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# Libraries, Linguistics and Artificial Intelligence: J. C. R. Licklider and the Libraries of the Future

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**ABSTRACT**

In 1965, J. C. R. Licklider published a book regarding the "Libraries of the future". This book was soon almost forgotten when a different paradigm of computing, partially created by Licklider himself, became dominant. However, a re-reading of the book, in hindsight, not only gives a glimpse of a seminal moment in the history human interaction with computers but allows to see in a different light many issues still relevant to the field.

**KEYWORDS**

J. C. R. Licklider; History of computing; History of interfaces; Speech understanding; History of libraries.

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## Introduction

*Libraries of the Future* by J. C. R. Licklider (1915-1990) is an interesting subject for re-evaluation. First of all, it has historical relevance: Licklider's work was probably the first to present a fully articulated view of computer-mediated interaction with the body of human knowledge, often encoded in natural language. Today, a similar view is often associated to proposals such as Tim Berners-Lee's Semantic Web; however, Licklider discussed in detail something clearly (even if roughly) related to this as a working technical program more than thirty years before the work of Berners-Lee. At the same time, Likclider's ideas allow us to see more clearly a set of issues in human-computer interaction and in linguistics that are still relevant today; in some cases, current experimentation may still draw inspiration from those reflections.[1]

## Context

J. C. R. Licklider was the holder of a Ph.D. in psychoacoustics, earned in 1951. He carried on for a long time his research in this area, but today he is mainly remembered for his role as a pioneer in the creation of modern computing. As such, his contribution is well understood and appreciated. In their reconstruction of the origins of Internet, Hafner and Lyon (1996) include a sympathetic portrait of Licklider, and he is often quoted even in later works such as Ryan (2010).

However, most of this recent scholarship is related only to Licklider's role in the establishment of modern computer interfaces and networks. This work arguably culminated in the seminal paper *The Computer as a Communication Device* (April 1968). Written by Licklider and by Robert Taylor, and illustrated by cartoons of Roland B. Wilson, this paper was published only a few months before Engelbart's famous "Mother of All Demos" in California. This history is also the facet explored in books by Hiltzik, Bardini and Rheingold, all of them published around the year 2000. From this vantage point, Licklider is seen as a pioneer of the paradigm of computing that took shape at the end of the Sixties, became generalized in the Eighties and still rules much of this world.

Comparatively less known is instead the wider scope of Licklider's thinking, starting with the general aims of it. In the Fifties, keeping track of the way he was spending his working days as expert in psychoacoustics, Licklider realized that a good part of his time was occupied by simple mechanical tasks which did not ask for use of intelligence. He came then to believe that in a reasonable time "most of the tasks (...) of any technical thinker would be performed more effectively by machines" (Rheingold 2000, 134).

Reflecting on this, in 1960 Licklider published the seminal paper *Man-Computer Symbiosis*, where he explicitly stated the importance of a direct interaction between the human operator and the machine to improve knowledge work. In this paper, among other things Licklider proposed the widespread use of three systems:

[1] A first draft of this work was presented at the 2nd HaPoC Conference in Paris, the 13th of October, 2013, under the title *Back to the (Libraries of) the Future*. In the meantime, I was able extend the scope of the discussion after many conversations with Elisabetta Mori, Simona Turbanti and Fabio Gadducci; I wish to thank them all for their many suggestions and insights.

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1. a "desk-surface display and control", i.e. a screen where the operator can trace characters and pen drawings that the computer then interprets and "regularizes"
2. a "computer-posted wall display" for meetings
3. "automatic speech production and recognition"

It is interesting to note that none of those three systems resembles closely the mainstream "personal computers" that from the late Seventies came to dominate the working lives of millions of people. The three systems are instead strictly related to prototypes and lines of experimentation tested at the time. The role of graphic tools in this broad proposal, for example, is explicitly linked to the pioneer work with TX computers at the Lincoln Laboratory that later culminated in the creation of programs like Sketchpad (1963), by Ivan Sutherland.

The idea that the computer could and should replace not the scientist, but his aides, at that time was already the focus of the work of other researchers, such as Douglas Engelbart. Licklider, however, soon found himself in a unique position that allowed him to take mighty steps toward the concretization of his idea: while he was busy writing *Libraries of the Future*, in October 1962 he became director of the Information Processing Techniques Office (IPTO) of the Pentagon, a structure that in practice was responsible for the allocation of funds from the U.S. Ministry of Defense to the computer industry.

Licklider left this place in 1964, but recommended the young Ivan Sutherland as his substitute for this post. In 1965 Sutherland himself was replaced as director of the IPTO not by a computer scientist, but by another expert in psychoacoustics: Robert Taylor, who followed scrupulously the search paths set by Licklider, of which he was indirectly a student (Hiltzik 1999, 15; in his new role, among other things, Taylor was one of the main supporters of the work of Engelbart in 1967: Bardini 2000, 23). In the funding policy of the IPTO, following the guidelines set in *Libraries of the Future*, a central role was given to tasks like the production of computers capable of time-sharing and of interacting through graphic displays, or as the creation of ARPAnet, the first embryo of the Internet.

In Licklider's vision, however, those bold moves were meant only as a section of a wider restructuring of knowledge work. From this more general point of view, *Libraries of the Future* constituted an eerily prescient description of some fields of study that were developed independently in the following decades. In the book, in particular, Licklider described in full detail the composition and the working ways of a "procognitive system". In this system, real-time computer networks and sophisticated tools of input and output were linked to natural language processing tools and to wide repositories of information archived in machine-readable format.

Licklider remained faithful to the vision described in *Man-Computer Symbiosis* up to the end of the Sixties: in 1968, the cartoons in *The Computer as a Communication Device* still show products strictly related to the systems 1 (upright, with the addition of a keyboard) and 2 as described in 1968. In the new paper, however, no reference was made to "automatic speech production and recognition" – an omission probably related both to the idea that the computer should be used as a communication device between human beings and to the problems that this stream of development was facing at the time.

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In the meantime, in fact, natural language processing had fallen out of favor. In 1966 the ALPAC report had presented a scathing assessment of the results in the field and of the possibilities of quick development. Research in speech was not completely obliterated: Pieraccini (2012, 91) notices the role of IPTO in the general direction of speech understanding, instead of simple speech recognition, and in particular its role in the seminal SUR program. However, while in *Libraries of the Future* it is declared that the future system described in the book will have a microphone (p. 47; at p. 49 it is also predicted that speech production would be included only in the fancier models of the system), the description of a voice interface is already left out. In 1968, in the same year when such an interface would be memorably depicted as the standard communication mode of the HAL 9000 computer in the movie *2001: A Space Odyssey*, Licklider, in a more realistic fashion, made no references to speech in *The Computer as a Communication Device.*

## The genesis of the project

*Libraries of the Future* was published in 1965. Arguably, today it is an underappreciated book, even if Castellucci (2009) has shown its relevance, its breadth of vision and its remarkable openness to the mixing of the humanities and of computer science.

In a general way, it is a book still firmly placed in the line of thought started twenty years before by the famous article *As We May Think* by Vannevar Bush – even if the influence of this article on the book, according to Likclider's introduction, was not direct but came only "through the community" (p. xii) of people working on the topic. Licklider in fact says he did read Bush's text only at the end of his work, even if he knew its outline.

In *Libraries of the Future* the only antecedent explicitly declared for the overall vision was the article written by Bush. Writing twenty years later, anyhow, Licklider took computers into account; moreover, he centered his whole proposal around computers and computer processing. This made possible the idea of a system that could not only display and store information, but also process it, exceeding by much Bush's speculation.

The starting place of the book is still the idea of a "proliferation of publication" that after the Second World War seemed to "choke" the research libraries (introduction by Clapp, vi). To deal with the issue, the Ford Foundation established the Council of Library Resources in 1956, and in 1961 this well-founded Council started "an inquiry into the characteristics of the 'library of the future'". This inquiry involved representatives of, among others, leading firms of the time such as IBM, Bell and Bolt, Beranek and Newman, the consulting and research firm Licklider was working for at the time.

Soon Licklider was selected as "the right man" (p. viii) to further the study. He worked on the issue for a year, from November 1961 to October 1962. He then became director of the IPTO, as we have already seen, but for a year he kept also a role of general direction of the work on the libraries. So, the work was actually carried out from November 1961 to November 1963. After this, "the study was brought to an end with the rendition, in January 1964, of the final report" upon which the printed volume was based.

Licklider was the acknowledged true author of the book, but the book is written in the first plural person, "we". In fact, it was in part the product of teamwork. The necessary activities for the studies

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were carried out by many people, especially at Bolt, Beranek and Newman (with Mario Grignetti) and at the MIT (by a team including Marvin Minsky). Probably it is also thanks to this teamwork if the book seems today wonderfully updated on the 1964 state of the art in many different fields.

## The work of the procognitive system

*Libraries of the Future* is a book composed of two parts:

1. Concepts and problems of man's interaction with the body of recorded knowledge
2. Explorations in the use of computers in information storage, organization, and retrieval

Today, the second part is mainly only of historical interest, since it describes the state of the art, in 1964, of 13 different technologies or fields of study: from the "Syntactic analysis of natural language by computer" to storage system.

One of those 13 descriptions, however, is central to the way the basic question asked by the Council was answered. In the chapter 13, in fact, "the concepts of a library" are examined in full, distinguishing between tools to provide documents and tools to provide information. As it is made clear since the introduction, it is the second approach that was chosen almost at the outset (p. 2). So, the "libraries" referred to in the title of the book are in fact carriers of information:

> We delimited the scope of the study, almost at the outset, to functions, classes of information, and domains of knowledge in which the items of basic interest are not the print or paper, and not the words and sentences themselves – but the facts, concepts, principles, and ideas the lie behind the visible and tangible aspects of documents (p. 2).

As to the scope, in the report the "future" was defined at the outset as the year 2000 – even if in the practical example that will be discussed below Licklider refers, instead, to the year 1994.

A date so removed in the future allowed a great deal of creative freedom. Licklider used it to define the so-called "procognitive systems", or "PC systems", that would have replaced "present-day libraries" (p. 6). This system was centered on a procognitive system that should have included (pp. 36-37), among its "structural" features:

> 4. Make available a body of knowledge that is organized both broadly and deeply – and foster the improvement of such organization through use (…)
>
> 6. Provide access to the body of knowledge through convenient procedure-oriented and field-oriented languages (…)
>
> 9. Permit users to deal either with metainformation (…), or with substantive information (…), or with both at once (…)
>
> 13. Reduce markedly the difficulties now caused by the diversity of publication languages, terminologies, and 'symbologies' (…)
>
> 15. Tend toward consolidation and purification of knowledge instead of, or as well as, toward progressive growth and unresolved equivocation [footnote: It may be desirable to preserve, in

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> a secondary or tertiary store, many contributes that do not qualify as "solid" material for the highly organized, rapidly accessible nucleus of the body of knowledge].

This list of features is a remarkable forecast of issues that became relevant only later and that at the time of writing were outside of the scope of available technology. The collection of tools devised by Licklider often recalls features of languages and frameworks like OWL and RDF, including transformation languages such as XSLT. Of course, as far as it is known, the whole of the Semantic Web idea was developed in a way totally independent from the work of Licklider.

On the hardware side, Licklider described his system as a "console": a typewriter keyboard having, on the left, a 11" X 14" flat screen for input and output (p. 46). Then he described in detail and in first person the activity of a knowledge worker with 1994 technology:

> It is easy to move this surface [the screen] to a position above the typewriter for easy viewing while I type, but, because I like to write and draw my inputs to the system, I usually leave the screen in its horizontal position beside the typewriter. In a penholder beside the screen is a pen that can mark on the screen very much as an ordinary pen marks on paper, except that there is an 'erase' mode (pp. 46-47).

With this system, the user starts his inquiry asking questions to the PC system in almost-natural language (p. 50). The queries are related to "a 1964 problem", managed through 1994 technology: how to program computers to understand natural language.

```
What are your descriptor expressions for:
      computer processing of natural language
      computer processing of English
      natural-language control of computers
      natural-language programming of computers
```

After a bit of tinkering, the PC system answers, displaying the terminology used in its "thesaurus" and including logic relationships between items (pp. 50-51):

```
Descriptor expressions:
   1. (natural language) ∧ (computer processing of)
   2. (natural language) ∧ (on-line man-computer interaction)
   3. (natural language) ∧ (machine translation of)
   4. (natural language) ∧ (computer programming)
   5. (computer program) ∧ (semantic net)
   6. (compiler) ∧ (semantic)
Descriptor inclusions:
   7. (natural language) includes (English)
Phrase equivalences:
   8. (control of computers) ≃ (on-line man-machine interaction)
   9. (programming of computers) ≃ (computer programming)
   10.      (semantic relations) ≃ (semantic nets)
```

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The user then types a set of orders in natural language, carrying on a true conversation with the system (p. 51):

```
Prepare bibliographies with abstracts (1, 2, 4, 5).

Best 25 references each. When will they be available?
```

The PC system answers (p. 52):

```
Requested bibliographies will be available at about 18:00. Do you want them delivered, or will you call, or will you request typeout?
```

Since this was written in 1964, the user requests "typeout" in order to collect the output in Monday – it seems he had no idea of working in weekends, or beyond 5 p.m.! But, apart from this, Licklider seems to make too low an estimate of the possible speed of interaction with a bibliographic database. This, however, is partly due to the very complex nature of the operations the system needs to carry on.

Things start to get interesting on Monday. During the weekend the system has "retrieved over 10,000 documents, scanned them all for sections rich in relevant material, analyzed all the rich sections into statements in a high-order predicate calculus, and entered the statements into the data base of the question-answering system" (p. 53). So, on Monday the user is not only able to read the texts but also to ask questions regarding the contents of the documents (p. 56):

```
Refer to bibliographies I requested last Friday.

Do cited or related references contain explicit definitions of "syntax", "syntactics", or "semantic"?

Do syntactic analyses of sentences yield many alternative parsings?

Give examples showing alternatives. Give examples illustrating how many.

Is there a description of a procedure in which an analysis based on mathematical syntax is used in tandem or in alternation with semantic analysis?

Display the description.

How long is Oettinger's syntactic analyzer?

Do you have it available now? §
```

Of course, even to find and to organize bibliographic references was not a trivial task in 1964 – and Licklider explains the necessity of an "elaborate thesaurus of descriptors and related terms and expressions" (p. 53), drawn from library science and similar to modern implementations. However, it was already clear, at the time, that the difficult part of the work was the second one, the question-answering system. It was also a new way of interacting with the body of knowledge, one not forecast in Bush's work; this way of interacting became conceivable only with the use of electronic computers.

How was Licklider hoping it would be implemented? He did it in a way deeply reminiscing of Semantic Web, trying to attack the problem of making computer process the treasure of information buried in tables and databases but also in books and papers, where it is expressed in natural language.

In the first place, it is interesting to note that Licklider's approach to the issue was based on four "Man-computer interaction languages" (p. 104), described in chapter four ("Man-computer interaction in precognitive systems", p. 90):

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- Programming language
- Organizing language
- User-oriented languages
- Representation language

The difference between those languages is defined in the book, but often it is not so clear; this fact is ironic, for the reasons we will see below. Licklider himself, however, knew he was vague, and knew that the four languages would have to share many features.

## The representation language

Let's start from the fourth language, the "representation language": apparently, the language used for storing data. It has the shortest description among the four languages Licklider introduces, since it is only one page and a half (pp. 125-126), while references to it are distributed in other, different, sections of the text, such as this one:

> The substantive findings are typically expressed in the form of a high-order formal language, or in the form of operable computer programs ('dynamic models'), or in the form of data structures such as lists, tables, matrixes. (…) During the future period to which this discussion refers, many scientists are beginning to use in their own work the formal language in terms of which the body of knowledge is represented in the procognitive system" (p. 112).

The exact nature of this "representation language" is left undefined. Especially in chapter three, Licklider describes some alternative proposals, such as relational nets and higher-order predicate calculi. However, as "high-order formal language" he seems to choose something strictly related to what he calls "unambiguous English". His most articulated model of the way to put information in the database includes in fact a sequence that goes (p. 89):

1. From natural (technical) language to "unambiguous English" using machine-aided human translators
2. From "unambiguous English", through "a purely machine translation", into "the language(s) of the computer or of the data-base itself" [this looks like the "representation language"].

Of course, in hindsight, this was a deeply flawed approach. Natural language, even in scientific texts, does not translate easily at all in formal structures. It is in practice impossible, except for very limited settings, to translate natural language into something "unambiguous", because the ambiguous nature of language it is what makes it usable by human beings – or at least, so it seems today to linguists.

At the time, Licklider was not the only one thinking in this way. Some people also tried to put in practice this idea creating "logical" languages, such as Lojban or, later, Loglan. Those languages, however, after fifty years of tinkering, have communities of practitioners, but not a single person able to use them fluently as spoken language, or to translate easily into them from the natural language (Okrent 2009).

At the same time, Licklider clearly spotted then the need for the representation language to be composed by many different languages or sublanguages, or more accurately the need for it to be a

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"language system" (p. 125), with cross compatibility between languages included in the system – introducing explicitly the notion of a "metalanguage": "the over-all language will be a system because all the sublanguages will fall within the scope of one metalanguage" (p. 126). This could be well the first introduction of the idea of a metalanguage to encode such a body of "encyclopedic" knowledge.

In hindsight, Licklider forecasts the use of something similar to XML made with natural language. Licklider also speaks of tools for "testing the logical consistency of statements in the representation language", that is, of tools for parsing. But, of course, the description is vague. It does not seem clear, for example, how "unambiguous English" could be broken in a "language system". Maybe Licklider was thinking to the differences in terminology in languages used in different areas of science and technology, but it is difficult to be more specific than this.

## The organizing language

Still more interesting is the "organizing language". According to Licklider, in the future described by the book this language is able to deal "with documents written in the various natural languages, with the mathematical models and computer-program models, with computer programs themselves, and – most intensively – with large, coherent systemizations of knowledge represented in the 'representation language' that constitutes the foundation of the question-answer system" (p. 111). One of the most detailed descriptions goes as follows:

> In this part of the work the language employed by the system specialist is essentially a language for controlling the operation for language algorithms, editing text (joint with a colleague at a distant console), testing the logical consistency of statements in the representation language, and checking the legality of information structures and formats. The part of the language concerned with editing is to a large extent graphical. Both the system specialist and the author point to words and sentences in the text, move them about with the aid of their styli, insert or substitute new segments of text, and so forth. The language used in controlling algorithms is essentially standard throughout the procognitive system (p. 113).

Licklider speaks in many sections of his work of "partial models" of knowledge (p. 78), and in general his idea is linked to a deep understanding of the complexity of the body of knowledge – an understanding often lacking in many schemes for knowledge representation.

Licklider goes then beyond a "Semantic Web" model with two still interesting ideas.

One is the possibility of many representations of knowledge. In addition to the hierarchical solution implemented by Semantic Web technologies, Licklider explicitly considered, among others, "coordinate indexing", "hybrid systems" and "space analogues" (pp. 73-76):

> The most promising approach, it seems to us, is to accept the notion that, for many years at least, we shall not achieve a complete integration of knowledge, that we shall have to content ourselves with diverse partial models of the universe. It may not be elegant to base some of the models in geometry, some in logic, and others in natural language, but that may be the most practicable solution (p. 78).

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Of course, in due time, considerations of ease of computing made the hierarchical solutions the preferred ones, but Licklider's idea of a more complex network of relationships seems to me to be still of use, and often overlooked (at least in the area I know better, that is, text encoding using XML) in favor of "shortcuts" taking hierarchies as their starting point.

The second interesting idea is the inclusion of powerful, standard processing instructions in the framework. XSLT and processing languages could be seen as a modern approximation of this; however, Licklider had a more powerful and optimistic vision. In part, this was grounded in underestimation of difficulties (similar to the underestimation seen in natural language processing) and in the idea – possibly inspired by structuralism – of the existence of a limited number of basic relationships between "things". Licklider in fact supposed that there were at most 100 different *kinds* of relationships (p. 82 and p. 119). This seemed promising for formalization and for languages dealing with very abstract structures. However, it would be very difficult to argue today for this.

## Conclusions

In hindsight, it seems that the success of some sections of Licklider's program (e.g. computer networks, or workstations) carried also the seeds of oblivion for the overall idea. Licklider's framework was in fact quickly forgotten and was not considered as a reference for the computing of the following decades. A quick survey of the state of the art shows instead, if not an ongoing relevance of the framework, at least its usefulness as benchmark for the progress of computing and for a better understanding of some recurrent misperceptions regarding the nature of the information used in knowledge work. The usefulness of alternative representations of knowledge, for example, is something that could still be investigated, starting from directions like library science.

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