Human Factors in the World of Digital Computing and Digital Information

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ABSTRACT

Encoding data and computation in the digital form has enabled us to extend our capability to process information at rates and scales never possible before. However, the digital medium carries inherent risks and poses grand challenges. First, ensuring a long-term and reliable access to digital assets is of paramount importance. Yet, we are still grappling with the meaning of preservation in the face of tight dependences and dynamic nature of the computing ecosystem. Second, interaction of humans and technologies has been fundamentally deficient. Humans cannot consume nor act on digital directly. It requires software to mediate the interaction. Furthermore, the contemporary computing systems are complex and inaccessible to average users. At the same time, the computer interaction models are insufficient to leverage intelligent feedback of an average user. In this presentation we discuss these issues in detail and consider the approaches to address them.

1 INTRODUCTION

History of the human civilization is underpinned by the development of technologies that are used to encode and transfer knowledge across generations and enable innovation. We are in the midst of the digital revolution, where the ability to store and process information in the digital form has extended our computing abilities. But can we pass digital information and technologies onto the next generation? How long-lasting is any digital object, computation, or system?

Furthermore, digital technologies extend the human abilities to compute but still fall short of achieving the full potential. Computational tools and services are built by software engineers and adopted by the end users. While the users can typically absorb the output of computation, the systems' ability to absorb user feedback is limited—it cannot process input that is beyond the original system design. Thus, as users are creative and extend their experience to new situations, the computing technology is limited to a specific set of scenarios. What would it take to bridge this gap and achieve a full symbiosis between computing and human intelligence?

2 PRESERVING DIGITAL ASSETS

2.1 The Nature of Digital

In contrast to other technological advances, digital computation has direct and profound effect on our ability to process information which, in turn, is fundamental to our ability to develop ideas and conceptualize solutions. However, we should not disregard the risks and challenges that are inherent to digital.

In effect, digital is most vulnerable of all the media we have used to store and transfer information. It requires sophisticated infrastructure and technologies to be persisted and reused. Furthermore, it cannot be experienced by humans directly. It requires an intermediary—an application that can render information in the human consumable form. This dependence on the software is problematic because applications cannot be easily sustained over time in the rapidly changing ecosystem. Indeed, software applications normally depend on a stack of technologies that can change at different rate and to different extent. Maintaining contemporary applications is already difficult and costly. Ensuring that any legacy application stays compatible with the changing ecosystem indefinitely is not feasible.

2.2 Digital Ecosystem

Fundamental to the design of digital technologies is a concept of a file which persists information that is essential for repeated use of applications across computational sessions. The structure of a file depends on the software program that produces it and is optimized for its use.

As new technologies emerge and original applications are modified or cease to exist, the old file formats become obsolete and any stored content becomes inaccessible. This poses a serious problem and risk to our intellectual assets. Mediating that risk is, in fact, rather difficult. It is fundamentally caused by the disconnect between the software development and the content production.

2.3 Preservation Methods

In the case of digital documents, preservation efforts have focused on the transformation of legacy formats into formats that are supported by the contemporary ecosystem.

However, that strategy is not suitable when file content is of secondary importance. Indeed, in some instances the files primarily facilitate the continuity of interaction with the application and the value is realized through the user experience rather than content, as in interactive games. In that case, the approach is either to ensure that original application can run within an emulated software environment or to re-write the software to comply with the new environment. In the first case, the software is functioning within an encapsulated self-sufficient environment but may be disconnected from the rest of the ecosystem. In the latter case, it may not be possible to re-implement the applications precisely. Then, we are faced with assessing the utility of the application in the old and the new ecosystem.

2.4 Significant Properties, Value, and Utility

A value of a digital artifact, such as an electronic document record, or data file, depends on the extent that applications in the contemporary ecosystem can access them and use for further processing. At the same time, many scenarios require that, during reuse, the digital artifact retains the properties that were created and applied in the original usage scenarios.

This is particularly the case with electronic documents that are primarily consumed through rendering content on the screen. For example, in the reading scenarios, the significant properties are related to the layout characteristics of the document. If we convert the document file format, we need to apply methods and metrics to characterize the layouts of the original and the converted document and identify possible discrepancies. The significance of these discrepancies, however, needs to be determined based on human input. Indeed, we need to determine which of the discrepancies are relevant to the human perception and to what degree.

3 COMPUTING AND HUMAN INTELLIGENCE

In many computing scenarios the human input is of paramount importance. Yet, we still need to find an optimal way to capture and incorporate human feedback into the computing technologies. In order to understand the depth of the problem we need to reflect on the processes involved in the lifecycle of the digital technologies.

3.1 Human Involvement in the Technology Lifecycle

From the early computing systems, we have observed different roles that humans play in facilitating computations. First, they required special skills of engineers to build hardware, develop algorithms to solve a problem, and then provide instructions to the computer in the machine actionable form. The output was in the form of a printout with computation results that were then interpreted by experts in the problem domain. This then led to further insights and decisions about the next steps which may or may not be supported by the original program. In the case when the programmer and domain expert are the same individuals, the domain expert can modify the program or create another one based on the gained insights and required actions. However, in many instances that is not the case.

Indeed, one important aspect of technological advances is automation of repeated tasks and distribution of tasks across individuals. This is not different with the computing technology, except that the computing results are often in the form of information that serves as an input to the intelligent processing in individual’s minds. Since both the computation and the human processing result in information, it is natural to expect a feedback loop that enables humans to communicate information to the computer and continue the cycle. This is to a certain level achieved with all the user interfaces but fundamentally limited by the original design of the application. At the moment the gap is closed by human-to-human communication where the domain experts and software engineers engage in the joint effort of setting the system requirements for further computations, possibly involving a new application. However, this happens at the time scale that is at odds with the speed of computation and expectations of interactive computing systems.

3.2 Human Factors

Established practices typically lead to complex computing systems that are used by a broad and underspecified population of users. The systems are equipped with user interfaces that are expected to deliver the main value to the users. In that approach, large portions of the system and its functionality are not accessible to the end users. The users are also unlikely to have sufficient technical background to understand their intricacies. Thus, the feedback and the control that the user can exert are restricted to the features of the provided interfaces.

This lack of transparency, limited skills, and restricted input facilities are particularly problematic when the system malfunctions. In many instances, the apparent application errors occur because the users do not have a full conceptual model of the system capabilities in relation to the usage scenarios. Information about the tools and features are generic. It is the user creativity in using the tools and features that creates the value in a particular context. However, the context and the user creativity challenge, often inadvertently, the original design of the computing system.

4 CONCLUDING REMARKS

Digital revolution has transformed all aspects of our lives. We have realized its benefits and embraced it. Digital technologies have become critical for our existence and our future. They have caused great disruptions, challenging economic models and defying traditional business practices. From the perspective of the society and human involvement, they have defined new roles and introduced disconnects that we need to consider and reconcile in order to achieve the full potential.