Cases, Reasoning and Bell's Telephone[1]

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This poster investigates memory issues that influence long-term creative problem solving and design activity, taking a case-based reasoning (Kolodner & Wills, 1993) perspective. Our exploration is based on a well-documented example: the invention of the telephone by Bell (1908). But to understand this act of creative design, we have to analyze Bell's earlier research goals. We abstract Bell's research method and the reasoning mechanisms he used that appear time and again in long-term creative problem solving. In particular, we identify an understanding mechanism used widely by those processes which rely on previous experience. Finally, we integrate the new mechanisms in a computer model, ALEC, which features creativity elements in case-based design.

Retrospectively, the obvious question related to the invention of the telephone is: what cognitive issues "delayed" the invention of the telephone till 1876? The basic principles of the telephone, electromagnetism and induction, had been known since 1831. Several inventors tried and failed to design the telephone, because they (1) relied too much on prevalent telegraphy practice, (2) ignored the basic principles of electromagnetism, and (3) gave up too soon. It looks like these inventors applied case-based reasoning poorly: they stuck to minor adaptations of telegraphy rather than reassessing the problem and analyzing it from a new perspective. In contrast, Bell reassessed the telephone problem as being acoustical and not electrical. When Bell was stuck in electrical details, he analyzed his telephony experiments using acoustical experiences and expertise.

Bell frequently interpreted and remembered his electrical experiments in terms of acoustics, that he could easily *perceive* without supplementary equipment. Consequently, in some cases he could *recognize opportunities* to solve suspended problems while pursuing other problems (i.e., the "undulatory current" was recognized while working on the multiple telegraph problem, by noticing peculiar acoustical effects). But not all the recognized opportunities fell in the above category. Sometimes, working on several problems *in the same period of time* facilitated knowledge transfer among them without any special perceptual elaboration (i.e., interleaved work on both the telephone and phonautograph inspired the microphone design for the telephone).

Our exploration of creative design (Kolodner & Wills, 1993; Simina & Kolodner, 1995) provides an initial framework (i.e., the IMPROVISER system) for a more enriched and dynamic case-based reasoning able to explain some interesting reasoning issues involved in the invention of the telephone. In this framework a designer evolves concurrently the design specification and a pool of alternatives under consideration, relying on his previous experience. But Bell's *understanding* and interpretation processes, exploring previous experience, seem far more complex than those handled by IMPROVISER. Bell used analogy when simple retrieval failed. When analogy also failed, Bell made new hypotheses by combining attributes of the (partial) design alternatives retrieved. This mechanism led to the famous hypothesis of the "undulatory current", by mixing properties of sound transmission and electrical currents. We realised that understanding is a memory issue that should play a more important role in a framework for creative design. IDeAL (Bhatta & al., 1994) stresses also the role of understanding in design. IDeAL revises its understanding of the problem based on generalizations built from specific experiences.

Based on Bell's case study, we are developing a computer model that integrates understanding and design problem solving to test our hypotheses about the role of case-based reasoning in long-term creative design. In our model the problem solving processes relying on previous experience call an understanding process, adapted from Moorman & Ram's (1994) creative understanding algorithm. The understanding process in turn may call design problem solving processes to achieve a better artifact understanding. We hope that a good understanding of creative design processes will help us build better tools to assist human designers.

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