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Recognition of Handwriting Research: Many Years of Achievement

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Abstract: *Previous research indicates that writing practice may be more beneficial than nonmotor practice for letter learning. Here, we report a training study comparing typing, visual, and writing learning conditions in adults (N = 42). We investigated the behavioral consequences of learning modality on literacy learning and evaluated the nature of the learned letter representations. Specifically, the study addressed three questions. First, are the benefits of handwriting practice due to motor learning per se or to other incidental factors? Second, do the benefits generalize to untrained tasks? And third, does handwriting practice lead to learning and strengthening only of motor representations or of other types of representations as well? Our results clearly show that handwriting compared with nonmotor practice produces faster learning and greater generalization to untrained tasks than previously reported. Furthermore, only handwriting practice leads to learning of both motor and amodal symbolic letter representations.*

Keywords: literacy, handwriting, letters, learning recognition

I. INTRODUCTION

This board conversation was a development to the principal release of the ICFHR series, which was advanced as a worldwide meeting after 10 serious and useful versions of the Global Work-shop on Boondocks in Penmanship Acknowledgment started in 1990 in Montreal. It is fundamental, in any case, to review that exploration on written by hand character acknowledgment started nearly quite a while back, and was extended around quite a while back to the more broad thought of hand-composing acknowledgment (presently not obliged to detached characters) that we work with today. The coordinators of ICFHR 2008 needed to make a move to sort out the board conversation, led by M. Cheriet, to feature progress in the field over the long course of its turn of events. Specialists M. El Yacoubi, H. Fujisawa, D. Lopresti, and G. Lorette discussed the accomplishments of twenty years of hand-composing acknowledgment and about its future. Following these outstand-ing introductions, meeting participants had the chance to air their different kinds of feedback during open and productive trades. Each part of this synopsis is drawn from the first presentation of a specialist. In Segment 1, Dr. Hiromichi Fujisawa of Hitachi (Japan) examines the effect of penmanship acknowledgment technologies on the modern area. In Segment -2 Dr. Mounim A. El Yacoubi of Institut Telecom, T&M SudParis (France) examines the need to re-structure the endeavors of the penmanship acknowledgment local area. In Area 3, Dr. Fellow Lorette of IRISA ─ Université de Rennes (France) features the new accomplishments in penmanship acknowledgment and others not too far off. In Area 4, Dr. Daniel Lopresti of Lehigh College (USA) examines the eventual fate of penmanship acknowledgment re-search as a "Fantastic Test" issue. Segment 5 closes this outline by featuring the striking focuses that will drive research on penmanship acknowledgment later on.
Impact on industrial sectors: niches to develop—*the long tail era*

1.1 The ongoing business sector for HR

The business and modern use of penmanship recognition started during the 1960s, and included business OCRs delivered by PC makers and postal (postal district) per users for mail arranging machines. Transcribed numerals were obliged at that point, as in the scholars were approached to follow a directing pat-tern in the composing enclose preprinted a dropout tone. As far as we could possibly know, unconstrained numeral acknowledgment was presented in

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the last part of the 1970s, with the goal of perusing bank really take a look at sums, including spelled-out numerals. In the last part of the 1980s and mid 1990s, unconstrained manually written word acknowledgment calculations, including those for Chinese characters, were created and applied to mail arranging frameworks in the US, Europe, and Japan.

The three business and modern applications referenced above, specifically, business structure perusing (business OCRs), bank really take a look at perusing, and full postal location perusing, have comprised most of the market for penmanship acknowledgment innovation. It appears, to some extent in Japan, that this market has been soaked, and that the outright size of the market is only adequate for a couple suc-cessful business players for each field of utilization. Because of this immersion, the quantity of players doesn't appear to increment, particularly in a few rewarding organizations.

As one of those business players in Japan, Hitachi has been attempting to grow the quantity of use fields. Our endeavor to do this is momentarily portrayed underneath.

1.2 The “long tail” of the market

Recently , the creator took a gander at the idea of the "long tail", and contrasted it with the circumstance of the OCR market, which represents what is going on of the market clearly. If we somehow managed to draw a chart of the quantity of OCR frameworks, or the quantity of exchanges dealt with by such frameworks, as an element of the applications arranged in diminishing request of their worth, then, at that point, we would have what we could call a "long tail" dissemination. To have an adequate number of uses to make the bend adequately lengthy, we just characterize "application" with no obvious end goal in mind to incorporate however many models as could be expected under the circumstances. For example, applications can be classified in view of the sort of (paper) structures being taken care of by OCR frameworks everywhere.

This, obviously, is only a speculative activity without real insights, performed for the motivations behind analogical conversation as it were. What is generally anticipated, in any case, is that the three significant applications depicted above would be situated on the left-hand side of the x-direction of a Cartesian diagram, and other various ap-plications would be circulated along the right-hand side of the x-coordinate, conceivably shaping a long tail. The inquiry then, at that point, be-comes, what could we at any point finish up from this relationship?

In the first place, the applications on the "head" (left) of the conveyance are related with rather rewarding organizations. Requests for the supportive of paper records, like bits of mail, can be colossal, resulting in an impressive errand for people to achieve. For example, each mail arranging machine in Japan processes in excess of 10 million New Year's hello cards in the fourteen day time frame toward the year's end

The items in the reports in those effective applications are distinct and frequently semantically rich. As such, the se-mantic, linguistic structure, and jargon are bound to a specific cutoff and obvious, which makes language and information handling so successful that penmanship acknowledgment frameworks can perceive unconstrained transcribed addresses with an adequately serious level of exactness in these cases. More significant is the way that the manufacturers at the top of the OCR market might have the option to put resources into promotion Vanced cutting edge advances, yielding positive criticism as far as the worth made by the items. This would prompt what we allude to as the righteous cycle, as per which further developed innovation prompts further developed items and frameworks, with the chance of additional benefits, etc.

However, the real question to be asked is whether or not this market head has been saturated. The answer seems to be that it has, at least in Japan. So, we now look at the “tail” of the OCR market to see what it is like.

The tail appropriation contains little specialty markets addressing various necessities. In contrast to the head, the benefits from the tail market applications are for the most part not enormous enough for a venture to be taken in an innovation jump toward create development. In such markets, there is an inclination for the concentration to move from modern applications to individual use applications, similar to the PDA, in the endeavor to track down new regions for development. Inferable from their tendency, these new applications request a substantially less compelled client climate, and specialized hardships related with it make an adequately serious level of exactness a test in such a climate. For instance, computerized pen applications would appear to be a promising region, yet we ought to guarantee that the clients of such applications are permitted to compose anything they need from the limitless decisions accessible,

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particularly while taking notes or clarifying paper reports. Up until this point, the main effective advanced pen applications have involved the information passage of numerals, names, and addresses .

One method for helping what is happening is make the acknowledgment innovation more flexible and simultaneously empower it to cover a more extensive area of use. More adaptable items and programming might prompt greater returns and one more pattern of venture. In the following area, we might want to address the specialized difficulties intrinsic in the mission for flexibility.

II. TECHNICAL CHALLENGES FOR VERSATILITY

As discussed above, the key to future growth will be *versatility* of handwriting recognition systems, which will enable them to cover wider areas of application. Listed below are the technical challenges that are considered crucial to overcome in order to achieve versatility:

Rapid and sustained adaptation is almost completely lacking at the present time, and most commercial and industrial OCRs do not have this feature. The recognition engines are usually customized at an engineering site prior to shipment. Customization, the fine tuning of parameters, and retraining are all carefully performed by the manufacturer's engineers. It is the lack of a method that theoretically guarantees the convergence of the adaptation process, or at least that the process will not diverge. How to provide class information for retraining is also a problem, but more important is the fact that there are many other parameters that have to be adapted than those for classifiers, for which no single algorithm for direct adaptation is known. These include parameters for layout analysis, word segmentation, character segmentation, and so on.

The mix of language handling into word acknowledgment has been fruitful in the restricted spaces of check sum and postal location perusing. Such calculations have been alluded to as dictionary coordinated techniques or information based strategies. In any case, even in the fruitful applications, fragmented information has been a difficult issue, albeit a work is constantly made to limit its impact. Address data, for instance, is consistently likely to change, thus, without support, the dictionary for a location per user is deficient. Inadequacy of the information base may likewise be the consequence of human mistake brought into information catch process. This is-sue is most critical when the area of use is limitless, as talked about with regards to the long tail.

Resistance to incorrect and deficient sources of info is another issue which has not yet been tended to. As far as we can tell of fostering a location per user, we found that catching normal mistake examples and coordinating them into an information base ahead of time, which is a sort of customization, is compelling. The flexibility we are searching for the present is the limit of the framework to consequently distinguish mistakes all alone and even to perceive the info accurately .

The creation of a language-independent recognition infrastructure which can be shared by many applications is an engineering issue. The aim is to drastically minimize the cost of developing multilingual OCR systems internationally. Such an infrastructure would include tools for lexicon development, pattern matching algorithms, an application interface, and so on.

Although the issue of search engines for handwriting cannot be addressed by the recognition algorithm by itself, it is listed here to emphasize those new applications, like digital pens for example, may have greater need for a search function than for a recognition function. Of course, if we had a perfect recognition engine, it would not be at all difficult to build a search engine for handwriting. One recommendation is to develop search algorithms that do not require perfect recognition engines, and then to develop applications that fully exploit the search capability. An annotation system using a digital pen would be an application of that kind.

At last, one our assumptions is that a logical report will be con-ducted to explain the connection among penmanship and mind exercises. The expectation is to respond to whether electronic frameworks, for example, a console and mouse, will completely override the actual demonstration of penmanship. Penmanship seems, by all accounts, to be the most immediate, normal approach to communicating the thoughts in our cerebrum. Simultaneously, the utilization of the hand to compose words and attract representations appears to animate the cerebrum more than the utilization of electronic means, as well as to upgrade the memory. This is guess, yet, on the off chance that valid, the consistent coordination of penmanship and electronic data handling would be an ideal type of human data handling, and a

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computerized pen arrangement would function admirably for this optimal framework.

2.1 Is there a need to restructure the HR community effort?

Effective handwriting recognition systems exist for constrained application domains, and two of the most successful so far have been automatic mail sorting and automatic check processing. One of the main features of these tasks is that both involve the processing of inputs exhibiting rich context and high redundancy.

In other words, zip code recognition allows for a dramatic and dynamic reduction in the vocabulary associated with cities. Furthermore, the combination and cross validation of the output zip, state, and city scores usually leads to an effective and reliable decision at the definitive *destination* (city–state–zip) level . prompts a powerful and solid choice at the conclusive objective (city-state-zip) level. The equivalent goes for the choice at the conveyance level, which proficiently utilizes the acknowledgment of the road (or mailing station box) number and the acknowledgment of the road (mailing station box) name. The objective and conveyance lines can likewise collaborate to deliver an ideal choice at the location level. Taking everything into account, the politeness sum and the lawful sum comprise the info data for cross approval, which assumes a comparative part in diminishing acknowledgment intricacy and in giving a dependable choice at the really look at level. The above perceptions don't imply that mail arranging and check handling are simple, since they include other non paltry undertakings, like the programmed area of the fields of interest (address alliance, individual location fields, civility and legal amount fields), and background removal (especially in the context of real checks associated with different financial institutions, each exhibiting a different and complex background). These tasks can be challenging on their own and require effective pre-processing techniques to make subsequent recognition feasible. The main point, however, is that impressive commercial systems could become a reality, despite insufficient handwriting recognition accuracy. The read rate of US handwritten mail pieces, for instance, is currently about 95%, with an error rate below 3%. Speech recognition research, in comparison, took another direction from the outset. The speech community benefited early on from the support of large-scale programs like DARPA, which organized and funded several competitions which, on each occasion, took speech recognition maturity to the next level. Large datasets from various sources had been made available and sound evaluation protocols de- fined to encourage researchers to compare their results on widely agreed-upon criteria. One of the immediate effects was that, unlike the handwriting community, the speech community quickly moved from *isolated* speech recognition to focus on the more challenging task of *continuous* speech recognition. The other major consequence was that most research labs quickly adopted state-of-the-art techniques on some speech recognition phases, like the widespread adoption of a common front end (roughly speaking, sampling at about 10 ms, Mel-frequency Cepstral Coefficients (MFCCs), and working under the log scale) and focused on open issues like discriminative and adaptive methods (beginning in the 1990s) and more robust language models. Assuming we take a gander at penmanship acknowledgment, there are some Questions that are shockingly difficult to reply, in spite of the colossal measure of exertion committed to them throughout the course of recent years: What is the most ideal element extraction strategy that anyone could hope to find today? Would it be advisable for us to over section written by hand words? Assuming that the response to this last option question is no, how could the sliding window width be ideally dissuade mined? Is the naming of capitalized and lowercase letters essential for an ideal presentation of an unconstrained penmanship recognizer? The fact of the matter is, it is difficult to address these inquiries be-cause there has been no efficient examination of cutting edge frameworks on normal datasets under special and distinct evaluation conventions. Besides, due to their differed exploratory set-chimes (size of datasets, jargon utilized, and so on), these frameworks can't profit from each other in an ideal manner according to an improvement viewpoint.

Despite the fact that many datasets exist for some dialects, what is missing is the huge scope reception of some of them as benchmarks for testing by the local area. Besides, the size of a significant number of these sets isn't adequate for this reason. Studies may in this manner be required to evaluate the necessities of the local area as far as datasets containing separated written by hand words, yet in addition transcribed sentences and manually written message pages. Exceptional assessment conventions will be utilized to pass judgment on the viability of an entire penmanship Recognizer , one of its modules (for example preprocessing or highlight extraction), or a language model.

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Recognizer considered for and prepared on transcribed information just may confuse a few printed information with written by hand information with a generally high certainty; (2) the improvement of language models (LMs) well defined for penmanship (accentuation marks, lowercase versus capitalized, complemented letters), as well as discourse can imagine LMs, and their dynamic transformation to penmanship style and to LMs (through a unique subject location technique, for example); (3) the advancement of dependable measures to survey the recognizer certainty and to incite a manual administrator record, as a 100 percent acknowledgment rate isn't possible ; and, at last; (4) sound proportions of picture quality, so less exertion is spent on information which are not difficult to perceive and more exertion and assets on information which are challenging to perceive.

Despite its current performances in unconstrained contexts, handwriting recognition will continue to attract commercial appli- cations involving a wide range of domains, including healthcare and insurance, as well as large stores and administration facilities. How- ever, the key to opening the door to far more businesses and new applications will be the maturity of context-independent natural handwriting recognition.

III. RECENT ACCOMPLISHMENTS IN HR AND FUTURE POSSIBILITIES

The internet based partners of the disconnected HR procedures, which are executed on little gadgets like PDAs and cell phones, have not yet been extremely fruitful. We accept there are a few explanations behind this. In the first place, the procurement surfaces of such gadgets are by and large viewed as by most clients to be excessively little, bringing about the restricted resolution of the digitizer and in too little space on the screen in which to compose in excess of a couple of words. Second, a virtual console is just OK for contributing exceptionally short snippets of data or messages, and HR is just helpful for the contribution of whole pages of notes, an-recorded charts, and so on. Third, most existing pen-based man-machine interfaces (MMI) are as yet not very easy to use, and some are exceptionally bulky or dreary to utilize. Fourth, the underlying penmanship recognition rate is by and large not adequately high to promptly persuade the client to change to another terminal. Besides, adjusting the sys-tem to the client's penmanship style is normally too tedious and too drawn-out a cycle.

3.1 Challenges for the not so distant future

With the exception of a few extremely fruitful modern applications portrayed beforehand, neither the online nor the disconnected HR strategies are in boundless use on an everyday premise, and the issues presented by HR are a long way from being settled. Further examination is required, and the HR area ought to be investigated both in more noteworthy profundity and more noteworthy broadness.

Examination of the space in more prominent profundity will comprise, for ex-more than adequate, of concentrating on the acknowledgment of misshaped, deficient, or loud penmanship information, creating strategies to empower penmanship styles to be gained from tiny examples, creating calculations for quick variation to another individual penmanship style, planning

3.2 A grand challenge problem for HR

On the one hand, the offline HR problem has not yet been totally solved, and cannot be considered as an off-the-shelf tool. There exist huge amounts of archived documents all around the world, which cannot be easily and immediately consulted at a distance by every- one on the Web. A new and major challenge might be to digitize massive quantities of these documents in order to create databases that are Web-accessible. This procedure would probably also require some specific search tools to help users find specific documents. From this point of view, it would be very useful to use offline HR for word spotting techniques in order to be able to automatically index the content of archived documents. This will require writer- independent offline HR systems, based on a great deal of linguistic knowledge.

On the other hand, because there is still a big demand for nomadic computing (computing everywhere, and standing up, for example), online HR is still of interest in this area too. Despite the fact that it exists in a number of devices, such as PDAs, smartphones, tablet PCs, and netbooks, there is still no light, highly user friendly, pen- based and cheap terminal device that can be used on a daily basis. Such a device would be very useful in the field or during lectures or meetings for taking notes, drawing schemas and diagrams, and so on. The study of such a device (both hardware and software)

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remains a challenge for the online scientific and industrial HR communities.

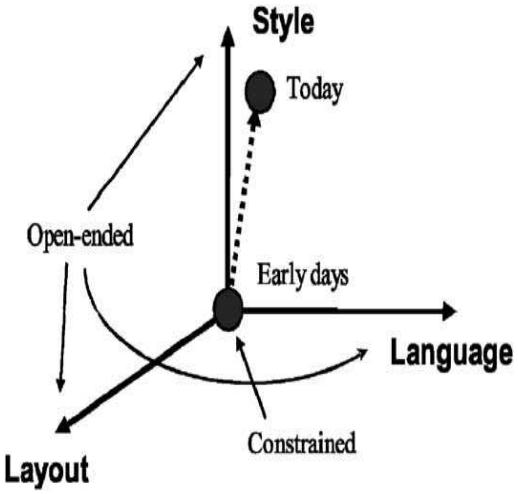
IV. FUTURE HANDWRITING RECOGNITION RESEARCH: A GRAND CHALLENGE PROBLEM

Since, to date, offline handwriting recognition research has achieved notable successes in certain focused application areas, including postal address reading and bank check and form pro- cessing, we might now wonder, why just here and not elsewhere? Certainly economics—i.e. business considerations—plays some part in this, but, as researchers, we can content ourselves with meeting the challenges posed by the technical side of the issue. What are barriers to solving the broader handwriting recognition problem?

One view that might help explain the present situation is to regard specific instances of handwriting recognition as points in a three- dimensional space, as illustrated in Fig. 1.

Here, the dimensions are style, language, and layout. The first of these represents the myriad ways that people express their individuality when writing, the second captures the complexities of human language (including the expression of visual concepts), and the third refers to the manner in which information is organized on the page. Of these three dimensions, substantial progress has been made in the first by developing techniques that can account for inter-writer variability, but we have seen much less movement along the other two dimensions. This is illustrated by the two data points in the fig- ure and the dashed line showing the direction of our progress.

Hence, handwriting recognition for inputs that are fully unconstrained in terms of layout and language remains an elusive goal. In an interesting (and perhaps instructive) side note, language model- ing has played a much more prevalent and productive role in the field of speech recognition, a problem that is in some sense "easier" than document analysis, because it is only two-dimensional (missing the layout component).



A truly unconstrained handwriting recognition system would be able to handle any of the inputs shown in Fig. 2 below, which provides only a very small sampling of the range of ways that humans express themselves in writing. Without the economic burden of having to worry about funding or requiring a "killer" business application, what is the most general formulation of the handwriting recognition problem?

This is an interesting question in its own right and has the flavor of what have come to be known as "Grand Challenge Problems." In 1900, the famous mathematician David Hilbert proposed 23 unsolved problems which helped define the field of modern mathematics and drove it forward for almost a century. Nearly all these problems have now been solved, and so, in 2000, the Clay Foundation proposed seven new problems, known as Millennium Problems, each with a $1 million prize (http://www.claymath.org/millennium/).

In fields that are perhaps more similar to an experimental science, like pattern recognition research, one can point to the recent DARPA Urban Challenge, which had as its goal the building of a driverless vehicle that could navigate a 96-km (60-mile) urban area course in less than 6 h, while obeying all traffic regulations and dealing with other vehicles and obstacles (http://www.darpa.mil/grandchallenge/index.asp). Teams from around the world competed, generating tremendous media attention and widespread interest in the field of robotics.

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In the area of artificial intelligence, at the website longbets.org, two well known founders in the field of computing, Mitch Kapor and Ray Kurzweil, have staked a $20,000 wager on the provocative statement, “By 2029 no computer—or `machine intelligence'—will have passed the Turing Test” (http://www.longbets.org/1). That this debate is taking place in a very public forum will undoubtedly cause bright, highly motivated students and researchers to ponder whether they might have something to contribute to answering the question and, in doing so, advance the science.

What, then, would be a Grand Challenge Problem for handwriting recognition? How would the task be formulated? How would success be measured? These are intriguing questions, and taking a step back from our day-to-day research activities to consider such issues can be illuminating. In considering the eventual fate of penmanship acknowledgment research, certain central issues come to the front. The first of these are viable in nature, and incorporate the need to foster plans of action where penmanship acknowledgment is the innovation of decision in applications that customers view as convincing. The prerequisites directed by the business commercial center will assist with outlining the issue in manners that are adequately general to be helpful, however not so excessively aggressive as to be illogical in the close to term.

Contemplating the issue from the other heading, it very well might be enlightening to attempt to approach penmanship acknowledgment as a Fantastic Challenge Issue, one deserving of thought and energy.

Thinking more deeply about the ground rules, it is possible to come up with a long list of related questions. Should all three dimensions be completely open-ended? Online or offline handwriting? Unilingual or multilingual? Text only, or anything a person can write or sketch? What level of performance is required to win? Is success measured by word error rate or a task-based evaluation? If the latter, what is the task? Should there be limits placed on com- putational resources or time used?

Fig. 2. Samples of challenging handwriting

There are more questions than answers, and we will not argue here for one formulation over another. Rather, we hope to spur de- bate within the community. Having our own set of Grand Challenge Problems for handwriting recognition research would advance the field and draw well-deserved attention to the good work that is al- ready being done.

V. CONCLUSION

In considering the eventual fate of penmanship acknowledgment research, certain central issues come to the front. The first of these are viable in nature, and incorporate the need to foster plans of action where penmanship acknowledgment is the innovation of decision in applications that customers view as convincing. The prerequisites directed by the business commercial center will assist with outlining the issue in manners that are adequately general to be helpful, however not so excessively aggressive as to be illogical in the close to term. Contemplating the issue from the other heading, very well might be enlightening to attempt to approach penmanship acknowledgment as a Fantastic Challenge

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Issue. e impractical in the near term. Thinking about the issue from the other direction, it may be instructive to try to frame handwriting recognition as a Grand Challenge Problem, one worthy of thought and energy unconstrained by monetary concerns. As an intellectual exercise, there is some value in taking such a view. In posing his famous test for machine intelligence, Alan Turing defined the question in such a way that few actually try to solve it, but everyone is aware of it. The goal of achieving performance which is indistinguishable from that of a human on a suitably broad range of inputs could be the starting point. People are not perfect, however, and this is a fact we sometimes forget. Given the myriad uses of handwriting and the sheer number of written languages in existence, it is clear that no single human could handle every possible input. Recognizing this limitation is also a human trait. So, how good would a machine have to be, to be declared the equal of a human? Attempts to define the Grand Challenge Problem for handwriting recognition lead naturally to two key sub-goals: the need for comprehensive, versatile multilingual datasets and the search for evaluation paradigms that extend beyond current measures derived from basic word or character accuracy rates. We encourage the international community to ponder these points, as we explore the papers included in this special issue and shape the goals for our own future research

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