, blur, light leaks, and other distortions of their inexpensive lenses for artistic effect as indicated in Figure 48.



Figure 47 The Diana F Lomography Camera



Figure 48 An Image from a Lomography Camera Showing a Vignetting Effect as a Consequence of Poor Lens Quality.

One further photographic development which could be a bit more controversial is the Camera Restricta from Philip Schmitt¹²⁹. This is a camera that connects with an internet-based database to see if there are too many photographs of a geotagged landmark available, and blocks the owners ability to take a photograph. This is supposed to be a trend to stop the cloud storage being filled up with multiple images of the same thing, but it seems a bit too much like censorship to me. However, Mr Schmitt's concept is being discussed in the literature¹³⁰ and while I don't think I approve of it, it is certainly a product for the post digital age.

Miscellaneous Post Digital Devices

In the course of this work I have identified some other responses to the post digital age but they do not really fall into a single category, so I have created this section to accumulate some images of these items. These are not sufficiently well explained to understand how they work, and I think they are more concepts than actual products. I have presented some images here which illustrate the concepts without much explanation, just for completeness.

¹²⁹ <https://philippschmitt.com/work/camera-restricta> accessed 20/01/2020

¹³⁰ <https://www.slrlounge.com/camera-restricta-camera-decide-photos-can-take/> Accessed 20/01/2020



Figure 49 Klemens Schillinger's Offline Lamp¹³¹



Figure 50 Seymour Powell's Smart Make-up Printer¹³²



Figure 51 Z-Shell – Breathing Cadence Monitor¹³³



Figure 52 Airborne- Sensor and Actuator For Making People aware of the Presence of Dangerous VOCs¹³⁴



Figure 53 Lax - Stress Combatting Mouse

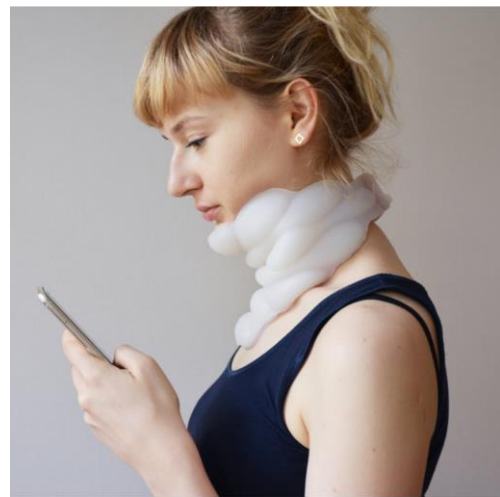


Figure 54 Detext- A Device for Eliminating Issues With Overuse of Mobile Media

¹³¹ <http://leibal.com/products/offline-lamp/> Accessed 23/01/2020

¹³² <https://www.designboom.com/technology/seymourpowell-elever-digital-makeup-03-29-2019/> Accessed 23/01/2020



Figure 55 Detext- A Device for Eliminating Issues With Overuse of Mobile Media (In action)



Figure 56 Meet Space – Diversity Detector and New Encounters Aid

Discussion

The technologies described in this chapter are all evidence of a trend that I identified earlier in my research activities. There is a clear shift away from people being dominated by digital technology and the smart phone in particular. People now recognise their phone addiction problem and are making a move towards a more harmonious world, where technology and the devices we live with, do what we want them to, do not provide us with extraneous information and do not interfere in our lives unbidden.

People who have engaged in a digital detox seem to be very happy that they have done it. They are also pleased that there are now products like the Light 2 and the Punkt 2 phones, because they want to use up to date technology but all that was available was legacy equipment from 10 years or more ago. It is interesting that both Punkt and Light have now a second-generation phone available because they both possibly overestimated the demand for a complexly stripped back phone product.

For the purposes of this work it is a shame that the Runcible Phone did not make it. It was a perfect example of a return to the analogue era. It looked like a gentleman's pocket watch, it was round and made of wood and you could buy watch chain type accessories to attach it to your waistcoat. Exactly the kind of thing I would buy, given the opportunity.

¹³³ Figures 39-44 originate from <https://designawards.core77.com/speculative-design/87060/Silicone-Valley-Breaking-Techno-Mediated-Habits> Accessed 23/01/2020

It is interesting that the most recent innovation in the photography world and the first deviation from the norm for many years is the creation of a camera without a display. The reason for this could be the desire to recreate a more analogue experience for the photographer and make them use their skills without the need for constant validation.

All these issues, and those from the previous chapter, indicate that a trend exists away from the excessive use of digital technology and an urge to replace it with a more human facing analogue experience.

Chapter Five - Potential Design Projects for the Post Digital Age.

Introduction

The aim of the preceding chapters has been to set the scene for the possible design projects that could be undertaken in the course of this dissertation. The design of an Analogue artefact, which fits into the post digital age based on technologies that are coming to the fore is the *raison-d'être* of this project. Several possible concepts are listed in the coming sections which fulfil the brief of the dissertation topic. These concepts address the brief and represent the ideation phase of the project.

There are roadmaps for technology developments^{135, 136 137} but there are no published roadmaps for product development because new product ideas are the lifeblood of individual companies. All of these ideas could become new products. However, for this design project, I must choose one. Four of a large selection of ideas for new products are discussed below to show the diversity of my response to the design brief. One of these would be better to be realised as an 'App¹³⁸' (The Veracity Indicator) and would not constitute an artefact *per se*. However, all these items would embrace the adoption of emerging technologies and could become something that people would be intrigued by.

Possible Design Projects

Veracity Indicator.

The concept of 'Fake News' has only arisen over the past few years, since Donald Trump has been in place as president of the USA¹³⁹. Perhaps this was happening prior to Trump's election but I certainly had never heard of it, it would also have been highly unusual for anyone of my generation to disbelieve what is written in the broadsheet newspapers. Until recently, I have always assumed that anything printed by a reputable newspaper had been fact checked and had no overt political agenda¹⁴⁰. Newspapers have been discredited over the last few years and they need a validation of their product to return confidence in them to the market. The question is thus, 'can we detect and identify fake news at its source and get evidence of substantiation in real time as it emerges?'. Such a system could

¹³⁵ <http://www.itrs2.net/> Accessed 29/11/2019

¹³⁶ <https://www.nereid-h2020.eu/> Accessed 29/11/2019

¹³⁷ <https://www.smart-systems-integration.org/> Accessed 29/11/2019

¹³⁸ https://en.wikipedia.org/wiki/Mobile_app Accessed 29/11/019

¹³⁹ <https://www.theguardian.com/books/2019/nov/22/factitious-taradiddle-dictionary-real-history-fake-news> Accessed 29/11/2019

¹⁴⁰ <https://www.nytimes.com/2019/07/30/reader-center/fact-checking-politics-presidential-election.html> Accessed 29/11/2019

be an App based in the cloud and running on something like the IBM Watson AI system¹⁴¹ (See Appendix p91). It should be able to investigate any published piece of text and establish whether the reader should believe it or not. It should also be able to detect plagiarism and supply indications of possible sources if required.

Facial Recognition Obscuration System

There is currently a very large amount of polemic involving countries, who are using AI based Facial Recognition Systems built into surveillance cameras ^{142 143 144 145 146}. In my view, this acts to the detriment of the freedom and liberty of their citizens¹⁴⁷. I do not believe that people should be scanned and catalogued by the state for what-ever reason governments choose. This is an abuse of the rights of the individual and permission should be granted for the taking and storage of images. Creating an optical system for an individual which could counteract AI-FR software could be an interesting solution to this incursion into human rights.

The possibility exists to install LED lights on hats¹⁴⁸, glasses¹⁴⁹ or in jewellery that shine Infra-red light, which is Invisible to humans directly into the detector of the FR system. This will saturate the system detector. It is also possible to reflect light off the face to distort its critical dimensions. It is proposed that this design implementation could be a pair of earrings which have LEDs built into the mounting of each one with stones like diamonds or other transparent media attached to the surface. Battery power and an on-off capability would be provided by the locking ring at the back of the ear.

The Do Not Disturb Table

It has been shown in the literature and discussed in the Appendix (p81), that people are becoming more and more addicted to using their mobile phones. This addiction causes them to look at their phones every few minutes and results in them reducing their social interactions to a point where

¹⁴¹ <https://www.ibm.com/watson> Accessed 29/11/2019

¹⁴² <https://www.wired.com/story/behind-rise-chinas-facial-recognition-giants/> Accessed 29/11/2019

¹⁴³ <https://www.cnn.com/2019/09/06/ai-worries-about-the-dangers-of-facial-recognition-growing-in-china.html> Accessed 29/11/2019

¹⁴⁴ <https://www.wsj.com/articles/huawei-technicians-helped-african-governments-spy-on-political-opponents-11565793017> Accessed 29/11/2019

¹⁴⁵ <https://www.nuffieldfoundation.org/news/british-public-want-restrictions-use-facial-recognition-technology> Accessed 29/11/2019

¹⁴⁶ <https://www.pbs.org/wgbh/frontline/article/how-chinas-government-is-using-ai-on-its-ughur-muslim-population/> Accessed 29/11/2019

¹⁴⁷ <https://www.theguardian.com/technology/2019/aug/16/privacy-campaigners-uk-facial-recognition-epidemic> Accessed 29/11/2019

¹⁴⁸ <https://www.digitaltrends.com/cool-tech/facial-recognition-hat-infrared/> Accessed 29/11/2019

¹⁴⁹ <https://www.digitaltrends.com/cool-tech/facial-recognition-glasses-security/> Accessed 29/11/2019

friction between family members is a common occurrence¹⁵⁰. Both parents and children blame each other for the lack of ‘family togetherness’ that has been generated by their ‘always-on’ connection to their networks¹⁵¹. It has also been observed that in industry, people read their phones and deal with their e-mail during meetings¹⁵². This causes meetings to last much longer than they need to¹⁵³.

It is possible to electrically screen an enclosure to inhibit the transmission of RF waves, essentially blocking the phone signal, by using a Faraday shield¹⁵⁴. Screened meeting rooms are starting to appear in companies and there is even an example of a cocktail bar owner who has constructed a Faraday screen in his bar to eliminate the impact that mobile phones have on the atmosphere and to facilitate conversation¹⁵⁵.

The concept of having a table that has electrostatically screened compartments for storing mobile phones at mealtimes, in the classroom or in meetings is proposed. This table would provide a storage and wireless charging function for the phones for the duration of the event. The aim of this table would be to encourage people to engage in more active or focused conversations, while not having visible access to their phones. They would also be isolated from all the push notifications that they receive while their mobile phone is in the screened compartment.

Postcards from The Cloud

As human beings we need to satisfy both our intellectual and emotional needs. Our emotional needs are obviously not being met by digital products, otherwise we would not be seeing the resurgence of analogue technologies in many aspects of our lives. In order to redress the impact of this deficit, we are seeking more and more analogue experiences and connections. The analogue world in the current decade has been characterised by an attempt to re-establish humanity and physical real time behaviour in many of the life experiences that have been converted to digital. People want to engage more with real, tactile objects, like books, notebooks, photographs, journals, boardgames etc. where physical interactions with people and objects transport them to a different time where maybe the austerity of the digital experience is diminished.

¹⁵⁰ ‘Alone Together – Why we Expect More from Technology and Less From Each Other’ Sherry Turkle, Basic Books. 2012

¹⁵¹ ‘Reclaiming Conversation: The Power of Talk in a Digital Age’ Sherry Turkle, Penguin Books. 2016

¹⁵² ‘Digital Minimalism: Choosing a Focused Life in a Noisy World’, Cal Newport, Penguin Books. 2019

¹⁵³ <https://blog.percolate.com/2014/06/6-meeting-rules-of-percolate/> Accessed 29/11/2019

¹⁵⁴ <https://science.howstuffworks.com/faraday-cage.htm> Accessed 29/11/2019

¹⁵⁵ <https://www.sciencealert.com/a-talented-bar-owner-in-the-uk-has-built-a-faraday-cage-to-stop-customers-using-their-phones> Accessed 29/11/2019

I believe that there is a market for a printer that can generate postcards from our digital memories for sharing with friends and family. There is also a mail art movement¹⁵⁶ to which this product could be aligned, and some examples are provided for information in Figure 57.

‘In the era of instant messaging and FaceTime on the go, it can be easy to forget the pleasure of shuffling out to the mailbox in hope of discovering a thoughtful note from an old friend. Removing a letter from its envelope is a rich tactile experience, and marginalia, cross-outs, distinct penmanship and quirky enclosures combine to give epistolary exchanges a uniquely personal flavour’.

Ryan P. Smith

‘The only thing the postman brings now is bills’. – Appostolos Rizos



Figure 57 Examples Of Post Art

¹⁵⁶ ‘Collaborative “Mail Art” Puts the Post in Postmodernism, Ryan P. Smith, SmithsonianMag.com July 30 2018 Accessed 3/01/2020/

There are several websites that convert digital photos into photo-albums ^{e.g.¹⁵⁷, ¹⁵⁸} These platforms address a growing consumer desire to turn their digital memories into physical keepsakes, so that they have a tangible record of them. Everybody has thousands of photographs stored in their phones or in the cloud, but I do not think they are being used to best effect. There is also an interest in finding more tangible and permanent ways to save the better images on a more solid platform, such as scrapbooks¹⁵⁹. When memories are stored in these digital media you are only one accident, phone update, computer crash or theft away, from losing all your valuable emotional connections.

Design Proposal

My proposal for the design of an artefact is one which would augment the existing photo books, but which would enable tourists to send photographs of themselves back to their friends and neighbours in the form of personalised postcards. Sending and receiving postcards from my vacations have always been a major feature of my holiday. Putting a cross on the card to show where you are staying or just letting people know you are thinking of them. It is possible to send a digital image message, but these are just part of the daily digital feed and are often blanket messages to a person's whole connection list and have virtually zero emotional resonance. I believe that it is a much nicer experience to find a postcard in your letterbox.

Prototyping and Test

I would like to design a recyclable postcard printer for people who wish to print personalised photographs from their phones and send them to their friends. There are apps that can do this^{160, 161}, but you don't get to write the message on the back of your card in your own handwriting. I envisage the consumer purchasing a package of cloud cards at the airport which contains, a recyclable printer, a set of ten blank free-post encoded postcards and a self-addressed envelope for sending the printer back to the manufacturer for recycling. I believe that this product would be used by a large number of travellers. It really rounds off a holiday to share it with people at home. This concept also addresses the *zeitgeist* by addressing the nostalgic aspects of the post digital age while providing a retro way to keep in touch with people you know and love. This could be a very interesting product going forward. The aesthetics of the printer will be to look and feel as inexpensive as possible on the outside, while retaining a high level of performance and print quality. The external shell will be made from waxed

¹⁵⁷ <https://www.shutterfly.com/> Accessed 2/12/2019

¹⁵⁸ <https://www.myphotobook.ie/photo-book-offer-sem-10> Accessed 2/12/2019

¹⁵⁹ <https://www.esquire.com/entertainment/music/a47793/what-happened-to-vaporwave/> Accessed 09/01/2020

¹⁶⁰ <https://www.mypostcard.com/> Accessed 09/01/2020

¹⁶¹ <https://www.funkypigeon.com/> Accessed 09/01/2020

paper or recycled PET (r-PET)¹⁶² which is material which is produced from used plastic packaging that cannot be used for food or drug use anymore.

Competitive Analysis

There are methods for creating hard copies of photographs including the polaroid and Instant cameras discussed in the previous chapter. There are also photo printers such as the HP sprocket ¹⁶³ which can print photographs on thermal paper, but these images would not be robust enough to send by post. Furthermore, polaroid images are normally too small to be considered postcards, there is an element of luck regarding the image you get from the technology and you can't write on the back of them. Instant cameras and HP-Sprockets also cost in excess of 100 euro and are more of an investment rather than a holiday venture. They also have very expensive consumables. Neither option addresses the issue of being able to send a robust, postcard format image, by post.

Design Proposal One

I propose to design a portable digital printer which will be called a Cloud Card Printer, with the tag line 'Send Some Love Home' on the packaging. It will print on thick card, suitable for postcards, and will be powered by USB. A Bluetooth connection will be used to transfer the information from the phone for printing. The postcard blanks will be stored in a cartridge inside the printer, with an external measure of how many blanks remain. The target price point will be 25 Euro.



Figure 58 The Cloud Cards Logo and Colourways

The intention for the Cloud Card device is, that it would be an ink jet printer¹⁶⁴ which has only enough ink for ten images and one ink cartridge that contains the four BCMY colours. This device would be different from other printers because all document printers have a separate black cartridge in order

¹⁶² <https://www.heritagepaper.net/understanding-pvc-and-rpet/> Accessed 09/01/2020

¹⁶³ <https://store.hp.com/us/en/slp/sprocket-photo-printers/hp-sprocket> Accessed 2/12/2019

¹⁶⁴ <https://computer.howstuffworks.com/inkjet-printer5.htm> Accessed 2/12/2019

to print documents. It is not the intention for the 'Cloud Card' printer to print words *per-se*, just images, so every colour could have equal priority and all the printing would require very low ink volumes. This application may require a change in the business model for inkjet printers which use consumables to generate the high profit on the device. However, maybe the enormous volumes of potential customers for this product will stimulate such a change, especially if the inkjet cartridges can be made and filled at wafer scale in a silicon foundry¹⁶⁵.

Most printers are heavy because they need to counteract the juddering of the moving parts while printing. This printer is going to be designed to be lightweight and recyclable. It is the intention to replace the weight of the printer with suction feet which will adhere the printer to a table or other flat surface for the duration of the printing process. Thus, creating a comprehensible, user friendly, device with compact size and portability. At this point, these feet are a functional part of the design and will be evaluated from an aesthetic perspective, if a prototype is built, to see if a more elegant footing can be provided while retaining a 'judder-free' function.

Dimensions

The standard size for a postcard is A6¹⁶⁶ or (148x105mm) with a thickness between 0.17 and 0.4 mm therefore, ten post cards will occupy a height of <5 mm in the postcard holder cassette. I envisage the cassette to be 2.5cm thick for reasons of rigidity and handling convenience.

The printer will be fed directly from the cassette into the receiving slot on the reverse side of the printer. All Inkjet printers have two movements. One is the linear movement of the paper being printed. This action is normally provided by small wheels which catch the paper and drag it forward into the printing apparatus. This microscopic linear motion is coupled and synchronised to the rapid horizontal scanning of the print head which moves perpendicular to the motion of the paper. The print heads sprays minute dots of ink in the appropriate places on each line and then moves the paper and prints another line of ink until the task is completed. Figure 59 shows the printer without its protective casing. It shows the print head, which moves perpendicular to the motion of the paper and moves along fixed rails to ensure fidelity of movement. This is shown in blue in the diagram. The paper is moved on and synchronised with the paper moving wheels, which drag the card through the printer in a fashion that is synchronised with the scanning of the inkjet head. They are shown in Pink in the diagram.

¹⁶⁵ https://www.fujifilmusa.com/shared/bin/MEMS_Solutions_Web.pdf Accessed 3/01/2020

¹⁶⁶ <https://www.papersizes.org/postcard-sizes.htm> Accessed 3/06/2020

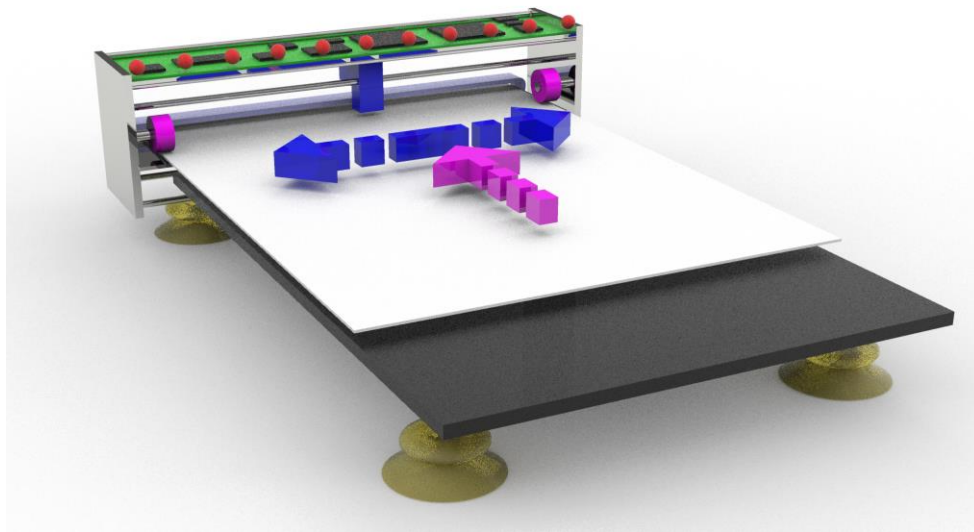


Figure 59 The Inner Workings of the Printer Indicating How It Would Function

The system proposed here is not readily available commercially, primarily because it is a new device concept. The print head and the ink dispensing process as well as the incremental position changes of the paper under it, are controlled by very accurate stepper motors which are addressed and driven by the microprocessor core that controls them¹⁶⁷.

The structure of the card cassette is shown in Figures, 60-64.

There is a need for the user to know how many postcards are left in the cassette, so LED lights on the top surface of the printer will show how many print actions have taken place. Clearly there are more elegant ways to indicate this, but I felt that a more retro and low-cost appearance would be more suitable in this instance. It is necessary, however, to have an 'on' or zero prints, indicator light because it will not be possible to work out if the printer is on or not if there have been no prints performed. Figure 65 shows a sketch of the printer and Figure 66 shows a rendered version of the Rhino Model. Figure 67 shows a mock-up (maquette) of the device to indicate scale and appearance and Figure 68 shows the proposed packaging for the device. Figure 69 shows an example of a postcard which could have been printed.

¹⁶⁷ <https://www.britannica.com/technology/ink-jet-printer> Accessed 5.12/2019

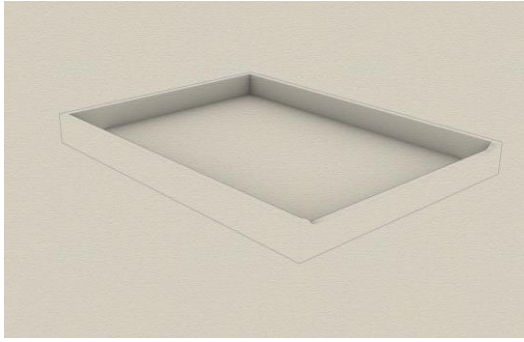


Figure 60 The Empty Card Cassette Without A Lid Note the Card Exit Portal in the Foreground

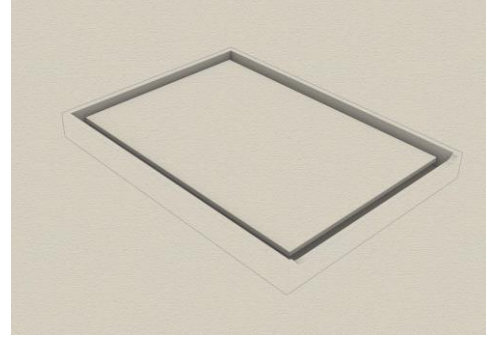


Figure 61 The Empty Card Cassette Showing the Spring-Loaded Platform Which Brings All Cards to The Printer Entry Port

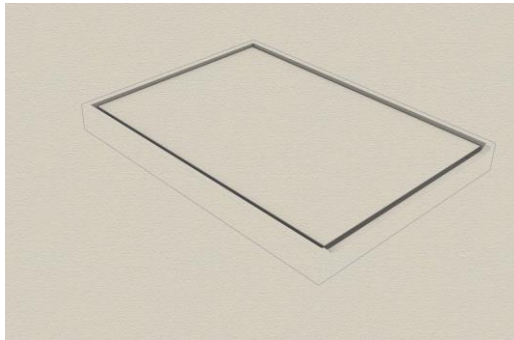


Figure 62 The Cassette Loaded with Postcard Blanks

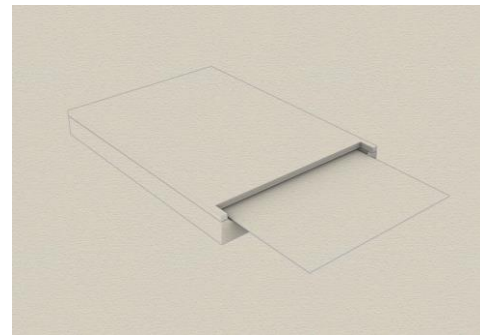


Figure 63 The Completed Card Cassette the Paper Movement Wheel Grabs the Paper at the Front Edge of the Cassette

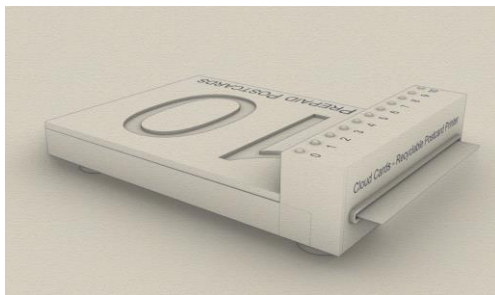


Figure 64 A Sketch of the Proposed Printer System



Figure 65 Model of the Printer

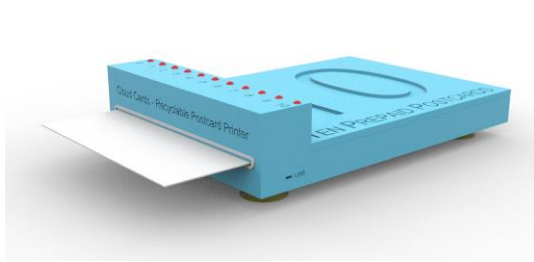


Figure 66 Cloud Cards Recyclable Postcard Printer, Showing Suction Feet



Figure 67 Proposed Product Packaging

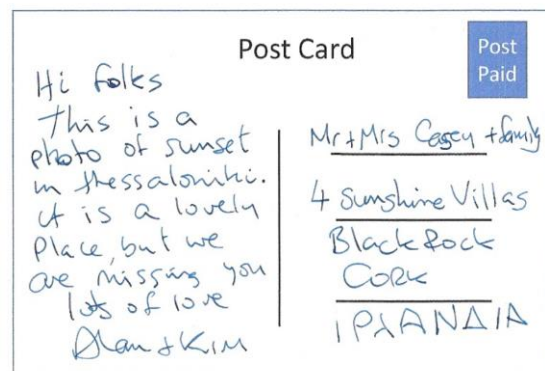
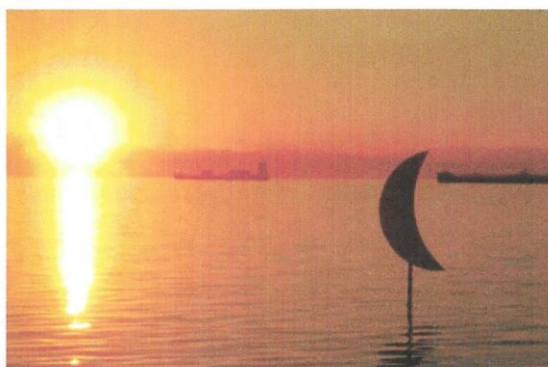


Figure 68 An Example Postcard to Illustrate the Concept (Not Full size)

Summary of Feedback on First Design

This design and the prototype device were discussed individually with a panel of ten people with a view to getting feedback on the concept, how it fits with the brief and how it could be improved from their perspective.

The people involved in the discussion were chosen, by necessity, from a very limited pool. However, I endeavoured to have as broad a range of ages and experience as possible. On my panel I had three university students (including one PhD student), two professional artists and two graphic designers as well as two health professionals and a university researcher in electronic systems. The age range spread from twenty to sixty years old with a median age of approximately forty to attempt to capture any age or experience impact on their opinions, although a much bigger sample would have been desirable and much more statistically relevant. The aim of the discussion was primarily to establish the best concept and fit with the brief. Clearly, when this study was performed it was very early in the

conceptualisation phase and my aim was to explain what I was trying to achieve with respect to the design brief. In the course of the discussion, I described the post digital design ideas and concepts discussed above to establish a priority rating for each one and the 'Postcards from the Edge' project was unanimously identified as the one that the panel preferred.

Everybody who saw the 'maquette'¹⁶⁸, were impressed with both the idea and the implementation of the concept and they very much liked the packaging. They were all, without exception, warmly enthusiastic about the idea and three suggested that it should be patented. Some more aesthetic remarks were made about the idea of the LED display and the shape of the printer module, which, admittedly, could have been more elegant. Three main modifications came from the discussions. One is that the printer section presents a '*shut line*' perpendicular to the card cartridge and this was 'very clunky looking'. Ideally the printer should be flatter when purchased, to make it more portable and take up less space on store shelves. A second was that the LED displays were inelegant and power hungry and should be replaced. The third which was not initially considered, is that this printer could be used as a printing medium for the creation of art works on different substrates and maybe it could be possible to replace the cartridge with other substrates for printing.

The idea of an App which would format the image into A6 format and facilitate the design of your own stamps was also suggested. This app would also allow control of each colour for use until the reservoir is *actually* empty. This is not the case with traditional printers, and it would make it more interesting to artists. Furthermore, even in its current form the printer could also be used as a building block for artistic installations in the same way as Nespresso cartridges are, (see Figures 69 and 70). The artistic applications for this artefact are wide ranging and have the potential to attract more people into the concept of *Art as Therapy*¹⁶⁹. However, feedback on the overall concept was excellent and very positive suggestions for improvement were gratefully received.

The most interesting and practical enhancements are to be implemented in a subsequent version. From recent experience¹⁷⁰, it is not possible to design an App, or even the interface to it, in the frame of this project. However, if this goes further, such an App will be required.

¹⁶⁸ 'Thinking: Objects: Contemporary Approaches to Product Design', Tim Parsons, Bloomsbury. 2017

¹⁶⁹ 'Art as Therapy' Alain de Botton, John Armstrong, Phaidon. 2013

¹⁷⁰ IHU Carpool App - Human Factors Coursework IHU, Mathewson, Christodoulou-Chasapis, Georgarou 2019

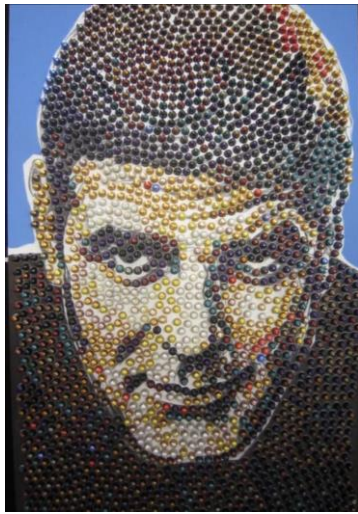


Figure 69 George Clooney Image Made from Nespresso Capsules¹⁷¹.



Figure 70 Lion Image Made from Nespresso Capsules¹⁷².

Design Proposal Two - The Revised Printer

As a consequence of the feedback from the review panel, the decision to make the printer flat when purchased was made. This has removed the shut line and has the added advantage of also making it possible for people to use the printer without the cartridge being connected if they want to print on different substrates. The LED display has been replaced with a single light, indicating Bluetooth availability and 'on', with a small window in the card cartridge revealing the number of cards printed

The printing unit has now been aligned to the same plane as the cartridge and supported on axles at the sides. In order to perform a postcard print in this instance, the head must be moved sideways, rotated and then placed at the interface to the cartridge by pushing it back along the guide and locking it in place at the end of the traverse. The sequence is shown in the figures 71-73. A new 'maquette' has been made and this is shown in Figure 74 and Figure 75 Although the packaging artwork remains the same, the package is now smaller as shown in Figure 76 and 77

¹⁷¹ 'George Clooney – What else? Capsules Nespresso', Emily, Xavier Ronse Gallery, Lille Art Fair 2012, (Pinterest) Accessed 05/01/2020

¹⁷² https://mir-s3-cdn-cf.behance.net/project_modules/2800_opt_1/119ca443680299.57f8205463f21.jpg Accessed 05/01/2020



Figure 71 Version Two of the Printer Showing the Device in Flat Mode.



Figure 72 The New Printer Mid Conversion



Figure 73a The Printer in Card Printing Mode

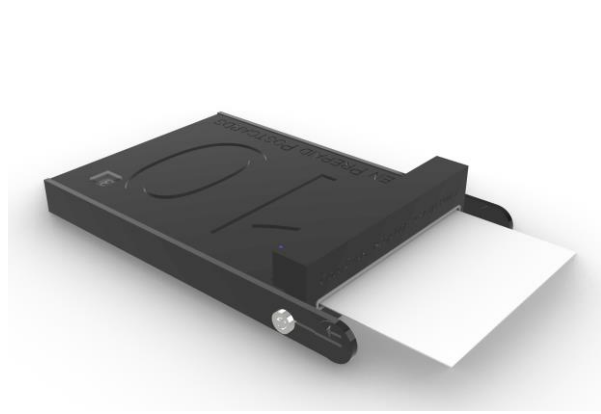


Figure 73b The Printer in Card Printing Mode

Obviously, the image on the packaging is me in front of the White Tower in the rain. However, if this project is to go further, it needs to be someone more attractive and younger or better images of local natural beauty to aid the sale of the concept.

One possible additional advantage of this device is that it will facilitate personal communications between people without the oversight of the state, or the communications and marketing giants who all use our online presence to extract information about our preferences and choices from our electronic correspondence.



Figure 74 Printer Maquette with Postcard Blank



Figure 75 New Printer Maquette in Normal Operation

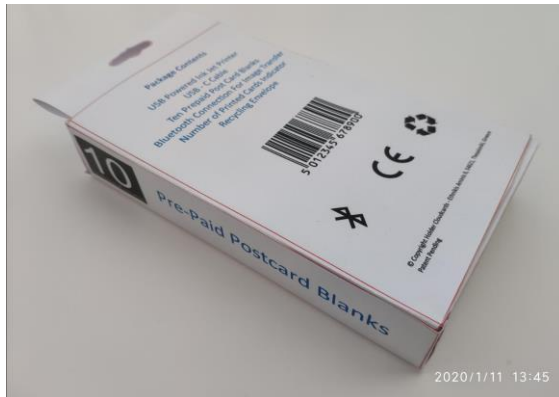


Figure 76 Printer Packaging (Rear View)

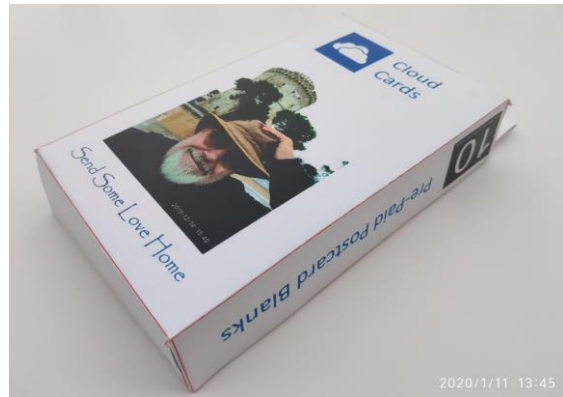


Figure 77 Printer Packaging (Front View)

Chapter Six - Discussion and Conclusions

Discussion

The post-digital age is going to have a massive impact on the way people live their lives and the way that business is done. It is evident that enormous strides have taken place over the last fifty years. We have gone from having no computers at all, to a state where everybody, at least, has access to a computer, and most people have mobile phones that are millions of times more powerful than the one that managed the moon landing. However, many people feel that the world is losing some of its humanity¹⁷³, and that while people are more connected now than ever before they are also more alone^{174 175}. Everything that helps us in some ways also has some drawbacks, and in the case of digital technologies we are losing the full sensational impact of everyday experiences because we are interacting with the world, in many cases, through the glass screen of a mobile phone or computer. Information is certainly being imparted, and it is very accessible and enormously beneficial, but the humanity is slowly being removed from the experience of receiving it.

Everybody has enormous numbers of photographs in the memory of their phone. The photographs stored there are easily accessible, you can carry your pictorial life around with you and if you want to show someone a photo, it is quite an easy thing to do. You can either share the phone, send an image by email or share an image with your social media network. All of these transactions short circuit the physical nature of the transfer and for example there is no way to know how old the image is, it has none of the patina of age, and essentially it cannot be seen as a treasured memory because it is sitting beside millions of others in a little box instead of being framed and displayed.

Photographs are the way that we have chosen to document our every-day lives, the growth and development of our families, the holidays we take and our triumphs. It is a shame that these are not visible to others anymore, because they are things that we are, in the main, proud of and want to share them. Nobody that I know prints out their photographs, even though there are huge numbers of pictures that they spent hours agonising over taking. Google photos can be an insular experience and people have become accustomed to looking at their pictures and sharing the phone to do it. However, a lost/stolen phone or a crashed computer can have disproportionate impact on their emotional state, and I believe that it is beneficial to get some hard copies of special moments. The

¹⁷³ 'The Porcelain Workshop: For a New Grammar of Politics', Antonio Negri, Harvard University Press. 2008

¹⁷⁴ 'Reclaiming Conversation - The Power of Talk in the Digital Age'. Sherry Turkle Penguin Press. 2015 pp 10-20

¹⁷⁵ 'Empire', Michael Hardt, Antonio Negri, Harvard University Press. 2001

tactile experience of handling these images, the fact that they age with time and develop a patina of their life, which parallels the life of their subjects is an important aspect.

It is not an enormous shift away from the digital world that I am describing. Everybody appreciates the benefits, convenience and sheer efficiency of their lives now compared to even twenty years ago, but some people are starting to miss the analogue experiences of interacting in the real world. There is a new wave of analogue (real life, real experience) products that are retro or nostalgic and which are building up momentum in a search to reclaim what was lost when we gave up our experiences to the advances in technology.

The resurgence of craft beers, vinyl records, Swiss watches, fountain pens, and notebooks as well as analogue Lomography film and recording media are all witnesses to this movement. They also show another aspect that is not evident from the preceding discussion, but it is significant. Digital technologies have created a common denominator in all our transactions. They have made everything cheaper and more accessible, and the cost for that, is the loss mentioned above. Digital Technologies have turned everything into a product, and we have all become consumers. All the analogue artefacts that are now coming to the fore represent a *push-back* against the digital, high volume consumer world, and they all tend to be more expensive (or more time consuming) than their digital equivalent. This is the price that some people are prepared to pay to experience something that is out of the ordinary and to be seen doing it, which possibly gives them some social cachet.

My response to the brief of creating a new analogue artefact for the post digital age has been to look at the ways that our photo library can be shared with our loved ones using a very traditional medium. The possibility of sending a postcard to people written in your own handwriting, with an image from your cell phone showing 'selfies', or spectacular views would be at least intriguing to many people. I have not performed a formal survey because I believe there is considerable potential in this idea, and I may wish to protect it. Furthermore, the ten people that I have spoken to informally and whose judgement I respect seem to think it is current, a good idea, and something they would buy if it was available.

I believe that, as part of the analogue revolution, the postcard printer proposed in this chapter completely addresses the brief. It is novel, there is not one of these on the market, to the best of my knowledge. It is also eco-friendly, because it is designed to be inexpensive but not disposable, with the intention of making the mechanisms recyclable as possible. The outer shell is designed to be made from either waxed card, from reconstituted paper or recycled R-PET. It will re-stimulate the use of the postal services and it may contribute to local employment.

Summary and Conclusions

In this design project, I was provided with a brief to create a product for the post digital age that has a 'New Analogue' component to it.

In the Appendix, I have provided the background to the growth of digital technologies from its very beginnings in the 1950's and shown some of the directions that companies are taking for the future. Companies are building technologies that will streamline the way that we purchase everything. They are building artificial intelligence systems that will revolutionise the way that they target their customers based on a better understanding of their data. They will be offering more and more variability in their product ranges as mass customisation of products occurs.

Autonomous vehicles are being rolled out now although it may be a few years before sightings are a regular occurrence in places away from California and other high-tech hubs.

The '*internet of things*' will support these technology visions by making measurements where they had not been used previously. Decisions in almost every sphere of life will become 'data based' in the future but there are enormous security and confidentiality issues that surround this entire platform. Furthermore, efforts in the use of quantum computing to ensure privacy of communications and data encryption will become more and more important once the problems associated with having what is the equivalent of up to 1000 mobile phones talking simultaneously in any given cubic metre volume. This may be an extreme example, but these sensors are becoming very small and when the IoT was first proposed it was considered to be achievable.

However, there is at least one major downside to these technological advances. It appears that our children are losing the ability to hold and write using a pencil as a function of continuous exposure to screen based devices. Their musculoskeletal development and manual dexterity is suffering from this exposure¹⁷⁶. There are many professions which require very dextrous people, e.g. surgeons, dentists, engineers, artists and craft workers and of course designers. A solution needs to be found to counteract this disturbing phenomenon.

As part of my ideation process, I described some of the areas where these new digital platforms could be used going forward. These application areas could be in the domain of secure transactions, better and more focused social interactions, better health monitoring and more trustworthy media. However, the most suitable vehicle to demonstrate the analogue aspects of these new technologies

¹⁷⁶ <https://www.theguardian.com/society/2018/feb/25/children-struggle-to-hold-pencils-due-to-too-much-tech-doctors-say> Accessed 09/01/2020

is the ink jet printer that will facilitate the printing of postcards. This is something that I have wanted to be able to do for a long time. However, I have never had the opportunity to think or do anything about it. I believe that the 'Cloud Card - Recyclable Postcard Printer' Is a product that people would like to buy, if the price was right.

I decided that it should contain pre stamped cards to minimise the needing to 'buy stamps', and to more closely reflect the seamlessness of current social media transactions. Having pre-paid cards will affect the price that people will have to pay and will probably mean that that the manufacturing cost for the printer assembly and the packaging will need to be approximately 7€; if the target price of 20-25€ for the printer and cards (including 10 pre-paid postage stamps) can be met.

This postcard printer completely captures *the zeitgeist* and will stimulate the economy in multiple different ways. It will be a new product to sell to tourists. It will create employment in manufacturing and recycling industries, it will require new technologies that will need to be protected, implemented and defended as demand grows. This product may look simple, but there is research in many different areas that needs to be completed before the first printer can be sold. Research is required in areas of materials, inks and coatings, printer compatible card, environmentally friendly and recyclable packaging, electronics, ink jet head manufacturing and low vibration printing mechanisms, as well as market research and brand concept and brand equity building in the tourism and hospitality sectors. All of this activity is perfectly achievable with the correct partners. Identifying and Choosing complementary partners is a feature of new digital business developments as described in the Appendix (p 78).

Based on the enormous strides taken over the last fifty years and looking forward, I can see where the industry could be going. However, it is unlikely to follow a linear pathway. Something disruptive like quantum computing, bio computing or the introduction of new nanomaterials which have remarkable properties, is highly likely to happen. The world will be transformed through the diversification of these new technologies into more mainstream products. I look forward to moving from where we are now to a brave new future. Moore's law for silicon may be topping out, but there will be another ambitious set of targets for maybe a different material set. There are certainly enough ambitious roadmaps for the technologies of the future. These will set ambitious targets for new technologies to pursue and surpass on an annual basis going forward. Hopefully, some of the analogue user experience described in this work will be retained in the course of these developments.

Appendix

Appendix - The Evolution Of Digital Technologies 1949-2020

Introduction

The 'Digital Era' really only 'happened' over the last seventy years. However, it 'started' in Ireland in 1847 with George Boole's mathematics, and it evolved over the last half century to be the enabling technology for an enormous industrial domain which has changed the lives of millions of people across the globe. The technologies that have been implemented to achieve this staggering growth have been a tribute to man's ingenuity, and how deep his pockets are. Micro and nano technologies are very expensive pursuits, and they are also high-risk, high-reward ventures. Investment in pushing the technological capabilities has been very fruitful over the years.

Early Days

George Boole

in 1847, George Boole, who was the Professor of Mathematics in Queens College Cork, Ireland (Now University College Cork) published a book entitled 'The Mathematical Analysis of Logic'¹⁷⁷ which outlines the thought process and an entire algebra for combining functions¹⁷⁸. This work was predominantly an academic text where he described the way that functions could be reduced and combined using a logical process. In 1886 Charles Sanders Pierce of Harvard University took the ideas behind Boole's work and worked on using the concept of switching circuits to implement combinational logical processes¹⁷⁹. Almost seventy years after Pierce's work was published, Claude Shannon made a breakthrough in demonstrating that Boole's work could form the basis for calculation mechanisms and secure communications processes in the real world.

¹⁷⁷ The Mathematical Analysis of Logic: Being an Essay Towards A Calculus Of Deductive Reasoning (1847) George Boole, Kessinger Publishing, LLC (November 3, 2007)

¹⁷⁸ Boolean Algebra and Its Applications (Dover Books on Computer Science) J. Eldon Whitesitt, Dover Publications, Mineola, New York.

¹⁷⁹ 'The Writings of Charles Sanders Pierce 1857-1866'. Charles Santiago Sanders Peirce, Charles Sanders Peirce, André De Tienne, Cornelis De Waal, Indiana University Press. ©2000 Pierce Edition Project

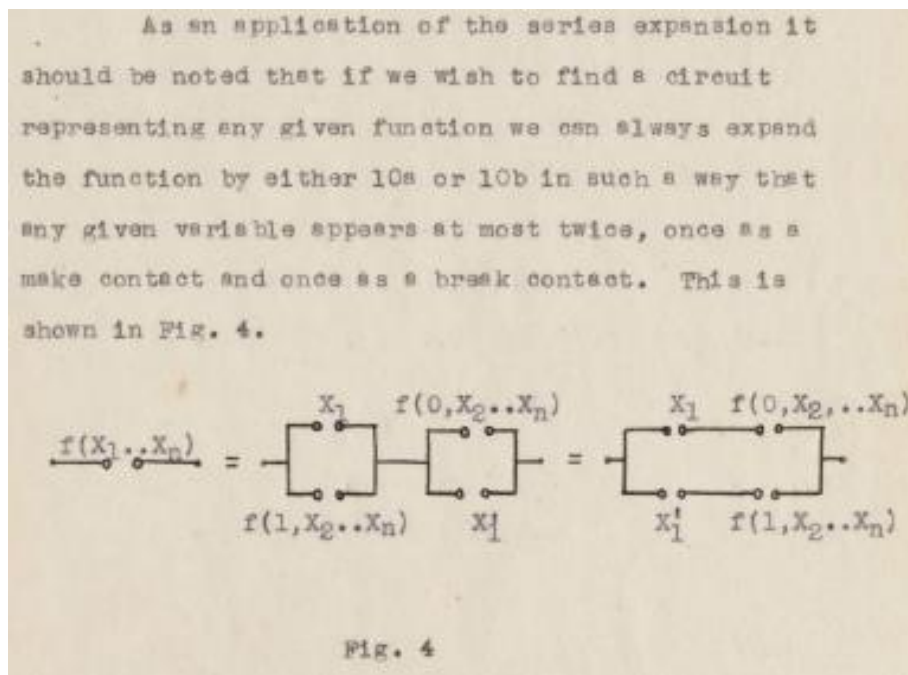


Figure A1 Extract from Shannon's Master's Showing How Logic Gates Could Be Implemented with Switches

In particular, Shannon showed that electromechanical relay circuits could be used to solve Boolean algebra problems when he presented his Master's Thesis entitled 'A Symbolic Analysis of Relay and Switching Circuits' in 1937¹⁸⁰. An extract from his thesis is presented in Figure A1 and this illustrates how functions can be represented by switches with a value of 'open' or 'closed'. Shannon completed his Master's while working, part-time, in Bell Telephone Laboratories in New York City. His thesis has been retrospectively considered to be the most significant Master's thesis of the 20th century, because of the theoretical basis it provided to the electronics and computing industries that grew after the second world war. His later publication 'A Mathematical Theory of Communication'¹⁸¹ was based on the reduction of signals to binary (digital) sequences and facilitated secure communications between Roosevelt and Churchill during the second world war. As a consequence of this work, Shannon was involved at the heart of the field of communications and information theory where he played a very active role in the area until his death in 2001¹⁸².

In the years following the publication of his master's Thesis, Shannon's work was built on by engineering luminaries such as Turing¹⁸³ and von Neuman¹⁸⁴, this work also took place during the

¹⁸⁰ 'A Symbolic Analysis of Relay and Switching Circuits' C. Shannon M.Sc., Massachusetts Institute Of Technology 1937

¹⁸¹ A Mathematical Theory of Communication. C. E. Shannon, Bell System Technical Journal.1949 pp 1-54

¹⁸² 'Claude Shannon: His Work and Its Legacy' Michelle Effros and H. Vincent Poor, EMS Newsletter March 2017 pp 29-34

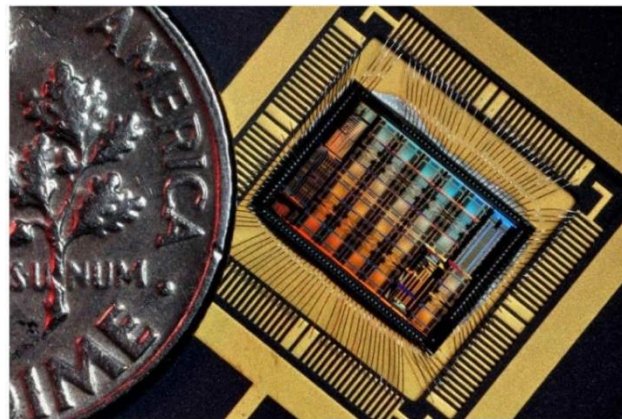
¹⁸³ 'Alan Turing: The Enigma', Andrew Hodges, Vintage Random House, London 1983, Reissued 2014

¹⁸⁴ 'The Legacy of John von Neumann', James Glimm, John Impagliazzo, and Isadore Singer, Editors Proc. Symposia in Pure Mathematics. Volume 50, 1988

Second World War where they created code-breaking and artillery calculations respectively. Ultimately, insights from this work lead to the concept of the stored programme digital computer. The stored programme computer was a system architecture that stored both data and instructions in the same memory system and is essentially the basis for all computing systems today.

The First Computers

The first computing systems that were built using thousands of vacuum tubes which drew massive amounts of current and could only operate for short periods of time. Statistically, any vacuum tube could break down at any moment, especially given the extremely high temperatures that the systems were operating at. There were computers on both sides of the conflict that could all be considered the first in their field, one in the UK (Colossus) which used 1800 vacuum tubes and which was used for breaking the enigma coded messages from intercepts of German radio transmissions and the ENIAC machine which was based in the University of Pennsylvania USA and which was used for performing ballistics range calculations for the military. The ENIAC computer contained nearly 20,000 vacuum tubes, another 100,000 other components and more than 5 Million hand-soldered joints. It occupied 167 m² and consumed 150 kW of electricity¹⁸⁵. It is also rumoured that when the ENIAC was running it caused the electric lights in Pennsylvania to reduce in intensity¹⁸⁶.



Packaged Eniac-on-a-Chip (photo by Felice Macera).

Trustees University of Pennsylvania. All rights reserved, 1998

Figure A2 The ENIAC On A Chip Integrated Circuit in Comparison to a 10 Cent Coin

N.B. In honour of the ENIAC's 50th anniversary in 1996, The University of Pennsylvania sponsored a project named, "*ENIAC-on-a-Chip*", where a very small silicon chip measuring 7.44 mm by 5.29 mm was built with the same functionality and architecture as ENIAC. This chip was many

¹⁸⁵ 'The Brief History of the ENIAC Computer' Steven Levy, Smithsonian Magazine, November 2013

¹⁸⁶ 'Elements of Quantum Computing: History, Theories and Engineering Applications', Seiki Akama Springer, 2015

times faster than ENIAC, and at 0.5 W it draws considerably less power. However, it also exhibits considerably less performance than its contemporary devices did in the late 1990s^{187, 188}.

The German armed forces also had a computer for performing military calculations which was called the Z4 after its inventor Konrad Zuse. This was a computer that was more programmable than the two other computer versions as well as being more general-purpose, it also used electromechanical relays instead of the 2,000 vacuum tubes it would have required if they had been available in wartime Germany¹⁸⁹.

These first computer systems relied on machine programming, assembly language (code) to tell them which operation to perform, how to do it and in what order¹⁹⁰. Assembly code is the lowest-level programming language that is understood by computers and the original machines could only solve one problem at a time. Furthermore, it could take days or even weeks to set-up a new problem because input was based on punched cards and paper tape. Output was displayed on hard copy printouts.

Boolean Algebra

Boolean numbers can be added and subtracted quite simply in a computer because the numbers have been coded into a base 2 representation. Our normal way of thinking about numbers is to use a base 10 scheme because we have ten fingers and we used them to count when we are children¹⁹¹. In a base ten system numbers are put into columns that represent their significance in terms of units, tens of units and hundreds of units etc.

From this table, it is clear how the system works, and this is the basis of our daily mathematical activities

When you add numbers together you add the first column first and move to the left, first adding units then adding tens and then adding 100s etc.

¹⁸⁷ 'Looking Back At ENIAC: Commemorating A Half-Century Of Computers In The Reviewing System' NEERAJA SANKARAN The Scientist, Aug 21, 1995

¹⁸⁸ The ENIAC - History, Operation and Reconstruction in VLSI", J. Van der Spiegel, J. Tau, T. Alailima and L.P. Ang in The First Computers--History and Architectures, MIT Press, eds. R. Rojas, 2000.

¹⁸⁹ 'Computer: A History of the Information Machine', Martin Campbell-Kelly, William Aspray, Westview Press, 2014, pp 41-65

¹⁹⁰ ENIAC in Action: Making and Remaking the Modern Computer, Thomas Haigh, Mark Priestley, Crispin Rope, MIT Press 2016

¹⁹¹ Beyond Base Ten: A Mathematics Unit for High-Ability Learners in Grades 3-6 , Dana Johnson, Prufrock Press 2008 pp 14-21

In a Base 2 (binary) system ¹⁹², numbers are represented by either one or zero and the columns are represented as shown as multiples of the base i.e. 2^n

Number	Number of hundreds (100)	Number of tens (10)	Number of units (0)
9	0	0	9
10	0	1	0
11	0	1	1
99	0	9	9
100	1	0	0
356	3	5	6

Table A1 The Base 10 Counting System

Number	$2^8(256)$	$2^7(128)$	$2^6(64)$	$2^5(32)$	$2^4(16)$	$2^3(8)$	$2^2(4)$	$2^1(2)$	$2^0(1)$
9	0	0	0	0	0	1	0	0	1
10	0	0	0	0	0	1	0	1	0
11	0	0	0	0	0	1	0	1	1
99	0	0	1	1	0	0	0	1	1
100	0	0	1	1	0	0	1	0	0
356	1	0	1	1	0	0	1	0	0

Table A2 Numbers in the Base 2 Representation

The rules for addition of two binary numbers are presented in what is called a truth table.

If A and B are both zero (0) $0 + 0 = 0$.

If A and B are either $1 + 0$ or $0 + 1 = 1$

¹⁹² Beyond Base Ten: A Mathematics Unit for High-Ability Learners in Grades 3-6, Dana Johnson, Prufrock Press, 2008 pp 51-65

If A and B are both (1). $1 + 1 = 10$ (which is binary for 2)

To illustrate this process the addition of two binary numbers from the above table is shown in Table 3 below.

	256	128	64	32	16	8	4	2	1
A = 9	0	0	0	0	0	1	0	0	1
B = 356	1	0	1	1	0	0	1	0	0
A+B = 365	1	0	1	1	0	1	1	0	1

Table A3 Adding Two Binary Numbers

This indicates the process used to convert numbers into useful functions in a computer and, also indicates how it can become possible to create a circuit which implements the adding process using the truth table shown above. There are also circuits for subtraction, multiplication (which is adding a number to its-self multiple times) and division (which is simply subtracting a number from its-self multiple times). In their electronic environment these numbers are now represented by a series of switches which are either open or closed (1 or 0). This type of calculation is typically performed on eight, sixteen or more currently thirty two-bit words where the numbers are loaded into ‘registers’. These streams of data are loaded sequentially, and mathematical functions are performed on the data stored in the registers. Manipulation of binary data using machine code is the lowest level of programming that can be performed on a computer. More advanced computer languages provide a user interface to the programmer which operates at a higher level and facilitates directly addressable operations. This is a great advance and replaced the need to use the binary representation of instructions to be performed on the data.

The First Transistor

In the 1950s the first germanium based bipolar transistor was demonstrated by Bardeen, Brittain and Shockley¹⁹³. This device was developed in Bell labs while they were attempting to understand the way that charges move in a doped semiconducting material¹⁹⁴. The wires in Figure A3 provide the bias of the substrate which was the major current-carrying region and a third wire was a probe which could

¹⁹³ ‘Crystal Fire: The Invention of the Transistor’ Michael Riordan, Lillian Hoddeson, Sloan Technology Series 1998 pp 1-28

¹⁹⁴ Electronic Properties of Doped Semiconductors, B.I Shklovskii, A.L. Efros, Springer Series in Solid State Sciences 1984

detect the current flowing in the germanium at different positions. When they tried to apply a bias to the probe, they found that it resulted in a modulation of the current passing between the other two terminals with a gain of up to 100 being observed. The development of the understanding of how this device operated and the subsequent technological developments which built on this discovery from other companies such as Texas Instruments and Fairchild, lead to the emergence of a microelectronics industry which is now one of the most profitable industries at a global scale^{195,196}.

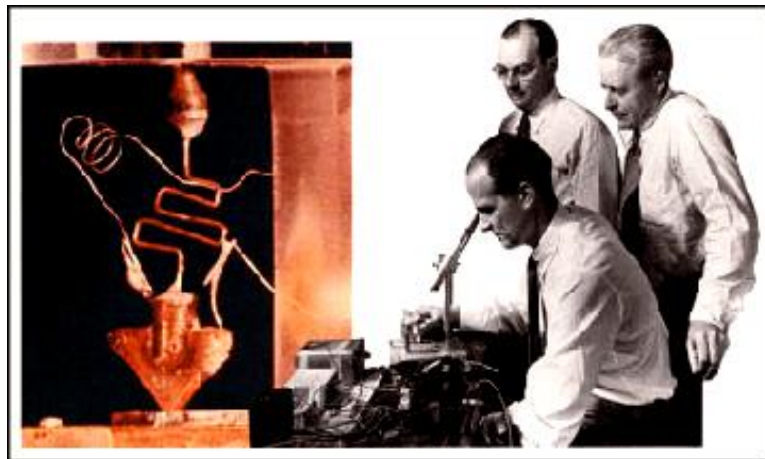


Figure A3 Bardeen, Brattain and Shockley With Their Transistor Invention

The first transistor was a single entity, which could replace a single vacuum tube and the next generation of computers which appeared, utilised single transistors as direct replacements for the vacuum tubes that were used previously. This made the systems considerably smaller but not much less power-hungry and they still generated enormous amounts of heat which is deleterious to transistor operation. They also exhibited millions of hand-soldered joints on circuit boards which were a significant reliability hazard. There was a very short period (from 1956 to 1963) where individual transistors were sufficiently manufacturable and well understood to be able to be used to replace vacuum tubes reliably in these sophisticated computer systems. In this time period more high-level languages, which used words instead of sequences of 1's and 0's were used to programme the computers.

Integrated Circuits

It also became very obvious that joining large numbers of these individual transistors into a single substrate or integrated circuit would have enormous beneficial effects over the discrete transistor technologies that were available at the time. The shift from germanium to silicon, the creation of a

¹⁹⁵ 'History of Semiconductor Engineering', Bo Lojek, Springer 2006

¹⁹⁶ 'Chips and Change: How Crisis Reshapes the Semiconductor Industry', Clair Brown, Greg Linden MIT Press 2019

surface isolation technology¹⁹⁷ and the invention of the metal oxide semiconductor field-effect transistor (MOSFET)¹⁹⁸ were all innovations which enhanced the potential of the technology by orders of magnitude in terms of the ability to mass-produce systems that were considerably smaller as well as highly reliable and more physically robust systems than those used up to that time.

The third generation of computers (1964-1971) was based on integrated circuits in which individual transistors were fabricated at the same time and in the same substrate¹⁹⁹. This capability dramatically reduced the space taken up by individual circuits and replaced many of the hand soldered joints with a single metal film which contacted all of the devices simultaneously and removed the electrical resistance of each soldered joint from the current paths in the circuit²⁰⁰. Furthermore, as a result of the considerable space-saving and integration of whole functions onto a single piece of semi-conducting material, the use of integrated circuits also facilitated much more effective cooling systems and the combination of these features enabled much smaller and more reliable systems to be created²⁰¹.

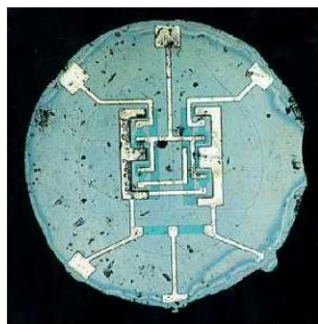


Figure A4 The First Commercially Available Integrated Circuit

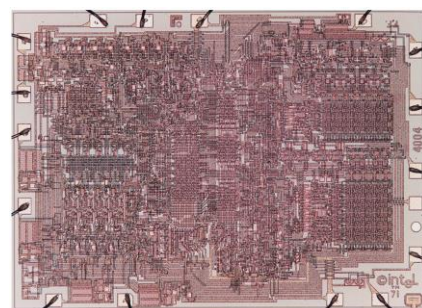


Figure A5 The Intel 4004 Microprocessor Integrated Circuit Layout 1971

The fourth generation of computers (1972-2010) became available when specialist computing chips built in a single substrate became available. These microprocessors used the integrated circuit technology described above to create a general-purpose computing capability in which a central processing unit (the calculation registers described above), memory and the input and output controls were all fabricated on the same integrated circuit. The Intel 4004 was the first microprocessor²⁰², It was built in 10 micrometre PMOS technology and contained 2250 transistors in a 12mm² single chip.

¹⁹⁷ 'History of Semiconductor Engineering', Bo Lojek, Springer 2006 pp 321-326

¹⁹⁸ 'History of Semiconductor Engineering', Bo Lojek, Springer 2006 pp 321-326

¹⁹⁹ 'To the Digital Age: Research Labs, Start-up Companies, and the Rise of MOS Technology', Ross Knox Bassett. JHU Press 2003

²⁰⁰ 'Fundamentals of Microfabrication: The Science of Miniaturization, Marc J. Madou, CRC Press 2002

²⁰¹ 'The Chip : How Two Americans Invented the Microchip and Launched a Revolution', T.R. Reid Random House, 2001 pp 1-25

²⁰² <https://www.intel.com/content/www/us/en/history/museum-story-of-intel-4004.html> accessed 13/11/2019

The 4004 paved the way for successive generations of progressively more and more powerful computing capabilities. This ultimately moved the scale of the computer from something stored in a big room and which caused power losses across a large city when operating, to something that could be held in the palm of the hand and could be run on batteries. Microprocessors could also work faster and solve more complex problems than their predecessors. This also moved the control of the computer away from highly trained engineers and scientists towards the scientific layman.

The increased computing power of these micro-processing units and the control of input/output devices also meant that they could be linked together to perform tasks in parallel which further reduced the time required to perform certain calculations. This ability also leads to the ability to create networks of computers and established interfacing protocols which facilitated the birth, growth and rapid evolution of the internet.



Figure A6a The First Computer Mouse

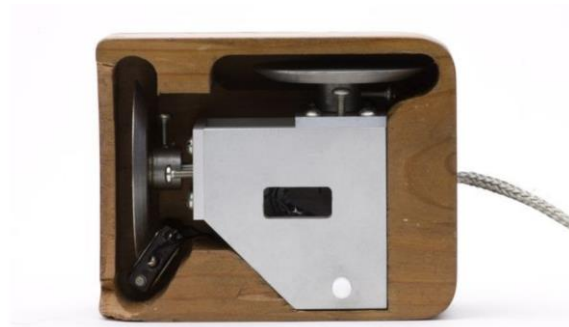


Figure A6b The Underside of the Engelbart Mouse

Other major advances at the time included 'the mouse', the graphical user interface and the ability to shrink highly performant computer systems into portable and laptop formats²⁰³. Other electronic aids such as Personal Digital assistants (PDAs) and mobile telephony also evolved from the capabilities involved in the creation of integrated circuit technologies.

Moore's Law

The first integrated circuits demonstrated to visionaries in the industry that very high levels of functionality could be created using this technology. This led to Gordon Moore from Intel Corp espousing his law for how the industry could grow over time based on research technology advancements and ever-growing financial investments ²⁰⁴. However, Moore's law is not an actual law of nature, it is a statement of intent as to how the microelectronics industry could grow by doubling

²⁰³ *Inventing Modern America: From the Microwave to the Mouse*, David E. Brown, The MIT Press, 2003

²⁰⁴ "Cramming More Components onto Integrated Circuits," *Electronics*, pp. 114–117, April 19, 1965

the number of transistors in a given area, every two years. This ‘more or less’ linear progression started in 1970 with about 2000 transistors and has now ended up at a stage where a typical microprocessor chip could contain between 10 and 50 billion transistors. The kinks in the curve relate to times when fundamental ‘physical’ limits were reached, and new technologies had to be invented so that the industry could stay on the curve. At the times, that these kinks occurred, very expensive innovations requiring billions of dollars of research were needed to overcome the obstacles encountered. The fact that the curve is now starting to tail off and flatten is testament to the fact that the cost of innovations in the semiconductor industry has now become incredibly expensive. The major driver for the scaling of technologies has been the lithography tools that permit the production of very fine (< 10nm dimensions) reliably and uniformly across a 400 mm silicon wafer. The tools that will print and create the next generations of technology use extreme UV light (wavelength 13.5nm) and can cost as much as a commercial airliner to purchase and install²⁰⁵. Furthermore, the running costs for these systems are so large that using them dramatically increases the cost per chip even though they have almost doubled (x1.778) the amount of silicon that can be processed at one step when moving from 300 to 400 mm diameter wafers.

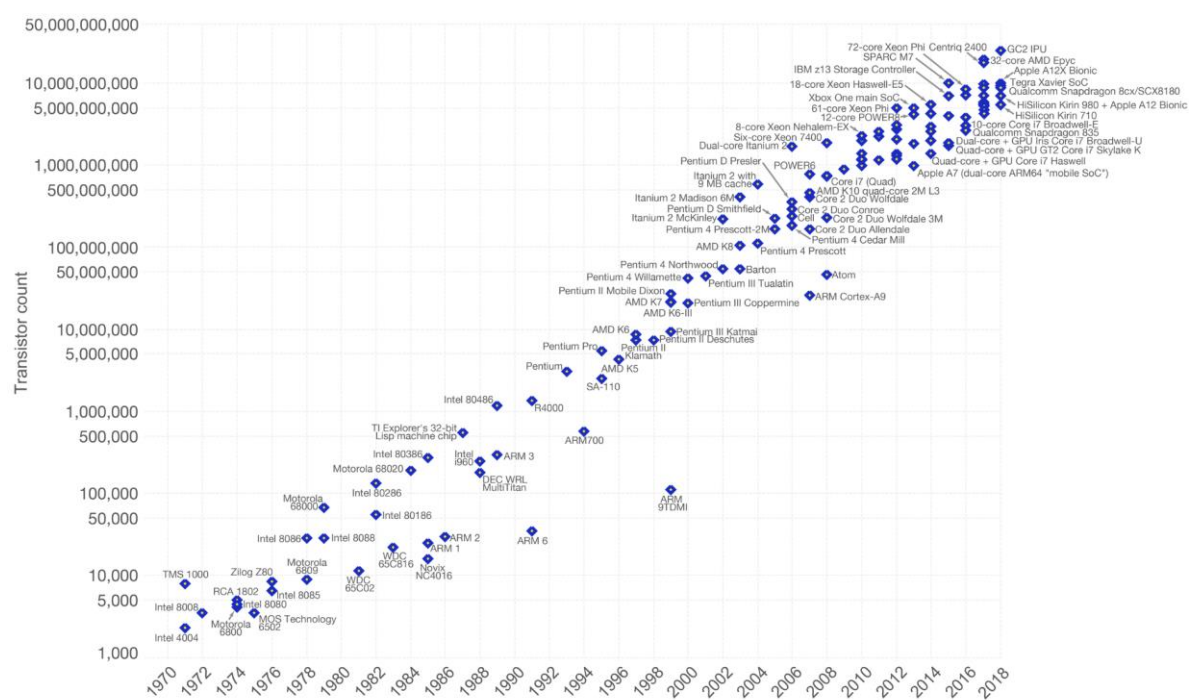


Figure A 7 A Version of the Moore's Law Curve. Showing chipsets and their Associated Transistor counts and a function of time since 197 (This Curve Was Produced by Max Rosser)

The cost of building a silicon chip fabrication area for the current technology nodes has increased to approximately \$5b from \$2b for the last generation and future outlays could be as much as \$20b for

²⁰⁵ 'Extreme Ultraviolet Lithography', Banqiu Wu (Author), Ajay Kumar McGraw Hill 2009

sub 5nm technologies²⁰⁶. It is hardly surprising that the rate of progress in trying to adhere to Moore's Law is starting to plateau because of these costs and the bigger problem is that all of this technology capability is being driven towards the creation of servers, laptop computers, tablets and phones with ever-increasing capacity and functionality. The growth in demand for these technologies is also slightly diminishing and the industry is looking to find other uses for its capacity. However, it is also clear, from the graph, that current generations of microprocessors and associated device systems can contain in excess of 30 Billion transistors. Which is dramatic progress from the 2000 transistors exhibited by the Intel 4004 over the last 40 years.

The Internet

The origins of the Internet date back nearly 40 years, with the U.S. government funding of a research network Advanced Research Projects Agency Network (ARPANET) in 1969^{207 208 209}. ARPANET was an early packet switching network and the first network to implement the TCP/IP protocol (Transmission Control Protocol/Internet Protocol) suite²¹⁰. Packet switching is a method for transmitting a message or data from one computer to another across a network. In a packet-switching network the message to be sent is broken into several pieces (packets) which include a 'from' address a 'to' address and a payload (the payload is the data to be transmitted) if the data in the payload is too large for one packet, the data is broken into several packets, each with its own 'to' and 'from' header and the order is noted. Packets are sent into the network and move from router to router, taking differing paths depending upon traffic at any router at any given time. This means that every packet moves at a different speed through the system and when they arrive at their destination they are stored and re-ordered and made available to the recipient when the message is complete. A message is then sent back to the sender to say that the information has been received. These technologies became the technical foundation of the internet.

The Internet is an interconnected network of private, public, academic, business, and government networks, that are all linked by a broad array of electronic, wireless, and optical networking technologies. The Internet carries a vast range of information resources and services, such as inter-

²⁰⁶ <https://www.theinquirer.net/inquirer/news/3018890/tsmc-says-3nm-plant-could-cost-it-more-than-usd20bn> Accessed 01/11.2019

²⁰⁷ 'Where Wizards Stay Up Late: The Origins Of The Internet', Katie Hafner, Mathew Lyon, Simon And Shuster Paperbacks 1998

²⁰⁸ 'How the Internet Happened', Brian McCullough. Liveright Publishing Corporation 2018

²⁰⁹ 'The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution' Walter Isaacson, Simon and Schuster 2014

²¹⁰ <https://www.geeksforgeeks.org/tcp-ip-model/> Accessed 11/11/2019

linked hypertext documents and applications of the World Wide Web (WWW), electronic mail, video, telephony, and file sharing.

The linking of commercial networks and enterprises occurred in the early 1990s and this began the transition to the modern Internet. It obviously expanded and exponential growth was observed as more and more institutional, personal, and mobile computers became connected to the network. Although the Internet had been extensively used by academic users since the 1980s, as it grew and generated access to more computers, entrepreneurial interests incorporated the capabilities and services that were available into every aspect of modern life.

The World Wide Web

The world-wide-web²¹¹ was introduced in 1989 and it was a communications protocol, instigated by Tim Berners-Lee and which originated from his work in CERN in the late eighties. CERN is an infrastructure which allows people from all over the globe perform experiments using their particle accelerator systems that they host and maintain. It was Berners-Lees job to help them to perform their experiments and gather their data and, if possible, incorporate their new data into the institutional memory. Obviously, there were also researchers who had also undertaken similar experiments before and their data and reports were available on their computer systems... if they could be accessed. However, this information was often stored in systems that were inaccessible for various reasons and were in data formats and languages that were incompatible with any of the computer systems available within CERN. Between 1989 and 1990 Dr Berners-Lee wrote the software that enabled people to post reports or web pages written (HTML) in Hypertext Markup Language²¹² and post them onto accessible locations on the CERN internal network using the internet as a data transport mechanism. The concept of a Uniform Resource Locator (URL) was introduced which gave identity and location to the web page and links within the HTML code enabled people to move directly to complementary pages, images or text. This meant that people could access information from the web sites of other groups and use their information in a collaborative fashion. This was a big breakthrough for the scientific collaboration aspects of CERN's remit and helped a lot of researchers to avoid the reinvention of the wheel that can occur when people are operating in silos. This ability was shared with the Stanford linear accelerator Centre in 1991 and many more laboratories followed

²¹¹ https://www.youtube.com/watch?v=sSqZ_hJu9zA

²¹² <https://www.techopedia.com/definition/5177/hypertext>

suit. IN 1993 CERN made the very important and significant decision to allow the web to become an open standard for anyone to use²¹³.

Access to the World Wide Web required an interrogation tool which enabled the user to interface the user to system. This tool was called a web browser, and while Berners-Lee had written his own browser, it was not adequate for the expansion of the web to a larger audience. Since Berners-Lee's browser completely facilitated the work that was being done in CERN, CERN were not really interested in developing a more commercial browser. The World Wide Web remained an academic facility until a browser called MOSAIC was developed by the National Centre for Supercomputing Applications in the University of Illinois²¹⁴. MOSAIC was subsequently developed for commercial use by its inventors through an entity called NETSCAPE²¹⁵ and it became was the most used web browser in the mid 1990's. However, NETSCAPE was superseded by Microsoft's NAVIGATOR²¹⁶ which was incorporated into Microsoft's Windows Operating System in 1996 and this effectively killed off the development of web browsers for PC / Windows clients. SAFARI²¹⁷ was released in 2003 and it has acted as the default browser for Apple products through to the current generation of i-phones. In 2008 Google introduced the Chrome browser²¹⁸ and by 2013 Chrome had become the most used browser on a global scale. While these Web Browsers were initially designed for use on computers, they have been adjusted to operate equally well on mobile platforms such as mobile phones and tablets and which are more and more becoming the dominant technology platforms for growth in the area.

The Internet of Things

A further advantage of using transistor technology for the creation of integrated circuits and systems is that not all the transistors that form part of the circuit need to be operated so that they produce a 1 or a 0 at its output. Transistors can also be operated in analogue mode where the output becomes a direct mapping of an input signal and where the value of the output can take any value between the fully on '1' and fully off '0' states. Analogue operation is the basis for a completely different sphere of electronics which relies on the linear operational region of transistors to form amplifiers, comparators and devices which can turn analogue signals into digital (ADC) and ones which can convert digital signals into analogue (DAC). These devices and circuits perform crucial roles in the creation of the

²¹³ 'Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor'. Tim Berners-Lee, Mark Fischetti, Harper Collins 2008

²¹⁴ The Worldwide Web, Mosaic and More Jason J. Manger McGraw Hill 1995

²¹⁵ How the Web was Born: The Story of the World Wide Web, James Gillies, Robert Cailliau, Oxford University Press, 2000

²¹⁶ <https://thehistoryoftheweb.com/browser-wars/> Accessed 12/11/2019

²¹⁷ [https://en.wikipedia.org/wiki/Safari_\(web_browser\)](https://en.wikipedia.org/wiki/Safari_(web_browser)) Accessed 13/11/2019

²¹⁸ 'Google's Chrome Browser is Now 10 Years Old, A Lot Has Changed in a Decade', Tom Warren, The Verge 2018, TheVerge.com Accessed 13/11/2019

digital technologies described above, but they also have niches which are starting to have very large impacts in their own right.

Everything that happens in the world, outside the digital domain, is analogue and time varying. When a sensor is measuring something in real time, its output can take any value that is a function of the input response and this is an analogue signal. Any sensor which measures a process in real time must have an interface which converts the time varying signal into a digital signal so that the computer can perform the necessary calculations to provide an output to the outside world.

Stand-alone sensors built in silicon (and other semiconductor materials) have been studied for almost as long as the transistors that make the majority of digital technologies have. Silicon is a very versatile material because it can be used to make devices which have a linear response as a function of stress, strain, pressure, temperature, magnetic field, mass and radiation dose amongst many more things. Different processes are required to create this linear response, but they are all well documented in the literature ^{Some examples e.g 219,220,221,222,223}. However, all these sensing technologies require an interface circuit to convert the signal from the sensor into something that can be treated by computer and read out. In the past these circuits have been made in discrete circuits and systems which plugged into a more complete system at a later stage. However, the technology has now evolved into a position where fully integrated sensors or stacked sensor systems can be created at the same time as the computer that they use to bias them and read out the output.

The advent of short-range radios and Bluetooth communications protocols, along with the technologies that are used to build the more advanced microprocessor technologies has created a paradigm where sensors can be connected to very small low power radios. These always have the capability to communicate with a host computer in real time and provide direct measurements of specific parameters completely unsupervised. In The IoT each sensor device will have an IP address and each system will be completely autonomous and will send real time data to the host computer continuously. This is the next generation of networked computers in which artificial intelligence (AI)

²¹⁹ 'Silicon Sensors'. S Middelhoek, A. A. Bellekom, U Dauderstadt, P J French, S R in 't Hout, W Kindt, F Riedijk and M J Vellekoop. Measurement Science and Technology, Volume 6, Number 12, 2006

²²⁰ 'A novel silicon Geiger-mode avalanche photodiode', JC Jackson, AP Morrison, D Phelan, A Mathewson, Digest. International Electron Devices Meeting 2002, 797-800

²²¹ 'Rapid amplification for the detection of Mycobacterium tuberculosis using a non-contact heating method in a silicon microreactor based thermal cycler', C Ke, H Berney, A Mathewson, MM Sheehan, Sensors and Actuators B: Chemical 102 (2), 308-31

²²² 'Silicon-Based Sensors for Biomedical Applications: A Review' Yongzhao Xu, Xiduo Hu, Sudip Kundu, Anindya Nag, Nasrin Afsarimanesh, Samta Sapra, Subhas Chandra Mukhopadhyay and Tao Han. Sensors, 19, 2908; 2019

²²³ 'Integrated Avalanche Photo Diode Arrays', A Mathewson PhD, National University of Ireland 1995

will be used in conjunction with measured real time data to make decisions on a broad range of important monitoring processes.

This concept is being called the Internet of Things²²⁴ or Industrie 4.0²²⁵. It is effectively the fourth industrial revolution in which a network of devices will be able to sense their environment and communicate the data that they measure to a different location where the data can be aggregated, and decisions made based on measurements. In the past, if it was available, this data was evaluated by people who understood the process. However, going forward, data will be aggregated by other electronic systems and the sensing systems and the management/decision making roles will be devolved to artificial Intelligence based systems. These systems will have been trained, in the first instance, by experts in the field, but as information grows and confidence in AI approaches develop, AI will grow into a very important role in many organisations. These data-driven decisions are essential in factories because it is impossible to control a complex industrial process effectively without knowing the variability of the product and the reasons for this variability. However, the Internet of Things is not just for the emerging factories of the future. IoT also addresses the ability to continuously monitor patients in hospitals and control their treatment. It will also be able to support and monitor the health of the elderly without them having to leave their homes. It will also be used to streamline deliveries from online shops. It most certainly currently does, and will into the future, provide the necessary control systems for autonomous vehicles.

Smart Phones

Smartphones have irrevocably changed our lives. Mobile internet access allows employees to work from anywhere, while countless apps help people find out how to get places, track their spending, or communicate with people in foreign languages etc. The first cellular telephone call was made in America on April 3, 1973 from Manhattan to Bell Labs in New Jersey. The call was made using a prototype version of the Motorola DynaTAC 8000x which took approximately ten years to reach the market in 1984. However, it was the start of a revolution in communications.

²²⁴ 'IoT Inc: How Your Company Can Use the Internet of Things to Win in the Outcome Economy', Bruce Sinclair McGraw-Hill Education, 2017

²²⁵ 'Shaping the Fourth Industrial Revolution' Klaus Schwab, Nicholas Davis, 2018 World Economic Forum Press 2008



Figure A8 The Motorola DynaTAC 8000x . The First Wireless Telephone 1984



Figure A9 The Motorola DynaTEC 9800x 1989

When it was introduced to the market the 8000x was very heavy (~1Kg) and took ten hours to charge for thirty minutes of talk time. In April 1989 The Motorola MicroTAC 9800x was released and it demonstrated better mobility with a weight of ~500g, and a compact form factor which was designed to fit into a pocket.

In 1994 The IBM Simon phone²²⁶ was released. This unit was the precursor to today's smartphones and although it was bulky, it was equipped with a touchscreen, calendar, address book and email capability. Although this was all available before most people had even heard of the World Wide Web.

²²⁶ 'The Cellphone: The History and Technology of the Gadget That Changed the World', Guy Klemens, McFarland, 2014



Figure A10 The IBM Simon Mobile Phone and Charger 1994



Figure A119 An i-Phone 4S and a Simon Phone Comparison (Science Museum (UK 2014) ²²⁷

However, the true smartphone revolution really started at Macworld 2007, when Steve Jobs revealed the first i-phone²²⁸. All previous phones had relied on keypads and could only navigate a limited version of the internet. The iPhone's large capacitive touchscreen could scroll through websites in the same way as a desktop computer, while looking more elegant and desirable than anything consumers had seen before.

It took both Samsung²²⁹ and HTC²³⁰ several years to come out with truly competitive products to the i-Phone running the Android operating system²³¹. However, extra features have been added to both i-Phone and Android platforms every year since and they now offer equivalent performance. Currently, the Android versions are considered by many to be more popular because of the flexibility of the Android operating system. Worldwide use of mobile phones is now in excess of 5 Billion and we use our mobiles for much more than simply placing phone calls. Mobile phones are used for checking the weather, dating, social media communications, watching movies etc. and the introduction of 5G networks across the globe in 2019-2020 promises faster connections, machine to machine communications (M2M) and the possibility of low latency Virtual/Augmented Reality and smart city infrastructures amongst many other exciting developments.

²²⁷ 'Constant Touch: A Global History of the Mobile Phone', Öñ Kapak, Jon Agar, Icon Books Ltd, 2013

²²⁸ <https://www.wired.com/story/guide-iphone/> Accessed 14/11/2019

²²⁹ <http://www.three.co.uk/hub/brief-history-samsung-phones/> Accessed 14/11/2019

²³⁰ <https://www.pocket-lint.com/phones/news/htc/136934-htc-through-the-ages-a-brief-history-of-htc-s-android-handsets> Accessed 14/11/2019

²³¹ <https://www.digitaltrends.com/mobile/android-version-history/> Accessed 14/11/2019



Figure A13 The Announcement of the i-Phone 20"An iPod, a phone, and an internet communicator. An iPod, a phone ... are you getting it? These are not three separate devices: This is one device, and we are calling it iPhone"²³²

Social Networking

Up until the mid-2000s web use had been mainly restricted to viewing content in a passive manner. However, and as a function of the growth of social media applications, the web has evolved to provide the possibility of users interacting and collaborating in real-time as creators of user-generated content²³³. The user-generated content is emanating from social media sites such as Facebook²³⁴, Instagram²³⁵, Twitter²³⁶ etc and it is creating communities of like-minded people across the globe. Indeed, Donald Trump, the President of the United States of America prefers to use Twitter to make announcements of his intentions than to use the more traditional print media²³⁷, which he feels will

²³² <https://www.businessinsider.com/watch-steve-jobs-first-iphone-10-years-ago-legendary-keynote-macworld-sale-2017-6#he-went-on-an-ipod-a-phone-and-an-internet-communicator-an-ipod-a-phone-are-you-getting-it-these-are-not-three-separate-devices-this-is-one-device-and-we-are-calling-it-iphone-4> Accessed 18/11/ 2019

²³³ The Art of Social Media: Power Tips for Power Users' Guy Kawasaki, Peg Fitzpatrick, Portfolio-Penguin 2004

²³⁴ <https://about.fb.com/company-info/> Accessed 10/11/2019

²³⁵ 'Digital Life on Instagram: New Social Communication of Photography', Elisa Serafinelli, Emerald Group Publishing, 2018

²³⁶ <https://about.twitter.com/> Accessed 10/11/2019

²³⁷ <https://www.diggitmagazine.com/articles/Trump-Twitter-Based-Presidency> Accessed 12/11/2019

not provide him with an unbiased reportage²³⁸. Social media has also created a new generation of professional people who have never been in a situation where there was no internet. Even though the world wide web is only 30 years old, to these people, the internet has always been available. They are a completely different demographic and they also have a completely different relationship with computers and digital media in all its forms to the previous generations. Younger people were also found to have an advanced understanding of technology devices, with six-year-olds having the same level of knowledge as the average 45-year-old²³⁹

Most of these users participate actively in social media. This is essentially the use of the internet and world wide web to create opportunities for sharing personal information to 'like-minded' people in virtual communities. Most of the content is real-time, user generated text, as well as photographs and videos which are presented to the virtual community to elicit comments or responses to their view on the subject matter. Some of the more common social media sites (with more than 1 Billion user accounts) include Facebook, YouTube, Instagram, Twitter, Linked-In, Snapchat, Tinder, Viber and Pinterest. People feel that there are both positive and negative aspects to the use of social media. It can improve a person's feeling of membership of a community or it can drive young people to depression and suicide if misused by anonymous and evil on-line trolls^{240,241}. In conjunction with apparently governing the social lives of many young people, social media is an effective communication and marketing tool²⁴² for businesses, academic institutions and as already indicated, governments.

The average person in the UK is online for 24 hours a week, and this is twice as long as 10 years ago, with one in five of all adults spending as much as 40 hours a week on the web. This is partly due to the rise in use by those aged 16 to 24, who average 34.3 hours a week on the internet and is fuelled by a rise in internet use by those aged 18 to 34 and the explosion in social media. A large part of the surge in time online is attributed to the rise of smartphones, which are now used by 78 per cent of the population compared with just 17 per cent in 2008, the year after the first iPhone was launched.

Many people are now so addicted to smartphone use that they check them every 12 minutes and 40 per cent of adults look at their phone within five minutes of waking up. This figure rises to 65 per cent for those aged under 35 years old. The younger generation is the most addicted. Those aged 15 to 24

²³⁸ https://twitter.com/realDonaldTrump?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor accessed 13/11/2019

²³⁹ <https://www.bbc.com/news/technology-28677674> Accessed 14/11/2019

²⁴⁰ https://www.huffingtonpost.co.uk/2014/07/25/social-media-mental-health_n_5619728.html?ir=UK+Tech&guccounter=2 Accessed 14/11/2019

²⁴¹ <https://www.standard.co.uk/lifestyle/health/two-thirds-of-schoolchildren-would-be-happy-if-social-media-didn-t-exist-study-reveals-a3651251.html> Accessed 14/11/2019

²⁴² <https://www.wordstream.com/social-media-marketing> Accessed 14/11/2019

on average spend four hours a day on the phone compared with 2 hours 49 minutes for all adults. The young also check their phones every 8.6 minutes, which is considerably more often than any other age group and this can create friction, stress and disruption to personal and family life²⁴³. Furthermore, for many people, being online has negative effects. Fifteen per cent of the people polled in an Ofcom report²⁴⁴ say it makes them feel they are always at work, and more than half (54%) admit that connected devices interrupt face-to-face conversations with friends and family. More than two in five (43%) also believe that they are spending too much time online²⁴⁵.

Social Media is clearly a source of information and for many people it can be the only source of news that they look at. This is quite disconcerting, because the information available on social media has no requirement to be true (although the intention when the world wide web was established was to include only content that was genuine and truthful²⁴⁶). This phenomenon of unfiltered propaganda and abuse being broadcast by oblivious social media platforms has had some high-profile impacts over the last few years and has effectively destabilised the democratic process in the USA as well as the UK and many other countries^{247 248}. Personally, I fail to see how this can be reversed without introducing some form of censorship or editorial process for content into the system. Certainly, the owners of these social media applications need to take some responsibility for the uses that their software are put to, if democracy is to survive into the next decade. There are steps being taken to address this situation from a web management perspective²⁴⁹ but there are many vested interests in this situation and these solutions may be difficult to implement, without compromising commercial revenues etc.

The internet is all pervasive now and there is no transaction that can be performed without recourse to some form of digital technology. There are large numbers of professions that have transformed or virtually disappeared since the turn of the century and this is all attributable to the digital era. The internet has changed the way we buy goods and services, it has transformed the way we travel, it has provided almost immediate access to publications for academics and it has transformed businesses and the way that products are designed, prototyped, pitched, fabricated demonstrated, marketed and sold at every point on the value chain between these milestone activities.

²⁴³ <https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/decade-of-digital-dependency> Accessed 14/11/2019

²⁴⁴ <https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/decade-of-digital-dependency> Accessed 14/11/2019

²⁴⁵ Ambient Commons: Attention in the Age of Embodied Information, Malcolm McCullough, MIT Press 2013

²⁴⁶ <https://www.vanityfair.com/news/2018/07/the-man-who-created-the-world-wide-web-has-some-regrets> Accessed 14/11/2019

²⁴⁷ 'The Big Hack', Netflix 2019 Accessed 12/11/2019

²⁴⁸ 'Facebook's Role in Brexit — and The Threat to Democracy', Carole Cadwalladr TED-Talk California 2019

<https://www.youtube.com/watch?v=OQSMr-3GGvQ> Accessed 14/11/2019

²⁴⁹ <https://qz.com/1618993/tim-berners-lee-thinks-we-can-still-fix-the-internet/> Accessed 14/11/2019

We are very much in the digital age now and as with every step in the evolution of industry, once everybody has the concept and is working with it, new visionaries need to step forward and identify what happens next. To quote the Accenture Post Digital Technology Vision²⁵⁰;

‘Just as people no longer say that they live in the ‘age of electricity’ the days of calling something ‘digital’ to insinuate that it is new and innovative are numbered’.

Every technology advance follows the pathway of discovery, engineering, and transformation before becoming completely absorbed into society. Today, digital technology has transformed much of our world, but soon there will be no need for companies to make statements about being a ‘digital business’, because if they are still in business, they will have found a way to make the digital world work for them. As digital technologies and applications mature, we need to push new frontiers of discovery. This means we need to start preparing for a new era of innovation, one in which technologies such as Artificial Intelligence (AI), Genomics, Virtual and Augmented Reality, Quantum Computing, Internet of Things and Robotics rise to the fore. All these use digital technologies as a platform on which to develop and which will drive innovation in the digital world. Just as we still use heavy industry but no longer say we live in the Industrial Era, in the future, we will still be using digital technologies, but we will be using them in new ways and for yet unknown applications.

Since most companies have now embraced some form of digital model for how they run their businesses, it is time to consider where the next industrial revolution is coming from. Over the last ten years digital businesses have been created on top of the platform that has historically been provided due to the massive strides that have been made in computing, data management, financial planning and user interfaces to the world wide web provided by digital technology.

The use of Digital capabilities has made companies more efficient, more cost effective and more accessible to its client base than ever before²⁵¹. There is now no enterprise that does not have a digital interface somewhere in its make-up or its value chain and this means that the differentiation that being a digital company has provided to their investors is diminishing because now all companies can be considered digital. The companies that have embraced digital technologies have developed personalisation strategies which customise their products to the customer base and provide on demand digital services. In the next few years companies will address more and more personal requirements and the concept of a ‘market of one’²⁵² will become established as a business model for companies going forward.

²⁵⁰ https://www.accenture.com/_acnmedia/pdf-94/accenture-techvision-2019-tech-trends-report.pdf Accessed 10.9.2019

²⁵¹ <https://voxeu.org/article/challenges-digital-age> Accessed 20/11/2019

²⁵² ‘Marketing Strategy: Based on First Principles and Data Analytics’, Robert W. Palmatier, Shrihari Sridhar Macmillan Press 2017

Companies have not been alone on the path to digital transformation. The global population has taken the journey with them where they absorb new business practices and technologies at an ever-increasing rate. When mobile phones were first introduced in the 1980s it took more than twelve years to reach 50 Million users, the internet only took seven years to reach the same position. Social media platforms have demonstrated even more remarkable growth in their user bases, with facebook taking four years, WeChat one year and Pokemon GO, only nineteen days²⁵³.

People are absorbing digital technologies very rapidly and they are becoming very savvy about what they will and will not accept from their suppliers. This is forcing companies to take much more notice of what their customers need and how they want it implemented. However, this feedback provides market intelligence and is providing tremendous insights into the way their markets are proceeding with regard to what the customer wants and how to grow their products to forge new market opportunities.

The rapid pace of development of digital technologies is almost forcing individuals and companies to value continuous professional development (CPD). Retraining is necessary as job functions disappear to be replaced by new and exciting opportunities. The argument that factory automation will impact on jobs and employment has been going on for decades²⁵⁴. In advanced economies, artificial intelligence and automation are poised to transform established roles in every sector. Algorithms are writing reports, designing financial service flows, delivering purchases and responding to customer inquiries. These tools are fundamentally changing the way that we work and how it is organized, impacting everything even those including the most specialized and human-intensive occupations. This need for training and re-training as well as Life-Long Learning LLL²⁵⁵ needs to be recognised in every industrial sector. Governments need to become involved to ensure that this happens appropriately and with sufficient rigour to support rapidly changing skills requirements in the world of work²⁵⁶.

We are not at that point yet, but companies with a post digital vision are looking to transform their way of doing business to make it highly personalised and more efficient. They are looking to build strategic alliances with synergistic companies to create more holistic enterprises. One example of this kind of development is Swiss Post's use of drones and flight systems from Matternet²⁵⁷ (a US drone and flight system supplier) to transfer urgent laboratory samples between two different hospitals in

²⁵³ <https://www.visualcapitalist.com/how-long-does-it-take-to-hit-50-million-users/> Accessed 21/11/2019

²⁵⁴ 'Rise of the Robots: Technology and the Threat of a Jobless Future', Martin Ford Basic Books 2016

²⁵⁵ 'Adult education and lifelong learning, Theory and Practice' Peter Jarvis, Routledge 2010

²⁵⁶ <https://www.politico.eu/sponsored-content/skills-are-more-important-than-ever-in-the-digital-age/> Accessed 201/11/2019

²⁵⁷ <https://mttr.net/> Accessed 25/11/2019

Lugano, Switzerland. In this collaboration each partner has its own expertise and capability. When they join their efforts together to a common purpose a new product concept becomes available²⁵⁸ which benefits humanity and improves global cooperation.

The post digital world is one where technologies can be aggregated to provide new business concepts and where companies can engage with their user communities to look for advantages and benefits for the future. A further example of this is in the area of clothing purchases from the web. There is a large disparity between what constitutes clothing sizes in different countries and the fact that our bodies are all different shapes means that all clothing is built for the median demographic. However, it is now possible to log your personal dimensions through an app on your smart phone so that you can purchase custom made clothing. This takes less than two weeks to create and deliver and is guaranteed to fit when you get it. Figure A15 illustrates the concept which comes from a new Japanese company Zozotown. When you sign up to the ZozoTown website, they send you a registration garment (a black spandex ZOZO Suit which has about 200 fiducial markers on it). When you receive the garment, you put it on and scan yourself with your smartphone. This creates a digital avatar and registers your critical dimensions. This in turn, enables the customer to try on clothing before it is made and make appropriate adjustments according to their taste and style requirements. The company then use their automated clothing factories to create bespoke (custom) clothing for individuals which fit the user exactly²⁵⁹.

²⁵⁸ <https://www.vox.com/2017/3/31/15133070/swiss-post-autonomous-drones-delivery-matternet> Accessed 21/01/2019

²⁵⁹ <https://www.racked.com/2018/7/3/17530830/zozotown-custom-clothes-zozosuit> Accessed 21/11/2019



Figure A15 The ZoZoSuit and What it Facilitates

Digital Platforms.

In the last decade with the Digital Revolution in full swing, a number of technology capabilities have been created which were ‘unheard of’ at the turn of the century; but are now so indispensable that people cannot imagine living without them. The mobile phone and smart phone have facilitated most of these developments. There is now a word that describes a fear of being separated from your smart phone; nomophobia, from which most of us to at least some extent suffer.

From a recent survey by the UK government²⁶⁰ it has been established that nine out of ten British people now own a smartphone and a substantial proportion (80%) of them would feel at least uncomfortable at the prospect of not having their phone for a single day. Most of the reasons for this disquiet stem from a fear of being uncontactable or from being incapable of contacting family or friends. Indeed, eighty percent of the 18-34 age group would feel weird because they would not know what to do. Furthermore, one in five smartphone users (19%) also said they would be anxious about not checking their emails for a day. SnapChat and Instagram users are most likely to feel uncomfortable at the loss of their phone, at 30% and 27% respectively. Twitter users were similar, with one in four (23%) saying they'd feel uncomfortable being away from their feed for a day.

Social Media

Despite having thousands of contacts through Facebook and Instagram, young people who use these social media platforms actively have been demonstrated to have very low levels of empathy, are unable to relate to others easily, are afraid of intimacy and seem to consider that their 'on-line' life trumps all other modes of social contact²⁶¹. In particular, it should be noted that difficult interactions between parents and children in this generation seem to be dominated by smart phone use. This is really a bone of contention on both sides of the generation gap. It is particularly evident at meal-times when both parents and children feel aggrieved at the lack of respect given to them because one protagonist or another's attention is devoted to their mobile phone²⁶².

This not only happens in the home. Businesses also suffer from a lack of attention from their employees and it has been shown that the presence of a mobile phone on a meeting table extends the time from about three to seven minutes when serious conversations start to happen. This is attributed to the fact that people are waiting for the phone to ring, and they do not want to start a 'heavy' conversation if it is going to be interrupted. It is also a feature of modern life that there is a 'rule of three' that applies when four or more young people are meeting or eating together. This rule suggests that if more than three people are talking together, it is socially acceptable to look at your phone for social media updates²⁶³. Furthermore, meetings seem to be the place when many people tend to deal with their e-mail overload and meetings could be considerably shorter, if people were devoting their entire attention to the proceedings. There are now some companies

²⁶⁰ <https://yougov.co.uk/topics/technology/articles-reports/2019/03/08/could-you-live-without-your-smartphone>
Accessed 21/11/2019

²⁶¹ 'Alone Together – Why We Expect More from Technology and Less From Each Other', Sherry Turkle. Basic Books 2011

²⁶² 'Reclaiming Conversation The Power of Talk in the Digital Age'. Sherry Turkle Penguin Press 2015

²⁶³ 'Reclaiming Conversation - The Power of Talk in the Digital Age'. Sherry Turkle Penguin Press 2015 pp 27-28

and universities which forbid laptops and mobile phones in meeting rooms and lecture rooms to ensure more attention from the participants^{264,265,266}.

Notifications from mobile phones (push notifications) are also a distraction. It is part of the business model for social media companies to have you look at your phone as often as possible so that you are exposed to advertising and stimulate revenue for the company²⁶⁷. In 2016 Deloitte found that people are looking at their phones 47 times a day on average and for young people this figure rises to 82²⁶⁸. As a function of all this attention sapping digital noise, it has been proposed by many people²⁶⁹ that it is important to impose a digital detox into their lives²⁷⁰. Uninstalling social media apps is one way to do it, but even leaving the phone out of the room or making a special charging place for phones outside the bedroom can help with this.

From all this data it can be inferred that the providers of digital solutions have established gigantic networks of highly connected people who use mobile communications to keep in touch with each other²⁷¹. However, they generally also share their experiences, as well as finding new employment opportunities and new romantic interests amongst many other things²⁷². Furthermore, as indicated above, people who participate in these networks are also very attached to their smart communications devices and look at them constantly, sometimes to their detriment. This creates opportunities for new businesses to advertise their wares and provide services which had heretofore not been available²⁷³.

The Cloud

The advent of the cloud²⁷⁴ as a provider of on demand computing resources, data storage mechanisms and new service models has also enormously enhanced the digital age. For the last ten years people have not needed to store all their data on their local drive, because they can now store it remotely and access it through their internet connection. However, I have found that

²⁶⁴ <https://blog.percolate.com/2014/06/6-meeting-rules-of-percolate/> accessed 28/11/2019

²⁶⁵ <https://www.vox.com/2014/6/4/5776804/note-taking-by-hand-versus-laptop> Accessed 28/11/2019

²⁶⁶ <https://www.forbes.com/sites/work-in-progress/2014/06/05/how-to-get-people-off-their-phones-in-meetings-without-being-a-jerk/> Accessed 22/11/2019

²⁶⁷ <https://www.wired.com/story/turn-off-your-push-notifications/> Accessed 22/11/2019

²⁶⁸ <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-global-mobile-consumer-survey-2016-executive-summary.pdf> Accessed 22/11/2019

²⁶⁹ Digital Minimisation, Cal Newport, Portfolio/Penguin/Random House publishers. 2019

²⁷⁰ <https://www.digitaldetox.com/> Accessed 22/11/2019

²⁷¹ 'Being Digital', Nicholas Negroponte Vintage 1996

²⁷² 'Advantages of Social Media', Bruce Hopkins Academia Apps (<https://www.academiaapps.com/>) Accessed 21/11/2019

²⁷³ 'The Extended Mind' Andy Clark and David Chalmers, Analysis, Vol. 58, No. 1 January 1998, pp. 7-19

²⁷⁴ 'Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS)', Michael J. Kavis, Wiley, 2014

it is probably worth storing data locally if you have the capacity. The cloud is essentially what has become of the internet. It is a massive collection of servers distributed across the world, normally in places that are intrinsically cold for most of the year, like Ireland²⁷⁵ and Greenland²⁷⁶, because it saves on cooling in the server farms. This allows people to store their documents and data, run services and licence access to software without having to buy and maintain it. The web can also be made available on a server that is connected to the internet through a router to run proprietary programmes and provide services to businesses across the globe. There are many business models that are used in dealing with 'the cloud' and access is monetized in many ways.

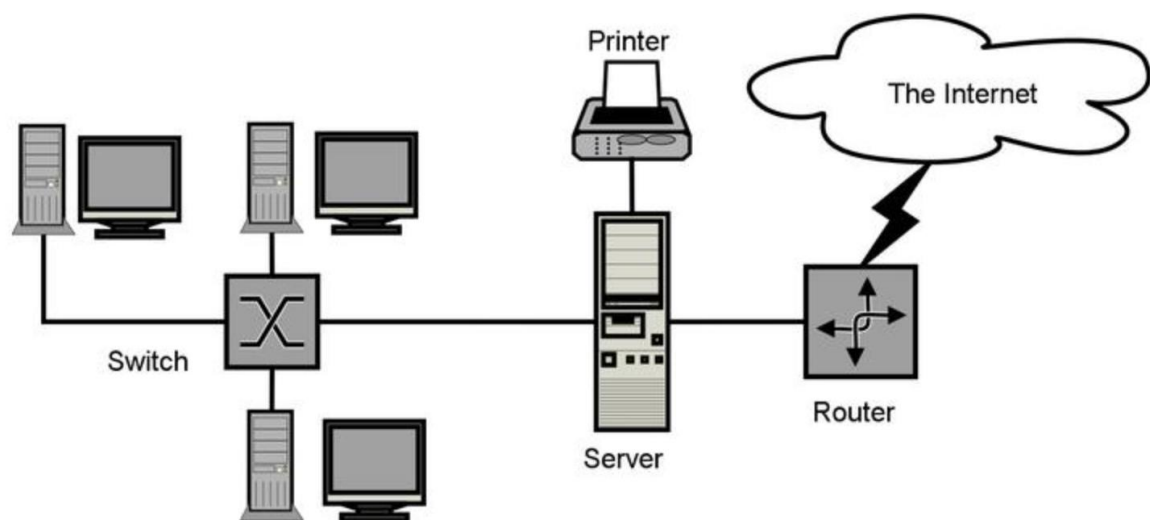


Figure A16 Where 'The Cloud' Fits into a Local Network²⁷⁷.

Some businesses choose to implement Software as a Service (SaaS), where they subscribe to an application that is hosted and accessed over the internet. 'Salesforce' is an example of such an approach. 'Salesforce' access allows companies to store and access customer records and perform opportunity logging and progress tracking on business leads as well as running data analytics on marketing and advertising campaigns²⁷⁸. Some companies can build a platform in the cloud for its own applications to run on and which is accessible to everybody in the company. This is called 'Platform as a Service' (PaaS)²⁷⁹. PaaS vendors provide hardware and software tools over the internet, and people use these tools to develop applications^{e.g. 280}. PaaS users tend to be developers of applications who

²⁷⁵ <https://www.siliconrepublic.com/enterprise/data-centre-network-ireland> Accessed 25/11/2019

²⁷⁶ <https://www.theguardian.com/environment/2016/dec/23/climate-change-in-greenland-adaptation-we-simply-refuse-to-be-victimised> Accessed 25/11/2019

²⁷⁷ <https://uk.pcmag.com/networking-communications-software/16824/what-is-cloud-computing> Accessed 21/11/2019

²⁷⁸ <https://www.salesforce.com/uk/products/> Accessed 22/11/2019

²⁷⁹ 'Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS)', Michael J. Kavis, Wiley, 2014 pp1-20

²⁸⁰ <https://www.avanade.com/> Accessed 22/11/2019

do not want to invest time and effort in all the necessary infrastructure for their requirements, but they lease already equipped space, technology capabilities and computer infrastructure. This is the equivalent of renting a venue for a concert rather than building one from scratch and working out what to do with it after it is built, and the concert has taken place. However, the most significant model and the one that we can relate to most is called Infrastructure as a Service (IaaS) where companies like Amazon, Microsoft and Google provide a platform that can be rented to other companies. For example, Netflix is a client of Amazons cloud service²⁸¹.

All cloud applications need an Internet connection at some point, but not all require a constant connection and some applications even offer an 'offline' mode for use anywhere. In this case it is only necessary to go online when you want to 'sync' the files you have been working on back to the cloud. Furthermore, there are a lot of cloud services which do not depend on a fast internet connection, although the connection speed obviously affects how quickly you can download and upload files.

Analytics and Artificial Intelligence

Building Artificial Intelligence (AI) into business decision making processes has now started to happen because of the access to data that is provided in the cloud²⁸². This access to data and the analytics that are now possible on that data is driving businesses forward based upon knowledge, backed up by measured data, rather than gut feelings which used to happen in the past. Furthermore, those companies that have adopted and embraced the use of AI and data analytics have experienced more growth than those who have not made that step yet²⁸³. Key issues of ownership of personal data, and it's use, are now emerging as key issues in the further development of these important capabilities. The public need to know what and how much of their data is being used. This is creating ethical dilemmas in companies who use data from the cloud to understand their markets and the algorithms that are used to make decisions.

There has recently been a controversy that illustrates this point very well. Some of the newly introduced Apple Card²⁸⁴ customers have announced that the credit card's issuer, Goldman Sachs, is giving women far lower credit limits, even if they share assets and accounts with their spouse²⁸⁵. Goldman Sachs deny the bias²⁸⁶ but the empirical evidence is there, and even Steve Wazniak, an Apple

²⁸¹ 'From Networks to Netflix, A Guide to Changing Channels', Edited by Derek Johnson, Routledge, 2018

²⁸² 'Pragmatic AI: An Introduction to Cloud-Based Machine Learning' Noah Gift, Addison Wesley Data & Analytics 2019

²⁸³ 'The Fourth Age: Smart Robots, Conscious Computers, and the Future of Humanity' Byron Reese Astria Books 2018

²⁸⁴ <https://www.apple.com/apple-card/> Accessed 22/11/2019

²⁸⁵ <https://www.bloomberg.com/news/articles/2019-11-11/apple-card-s-ai-stumble-looks-familiar-to-old-school-banks> Accessed 22/11/2019

²⁸⁶ <https://techxplore.com/news/2019-11-goldman-sachs-ceo-gender-bias.html> Accessed 22/11/2019

co-founder found that his credit score was ten times larger than his wife's even though they share assets and accounts. The explanations for this from Goldman Sachs are rather vague, but it is clear that more transparency into the algorithms that are used to make these decisions need to be made accessible or the technology will become discredited. Incidentally, this is also an example of the new kind of collaborations mentioned above and facilitated by the requirements to grow the digital market influence where new non-traditional partnerships are being forged to create new businesses.

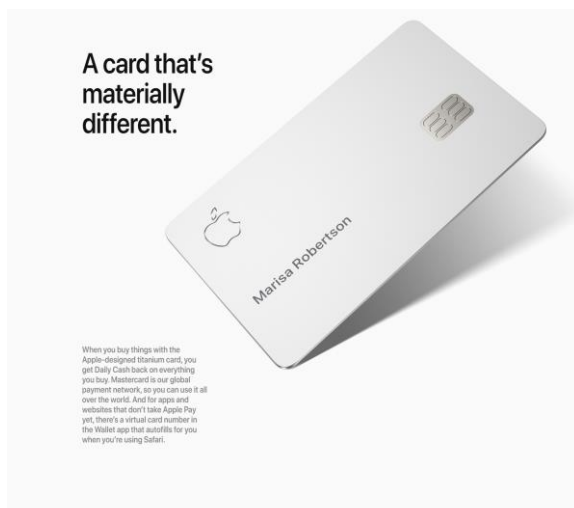


Figure A17 The Apple Credit Card

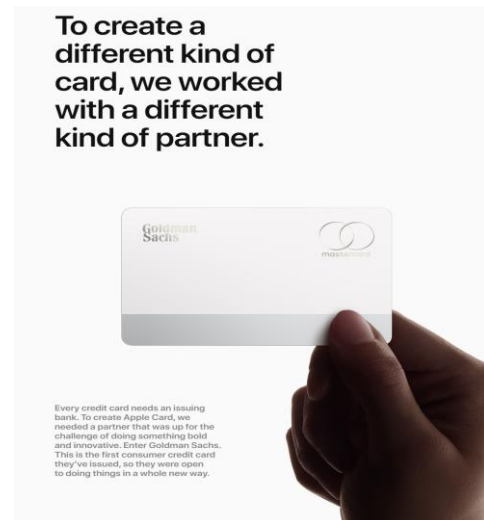


Figure A18 The Synergistic Partner Collaboration

The Post Digital Era

The world is moving into a post-digital era. Companies with large technology portfolios are moving towards shaping the way that governments, business partners, employees and their customer base, interact with the world through their technologies. New technologies will be required and some of them will be incremental improvements of what has gone before. There will also be completely new technology offerings which are currently still at the research stage but haven't really broken out into the mainstream. However, both will be required to change the marketplace and ensure the take up of post digital systems. Admittedly, all these technologies will be built on digital technology platforms, but the direction that they will take will transform the world as we know it. There are four main types of technological innovation that are mooted to be 'the next big thing' in the digital world and which could be, the upcoming post digital technologies. These are; Artificial Intelligence, Expanded Reality, Quantum Computing and Blockchain based secure transactions. These will be dealt with in more detail below.

Artificial Intelligence

Artificial Intelligence (AI)^{287,288} is the simulation of human intelligence processes by machines, and, computer systems which are often based in ‘the cloud’. These processes include *learning* which is the acquisition of information and the rules for using it, *reasoning* i.e. using rules to reach conclusions and *self-correction*. Applications of AI include expert systems, speech recognition and machine vision. Essentially, Artificial Intelligence makes it possible for machines to learn from experience, adjust to new inputs and perform tasks in similar ways to that which a human would. Many AI examples are coming to the fore which range from chess-playing computers²⁸⁹ to systems that define smart health monitoring^{290, 291} and demotics applications^{292, 293}. In all these application domains, AI relies heavily on deep learning and natural language processing, as well as access to continuous and real time data feeds from smart sensing systems (IoT). Using these technologies, computers can be trained to accomplish specific tasks by processing enormous amounts of data and recognizing previously unseen patterns in the measured data²⁹⁴.

It is claimed by IBM that using their Watson AI system can reduce time spent on research by 75%.

‘The Watson AI search augments human research by quickly uncovering information inside your organization’s complex knowledge silos and surfacing specific answers – not just the relevant document’²⁹⁵.

With IBM Watson - Discovery, it is apparently possible to institute an AI enterprise search ‘anywhere’ to reach data stored on company premises or in any *accessible*^{N.B.²⁹⁶} private, public, hybrid, or multi-cloud environment. This can be used to empower company employees to accurately analyse millions of documents no matter where the content resides.

²⁸⁷ ‘Understanding Machine Learning: From Theory to Algorithms’, Shai Shalev-Shwartz, Shai Ben-David, Cambridge University Press 2014

²⁸⁸ ‘Life 3.0: Being Human in the Age of Artificial Intelligence’, Max Tegmark Penguin 2017

²⁸⁹ <https://www.bbc.com/future/article/20151201-the-cyborg-chess-players-that-cant-be-beaten> accessed 24/11/2019

²⁹⁰ ‘The “inconvenient truth” about AI in healthcare’, Trishan Panch, Heather Mattie & Leo Anthony Celi Panch. npj Digit. Med. 2, 77 (2019) doi:10.1038/s41746-019-0155-4

²⁹¹ ‘Artificial Intelligence in Medicine: Current Trends and Future Possibilities’, Varun H Buch, Irfan Ahmed, Mahiben Maruthappu, British Journal Of General Practice Br J Gen Pract. 2018 Mar; 68(668): 143–144. doi: 10.3399/bjgp18X695213

²⁹² ‘The Future Of The Smart Home: How Homes Powered By Artificial Intelligence Will Know & Care For You’ Andrew Weinreich Forbes February 8 2018

²⁹³ ‘What Will Smart Homes Look Like 10 Years From Now?’ , Patrick Lucas Austin, Time July 25, 2019

²⁹⁴ <https://www.ibm.com/watson> Accessed 22/11/2019

²⁹⁵ <https://www.ibm.com/watson/ai-search> accessed 22/1/2019

²⁹⁶ N.B. The word accessible has been added by me into this text. What is written here is almost verbatim from the IBM supplied text, I have amended it for my purposes, but I prefer to think that they would need to get permission to access information from private servers etc. before drawing their conclusions.

Automotive applications are also a very fertile ground for AI applications²⁹⁷. Most of the autonomous vehicles under investigation currently combine AI software, sensors, real time cameras and enormous amounts of measured data (real and virtual test miles) to ensure safe decisions on the road



Figure A19 The Waymo and ZooX Vehicles

In the case of AutoX²⁹⁸, they build vehicles that will go to the supermarket and pick up groceries that you requested on your mobile phone. Waymo²⁹⁹ is a spin off from Google devoted to creating driverless vehicles that can safely pick people up and deliver them to their destination. Key to their success is their extensive testing and their 360-degree perception technology which detects pedestrians, other vehicles, cyclists, road works and other obstacles at a range of 300 yards. ZooX³⁰⁰ are creating their own autonomous vehicles rather than augmenting existing models and their aim is to create a robotic ride share vehicle in a similar vein to the offering from UBER³⁰¹ and LYFT³⁰².

DataRPM³⁰³, a subsidiary of Progress Software Corporation, provides anomaly detection and prediction solutions for a variety of industries. Their machine learning technology develops an understanding of a machine's normal patterns of behaviour. It is also able to predict future issues and breakdowns which saves time and money, reduced equipment downtime and makes preventative maintenance more effective and efficient. These are examples of the use of AI in industry, although AI is playing a large role in many other industries as well including Agriculture, Aviation, Environment, Financial Services, Freight and Logistics, Government, Healthcare, Insurance, Manufacturing, Oil and Gas, Retail, Sport, Telecom, Media and Utilities.

²⁹⁷ 'Self-Driving Cars: "The Mother of All AI Projects@: Practical Advances in Artificial Intelligence (AI)' Lance B. Eliot, Personal Publication 2017

²⁹⁸ <https://www.autox.ai/> Accessed 22/11/2019

²⁹⁹ <https://waymo.com/> Accessed 22/11/2019

³⁰⁰ <https://zoox.com/> Accessed 22/11/2019

³⁰¹ <https://www.uber.com/gb/en/atg/> Accessed 22/11/2019

³⁰² <https://www.cnn.com/2019/11/05/lyft-is-developing-self-driving-cars-at-its-level-5-lab-in-palo-alto.html> Accessed 22/11/2019

³⁰³ <https://www.businesswire.com/news/home/20170329005967/en/Progress-Acquires-DataRPM-Best-of-Breed-Machine-Learning-Company> Accessed 22/11/2019



Figure A20 The HAAN Rethink Robotics - Sawyer Equipment

Extended Reality

Extended Reality (XR)³⁰⁴³⁰⁵ is an umbrella term for all the immersive, experience and vision driven technologies, that extend the reality we experience by either blending the virtual and “real” worlds or by creating a fully immersive experience. The ones that are currently starting to emerge are Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) and there are more, yet undefined, to come.

In a virtual reality experience, users become fully immersed in a simulated digital environment. They must wear a VR headset or head-mounted display to get a 360 degree view of an artificial world that fools their brain into believing they are, e.g. riding a roller coaster³⁰⁶, walking with dinosaurs³⁰⁷ or moving in a guided tour through the Great Pyramid of Giza³⁰⁸. Additional stimuli are also provided using treadmills and other mechanical aids which ensure that the user experiences walking and travelling over undulating terrain. The gaming and entertainment industry were early adopters of this technology; however, companies in several industries, such as healthcare, construction, engineering and the military, are now finding VR to be very useful in many different ways.

In augmented reality, virtual information and objects are overlaid on the real world. This experience enhances the real world with digital details such as images, text, and animation. AR can be experienced using AR glasses or via screens, tablets, and smartphones. This ensures that users are not isolated from the real world and they can still interact with, and see, what is going on in front and around

³⁰⁴ ‘Virtual Reality’, Samuel Greengard, MIT Press Essential Knowledge Series 2019

³⁰⁵ ‘Virtual Reality Human Computer Interaction’, Ajit Singh, Independently Published 2019

³⁰⁶ <https://www.youtube.com/watch?v=5gF4tyf-zVo> (Roller-Coaster) Accessed 24/11/2019

³⁰⁷ <https://www.youtube.com/watch?v=yOHjlwbuyg8> (Dinosaurs) Accessed 24/11/2019

³⁰⁸ <https://www.youtube.com/watch?v=MqtePH49pHI> (Gysa) accessed 24/11/2019

them. For example, IKEA use Augmented Reality to help customers to see what their furniture products look like in their homes with full 360-degree perspectives.^{309,310}



Figure A21 Views from Virtual Reality Headsets in Roller-Coaster and Dinosaur Applications.

(Note There are Two Images in Each. These Represent Each Eye in Stereoscopic Vision).

AR also permits the transmission of expanded information on products in supermarkets and their uses, i.e. recipes, nutrition information and promotional offers etc by scanning the product with a smart phone³¹¹. Augmented Reality has also been used in educational projects such as interactively demonstrating the impact of how changing altitude and shapes of surfaces will change contour lines in a sandbox³¹².

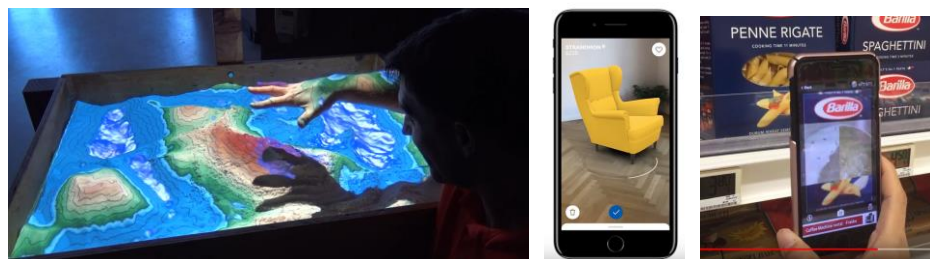


Figure A22 An Augmented Reality Sandbox for Displaying Contours, IKEA's Furniture App and The Barilla Pasta AR

In a mixed reality system, digital and real-world objects co-exist and can interact with one another in real-time³¹³. This is the more recent immersive technology and is sometimes referred to as Hybrid Reality³¹⁴. It requires an MR headset and a lot more processing power than VR or AR. Microsoft's HoloLens³¹⁵ is a great example of this. It enables the user to place digital objects into the room they are standing in and gives them the ability to spin it around or interact with the digital object in any

³⁰⁹ <https://www.youtube.com/watch?v=vDNzTasuYEW> (IKEA) Accessed 24/11/2019

³¹⁰ <https://www.youtube.com/watch?v=cdv0b0nBqPk> (IKEA) Accessed 24/11/2019

³¹¹ <https://www.youtube.com/watch?v=2fxH4iRu0vA> (Barilla) Accessed 24/11/2019

³¹² <https://www.youtube.com/watch?v=bA4uvkAStPc> (Contours) Accessed 24/11/2019

³¹³ 'Mixed Reality A Complete Guide' Gerardus Blokdyk The Art Of service, 2019

³¹⁴ 'The Engineering of Mixed Reality Systems' Editors: Emmanuel Dubois, Philip Gray, Laurence Nigay, Springer 2012

³¹⁵ <https://www.microsoft.com/en-us/hololens> Accessed 24/11/2019

way possible. It can also project what lies beneath a surface on top of the surface to provide insights into how things work etc. Companies are exploring ways they can put mixed reality to work to solve problems, provide training as well as being able to provide expert remote support for maintenance work being carried out in the field.

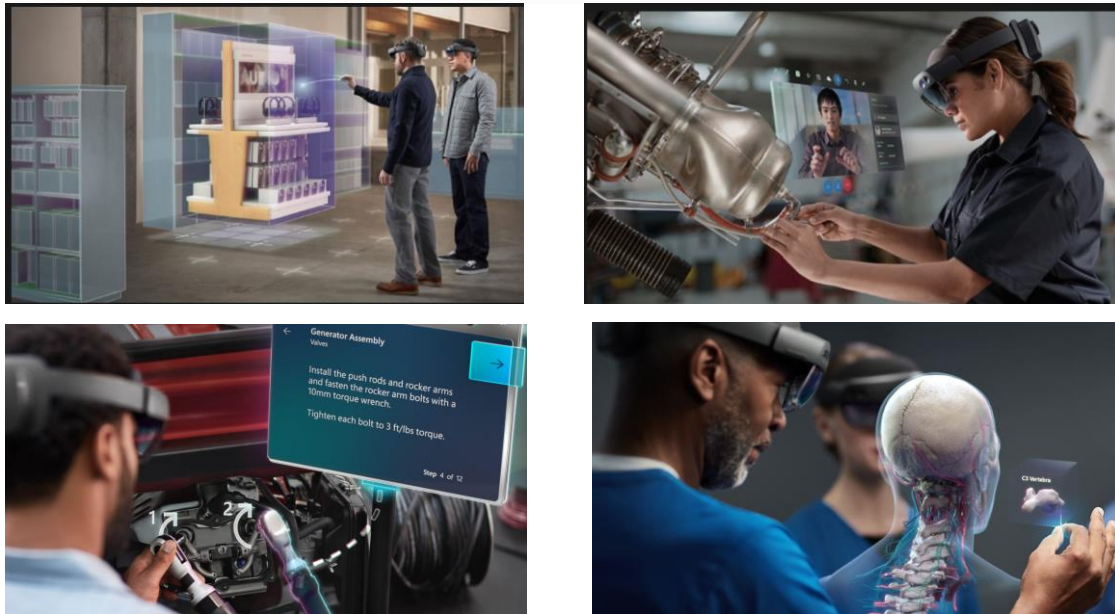


Figure A23 Some Examples of Mixed Reality in Action

Challenges of Extended Reality (XR)

There are some challenges to mainstream adoption of Extended Reality technologies. These emanate from the fact that these technologies collect and process huge amounts of very detailed and personal data about what people do, what they look at, and even their emotions at any given time. All this information needs to be secured and protected and this amongst other things is very expensive to implement. Furthermore, it is very important that those wearable devices which allow a full XR experience are comfortable as well as always connected, intelligent, and immersive. Furthermore, eliminating issues such as the impact of latency on VR sickness, which is a form of motion sickness sometimes experienced by VR participants will be a very important aspect³¹⁶. There are also significant technical and hardware related issues that need to be resolved to optimise the immersive experience, these include display, power and thermal management, motion tracking and connectivity amongst others.

³¹⁶ 'Bodies in Code' Mark B. N. Hansen, Routledge 2006

Quantum Computing

Today, our conventional computers pretty much employ the same hardware architecture that is described in chapter 2 and that they have, since the origins of the computer itself. The hardware has become faster, smaller, less power hungry and cheaper but the underlying design principles and operational approach remains the same. This is often referred to as classical computing and this exhibits what is called a von Neumann architecture.

Quantum Computing (QC) represents a leap forward in the idea of computing which is based on the conceptually complex field of physics, called quantum mechanics. This relates mainly to the statistics of how various solid-state particles can move and at the atomic and subatomic level of matter, there are transport phenomena that are not easily explained by more conventional physics. For example, particles can be demonstrated to be connected to each other even when they are separated by 'relatively' long distances. This is known as quantum entanglement and is the core of the Quantum Computing concept. Using Quantum entanglement it becomes possible to construct the digital registers described earlier using quantum elements as the memory components (qubits). These would be able to dramatically speed-up access to the computer memory and hence dramatically speed up transactions and calculations compared to existing state of the art systems. These systems are research tools and are being built on experimental platforms. They take up big rooms (a bit like ENIAC as an analogy), require immense amounts of cryogenic cooling and they currently do not have many active qubits (The biggest one in 2018 was Google's 72 qubit machine³¹⁷). However, the progress in this field is taking place at a tremendous pace and it is reasonable that quantum computers will become more of a commodity as time progresses.

One area where this faster speed is generating interest is in the area of data encryption and transmission. Encryption and data security can be achieved as a function of the operating principles of quantum computing. Using this technology, it is possible to have supreme confidence that if a message has been received, it has not been read by anyone else.

Quantum computers are not just useful for cryptography applications and communication. One of the most immediate applications is in machine-learning, where we are already on the cusp of a tremendous benefit and the quantum algorithms for machine learning will outperform any classical algorithm. It is believed that the speed advantage over classical computing for machine-learning will be achieved within the next year.

³¹⁷ <https://quantumcomputingreport.com/news/news-archive-2018/google-announces-a-72-qubit-superconducting-quantum-chip/> Accessed 5/12/2019

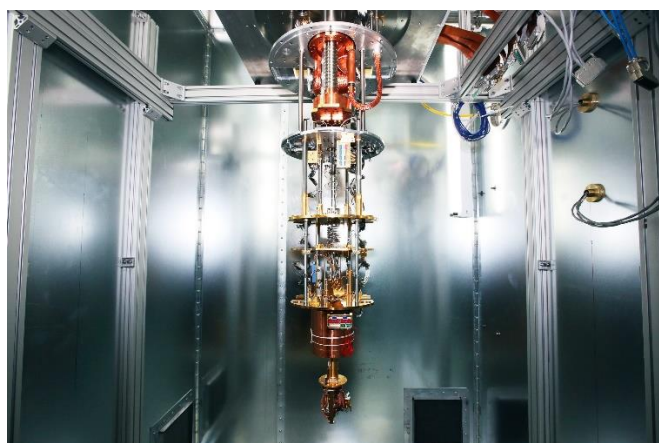


Figure A24 Google's quantum computer performed a task in 200 seconds that would have taken the world's fastest supercomputer 100,000 years³¹⁸

The near-term applications for quantum computing are endless: cryptography, machine-learning, chemical process modelling, process optimization, communications and many more. This powerful technology will, when taken in conjunction with Artificial intelligence and other post digital age technologies, ensure data security and secure web-based transactions. This will facilitate confidence in, and demonstrable security, for the next generation of financial services.

Secure Financial Transactions (Block Chain)

A blockchain³¹⁹ is, in the simplest of terms, a time-stamped series of data records that is managed by a cluster of computers not owned by any single entity. Each of these blocks of data (i.e. block) is secured and bound to each other using cryptographic principles and in a chain so that each new element is attached to the end of the chain. This chain is shared with every valid entity in the network. This ensures that no retrospective transactions can take place and that all financial transactions are unalterable and completely transparent.

Since a blockchain network is a shared and immutable ledger, the information in it is open for anyone and everyone to see. Hence, anything that is built on the blockchain is by its very nature transparent and everyone involved is accountable for their actions. Furthermore, the blockchain carries no transaction cost. The blockchain is a simple method for transmitting information from A to B in a fully automated and safe manner. One party to a transaction initiates the process by creating a block and this block is verified by millions of computers distributed around the net. The verified block is added to a chain, which is stored across the net, creating not just a unique record, but a unique record with

³¹⁸ 'Google moves toward quantum supremacy with 72-qubit computer', Emily Conover Science News March 5, 2018

³¹⁹ 'Blockchain Science: Distributed Ledger Technology', Roger Wattenhofer, Independently Published, 2019

a unique history. Falsifying a single record would mean falsifying the entire chain in millions of instances which is virtually impossible. Bitcoin uses this model for monetary transactions, but it can be deployed in many other ways.

Now, when we buy e.g. bus tickets on an app or the web, the credit card company takes a cut for processing the transaction. In the future, with blockchain, not only can the bus operator save on credit card processing fees, it can move the entire ticketing process to the blockchain and the two parties in the transaction become the bus company and the passenger. The ticket becomes a block, which will be added to a ticket blockchain. So, just as a monetary transaction on the blockchain is a unique, unfalsifiable record so is the ticket. Incidentally, the final ticket blockchain is also a record of all transactions for, say, a certain route, or even the entire bus network, comprising every ticket ever sold, every journey ever taken. This will have a massive impact on financial transactions because it will eliminate the fees that agents insert into the process for acting as intermediaries. Not only can the blockchain transfer and store money, it can also replace all processes and business models that rely on charging a small fee for a transaction. This will ultimately be good for the consumer.

Furthermore, because blockchain transactions are free, suppliers can charge infinitesimally small amounts, to watch a video or read an article. Blockchain may make selling recorded music profitable for artists by cutting out music companies' agents and streaming services like Spotify and i-tunes. Ultimately, the music that people buy could even be encoded in the blockchain itself, making a cloud archive for any song purchased. Since the amounts charged can be so small, subscription and streaming services will also become irrelevant.

In the financial world the applications are more obvious and the revolutionary changes more imminent. Ideally, Blockchains will change the way that stock market works. These apps will eliminate the need for bank accounts and most of the services offered by banks, once the advantages of a safe ledger without transaction fees are widely understood and implemented. However, there will still be a requirement for credit facilities.

The reason why the blockchain has gained so much traction and has so much potential, is that nobody owns it. It is decentralized, all the data is cryptographically stored inside the blockchain and it is also immutable. This means that no external entity can tamper with the data that is inside the blockchain. Furthermore, the blockchain is transparent so anyone can track their data if they need to.

These benefits will ultimately provide confidence and local control of financial transactions although there will still be roles for financial institutions in facilitating credit, loans etc. Day to day transactions and payment for goods and services will be considerably streamlined. All of this will be of huge benefit

to the way that the world of finance works. If Blockchain technologies had existed and in use earlier there would probably have been considerably less theft and embezzlement and maybe even some of the recent crises could have been avoided. The reason that this has taken so long to implement is that there are a lot of technical issues to resolve and the networks and data security that are needed to implement it need to be strengthened. There is presumably also a considerable amount of *'push back'* from those institutions who will be impacted financially by this new business model.

Summary and Conclusions

The digital era is ending and it is being absorbed into the post digital age. It is no longer a distinguishing feature to describe something as 'digital' and all the benefits of digital technologies are being used and have stopped being special advantages. The technologies that have brought us to where we are now have been explained and described and the upcoming technologies and where they will be deployed has also been elaborated.

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