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On the Capabilities of Digital Artifacts

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Abstract

We propose and discuss a model of digital artifacts that highlights the significant roles played by stored bit patterns and that indicates a set of capability types that digital artifacts may possess. It is based on and supplements existing conceptualizations of digital artifacts. The model represents the basic constituents of digital artifacts in terms of storage technology with bit patterns, digital processing technology, and non-digital technology. Furthermore, it represents the following set of action capability types that digital artifacts may possess: Moving, controlling, modifying, sensing, and presenting. The model can be used to analyse and design existing and envisioned networks of interconnected digital artifacts.

Keywords: Digital artifact, architecture, capabilities.

1 Introduction

The ways in which digital technology is being used to transform areas like business models, public institutions, production technology and consumer products is changing quite fast. Many capabilities of early main frame computers are identical to many core functionalities of, say, modern cars. In both cases, binary digits are used to represent information and the technology that is used to process the binary digits are is based on the same type of computational logic. However, the main frames were mostly used to store, manipulate and present information for human use. In addition to information processing for human use the digital technology in cars is used to monitor and control different components in the cars.

We present and discuss a model of digital artifacts and their potential capabilities. Building on previous research (Ekbia 2009, Yoo, Henfridsson et al. 2010, Hylving, Henfridsson et al. 2012, Kallinikos, Aaltonen et al. 2013, Henfridsson, Mathiassen et al. 2014), the proposed model represents the role of binary digits and it highlights important types of capabilities that may be offered by digital artifacts.

We expect that our model can be used to support analysis and design of networks of interconnected digital and non-digital artifacts. Traditionally, information systems have been understood as systems that capture, store, manipulate and present information (Avison and Fitzgerald 2006). In order to analyse and design systems that utilize the action capabilities of mechanical-electrical artifacts we need concepts and models that extend and transcend the conventional information processing perspective. Our work should be seen as an addition to recent research that goes beyond the conventional information-processing perspective (Tilson, Lyytinen et al. 2010, Yoo, Henfridsson et al. 2010, Setia, Venkatesh et al. 2013, Fichman, Dos Santos et al.

2014). We believe that our proposed set of capability types is a useful contribution to the existing body of research.

The paper is organized as follows. In Section 2, discuss the notion of technological artifacts as objects with structure and function. In Section 3, we discuss essential aspects of the binary language that constitutes the essential prerequisite of digital technology. In Section 4, we discuss digital artifacts as special types of technological artifacts that can store and potentially process binary expressions. Furthermore, we discuss a set of fundamental types of capabilities that digital artifacts can possess. In Section 5, we conclude the paper and suggest directions for future research.

2 Technological Artifacts

The term artifact may have at least two different meanings (Dictionary 2014, FreeDictionary 2014). First, the term may refer to objects like houses, computers, documents and pens that have been made by human beings. Second, the term may refer to objects that do not usually belong to the places in which they are observed. For example, it can be substances or structures introduced as side effects of the use of technology.

We view artifacts as enduring objects that are created by human beings and that have structure and function (Baker 2004, Kroes 2010, Faulkner and Runde 2011, Faulkner and Runde 2013). The structure of an artifact represents its form and its constitution in terms of related components (Baker 2004). The functions of an artifact represents what it can do for its users (Faulkner and Runde 2011, Faulkner and Runde 2013).

In some situations, both the structure and function of an artifact are created by human beings. The structure and function of, say, a car is created by human beings. In other situations, only the function of an artifact is created by human beings. When, say, a stone is used as a paper weight its structure is not created by human beings but its function as a paper weight is created by human beings.

It is possible to distinguish between material and non-material artifacts (Faulkner and Runde 2011, Faulkner and Runde 2013). Using this distinction, material artifacts like cars and computers possess attributes like location, shape, volume, and mass whereas non-material artifacts like designs and computer files do not possess such attributes. Furthermore, non-material artifacts are different form the material objects that represent them: "... however much syntactic objects may depend on material objects to be stored, accessed, transferred and communicated, they are always distinct from any and all material things in virtue of their non-material mode of being." (Faulkner and Runde 2011, Faulkner and Runde 2013).

3 The Binary Language

The binary numeral system can be viewed as a non-material artifact in the sense that we discussed in the previous section (Faulkner and Runde 2011, Faulkner and Runde 2013). Usually, the symbols 0 and 1 are used to represent binary digits in the binary numeral system in which sequences of bits are used to represent numbers.

Viewed as a language the binary numeral system (and its syntax and semantics) has no materiality and no spatial attributes. It is purely conceptual. Likewise, binary expressions like 101 and 1100011 have no materiality and spatial attributes. But it is very hard to handle the binary numeral system without representations of its syntax and semantics and of the expressions that represent numbers.

The syntax and semantics of the binary numeral system can be represented by written expressions on, say, paper and the same holds for binary expressions. The paper in use can be called a bearer of the expressions (Faulkner and Runde 2011, Faulkner and Runde 2013). Bearers and the expression they bear represent a material aspect of language. In semiotic terms a materialized expression can be viewed as a signifier that signifies some meaning or interpretation.

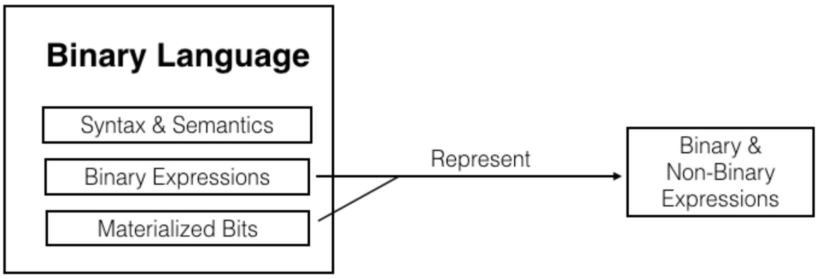

Figure 1 A model of the binary language.

Figure 1 illustrates the major aspects of the binary language (the binary numeral system). It is language with a simple syntax. An expression is a sequence of bits. Various semantics can be used to interpret binary expressions. For example, binary expressions can be interpreted as binary numbers based on base 2 positional semantics. Alternatively, binary expressions can be used to represent text strings, audio, video etc.

4 Digital Artifacts

We view a digital artifact as a technological artifact that contains information that is represented by means of bits (binary digits). A digital artifact may (but does not have to) contain technology that can process information that is represented by means of bits.

When a binary expression is materialized on, say, a hard disk it plays a double role. It can be viewed as a semiotic signifier that is interpreted by a human being by means of, say, the syntax and semantics of the binary numeral system. Also, the binary expression may be used and manipulated by digital processing technology based on algorithmic rules.

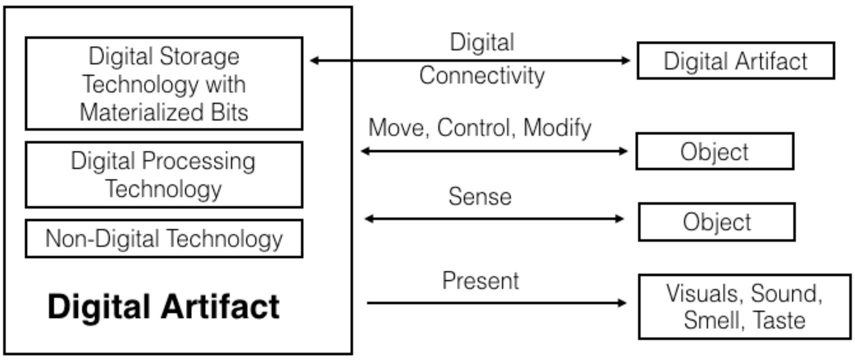

Figure 2 A model of digital artifacts and their potential capabilities.

The left-hand-side of Figure 2 represent a model of constituents of digital artifacts. The core of a digital artifact is constituted by bit patterns that are stored on digital storage technology. The bit patterns may be used and manipulated by digital processing technology. Non-digital technology may be related to the digital technology by means of bit patterns that can be transmitted as, say, electrical signals.

Example - digital camera: A light-sensitive sensor in the camera can capture light patterns and by means of a combination of digital and non-digital technology the captured light patterns can be transformed into bit patterns. The camera can store such bit patterns (representations of images) on storage media (digital storage technology).

Example - laptop computer: A laptop computer can store bit patterns on a hard disk. It contains non-digital technology like key board and monitor. These technologies are connected to digital technology by means of electrically represented bit patterns that can be accessed by digital processing technology.

Networks of digital artifacts may be organized by a combination of modular and layered architectures. In a modular architecture, a complex technological artifact is organized as a set of related modules or components. When digital technology is embedded in non-digital products the modularity potentials of software may be used to modularize digital artifacts (Henfridsson, Mathiassen et al. 2009). In a layered architecture each component may contain elements of specific layers. Examples of layered architecture models are model-function (Jackson 1983) and interface-function-model (Mathiassen, Munk-Madsen et al. 2000), and content-service-network-device (Yoo, Henfridsson et al. 2010).

The potential capabilities of digital artifacts have been discussed in different ways in the research literature as illustrated by the following examples. Digital artifacts are programmable, addressable, sensible, communicable, memorable, traceable, and associable (Yoo, Henfridsson et al. 2010); Digital artifacts are open, editable, and expandable (Kallinikos and Mariátegui 2011); Digital artifacts are interactive, editable, reflexive, open, distributed, modular, and granular (Kallinikos, Aaltonen et al. 2013); Digital artifacts support late binding of properties (Hylving, Henfridsson et al. 2012).

Our proposed model (Figure 2) implies that digital artifacts may possess the following types of basic capabilities.

Binary representation of information. Digital artifacts can represent information by means of binary expressions. For example, the digital patterns on a hard disk can represent information about customers and products and they can represent media content like images and audio.

Digital connectivity. Digital artifacts can be connected to other digital artifacts by means of exchange of binary expressions. For example, computers and other digital artifacts can be connected in networks.

Digital processing. Many digital artifacts can process binary expressions. Binary expressions can be used to control the manipulation and transformation of binary expressions.

The basic capabilities representation, connectivity, and processing form the basis of a set of action capabilities that digital artifacts may possess. Digital artifacts can utilize the basic capabilities to perform the following action capabilities (Bækgaard 2006, Bækgaard 2011).

Moving. Digital artifacts can move objects and be moved by objects. For example, robots can move objects.

Controlling. Digital artifacts can control objects and be controlled by objects. For example, mobile phone apps can control heating devices and drones.

Modifying. Digital artifacts can modify objects and be modified by objects. For example, 3D printers can transform ink into 3-dimensional objects. And programmers can modify software.

Sensing. Digital artifacts can sense aspects of objects and they can be sensed by objects. Example, digital cameras can sense light waves. Digital watches can sense movement.

Presenting. Digital artifacts can present visuals, sound, smell, and taste. Examples: Lap top computers can present information on monitors. Digital cameras can present images on displays. Home audio systems can present audio through speakers.

5 Conclusion

We have proposed a model of digital artifacts (Figure 2) and a set of capability types that digital artifacts may possess. The model can be used to explain how a non-material artifact (the binary numeral system) can constitute the defining property of digital artifacts. As illustrated in the preceding sections digital artifacts can possess important types of capabilities that represent the core of the transforming potential of digital technology.

Our model highlights potential constituents of digital artifacts and it highlights potential types of capabilities that digital artifacts may possess. Furthermore, when combined with a model of the binary language (Figure 1) it highlights the significant role of materialized binary expressions that can be viewed as the defining connection between material objects (digital artifacts) and non-material, linguistic objects (Faulkner and Runde 2011).

The capability types can be used to understand and design the materiality of digital artifacts in a manner that utilizes the many different types of mechanical-electrical artifacts that are available as components in networks of interconnected digital artifacts and non-digital artifacts.

Networks of interconnected digital artifacts may possess action capabilities that emerge as combined capabilities of more than one of the involved digital artifacts. Such networks may be understood by means layered views and modular component views (Jackson 1983, Mathiassen, Munk-Madsen et al. 2000, Yoo, Henfridsson et al. 2010). Additionally, they may be understood as networks of interacting capabilities.

Future work includes analysis of implications for the analysis and design. We expect that our model (Figure 2) can be used to support analysis and design of networks of interconnected digital and non-digital artifacts. Furthermore, future work includes use of the notions of assemblage (Hondros 2016), sociomateriality (Orlikowski 2007, Leonardi 2012, Leonardi 2013), and affordance (Maier 2008, Maier and Fadel 2009) to frame our proposed model in a socio-technical context. Finally, our proposed model may be used to shed light on the notion of digital materiality (Dourish 2016).

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