Detecting and treating invasion in the courtesy amount field on bank checks

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Abstract

An approach is proposed for detecting and eliminating invasion in courtesy amount fields. This is a important step toward automatizing the bank check process. In a real database, 18% of handwritten courtesy amount fields exhibited invasions in the legal amount and signature fields. Experimental results have shown that the proposed approach is robust and efficient for improving the automatic recognition of real Brazilian bank checks.

Keywords: Contour Invasion Detection, Courtesy Amount Recognition, Automatic Check Processing.

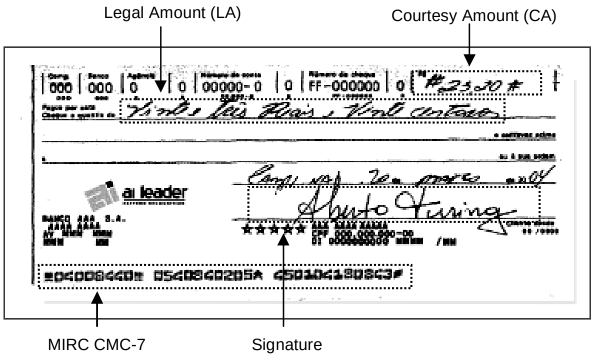


Figure 1. Sample of an Brazilian check image.

1. Introduction

Automatic check processing is a real banking industry interest, as a large part of checks are still processed manually. This processing normally involves the manual reading of the checks and keying their respective values into the computer. As there is a high volume of this kind of document, this procedure involves high cost due to its labor-consuming operation.

A bank check image is formed by a set of fields. These fields may be handwritten, handprinted or printed. The amount written in numbers is supposed to be for courtesy purposes only and is therefore called the "courtesy amount". The information contained in a check is frequently handwritten. In real databases, only about 11% of checks are print filled [17]. The check document also contains the name of the recipient, the date, the amount to be paid (textual format), the courtesy amount (numerical format) and the signature of the person who wrote the check as well as symbols and graphics [15, 7, 13, 14]. The official value of the check is the amount written in words. This field of the check is called the "legal amount". However, the courtesy amount is more effective in the automatic recognition process. Figure 1 is an example of a bank check.

The recognition of machine-printed documents has been a very successful application [17, 10]. In contrast, computer systems find it more difficult to read handwritten texts and numbers. In the processing of handwritten fields, computer systems are generally slower and yield less accurate results than humans [4, 14].

The challenge for the automatic bank check reading process is the recognition of the courtesy amount field. The difficulty is due to the great variability in handwriting styles, handwriting devices, a lack of patterns and symbols used by writers to prevent fraud. The courtesy amount field also exhibits noise, irregularities in the boundary of the components and part of the digits from other check fields. Thus, the main problem facing all automatic recognition systems is their limited accuracy due to the high level of variability with which they have to cope.

The segmentation of the string that contains the courtesy amount into individual digits is the most critical task in check processing [13]. This process may involve the separation of touching characters and the merging of character fragments with other pieces.

There are studies in the literature on locating the courtesy amount block on bank checks [14, 6, 9] and segmentation of unconstrained handwritten connected numerals [1, 11, 3, 16, 8]. However, papers on neighbor-

Figure 2. Examples of courtesy amount invasion.

hood invasion from other fields in courtesy amount field are rare. Letters from the legal amount field often cross the courtesy amount elements. Parallel lines may also pass through the entire extension of the check, including the courtesy amount field. Sometimes this invasion may even come from the signature field.

Figure 2 presents samples of these problems. It is important to note that this kind of problem rarely occurs in printed courtesy amounts. It is, however, very common in handwritten fields because account holders do not have any predefined pattern for writing, which makes automatic reading much more difficult.

The segmentation of connected numbers is the main bottleneck in the handwritten numeral recognition system [12]. In general, there are two types of segmentation schemes: recognition-free segmentation and recognition-based segmentation [5]. In recognition-free segmentation, a numeral string is divided into segments by rules without recognition. In recognition-based segmentation, candidate segmentation points are verified with a recognizer. In the case of courtesy amount segment invasion, we cannot use a recognizer because there is no pattern to the values of the field and it is not easy to define general rules for dealing with this complex problem.

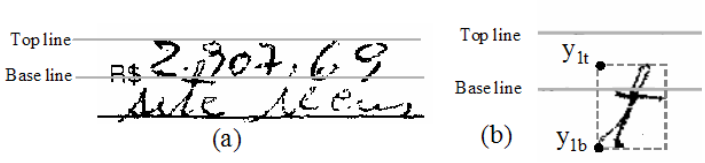
In this paper, an heuristic approach is proposed for dealing with courtesy amount invasion. The invasion problem in the courtesy amount field is rather common. Approximately 18% of the Brazilian checks exhibit invasion from the legal amount and signature fields. Solving this problem is an essential step toward the correct digit segmentation and classification of courtesy amount values. To the best of our knowledge, this is the first work that deals specifically with the problem of courtesy amount invasion.

2. Brazilian check difficulties

Brazilian bank checks have certain characteristics that render the recognition process of the courtesy amount a challenging problem: *(i)* one such characteristic is behavioral, as many bank account holders include delimiters in the courtesy amount field with the aim of protecting their checks from possible fraud; in this case, there is no roadmap to be followed when filling in the courtesy amount; *(ii)* another characteristic is the physical aspect of the image from the bank, such as security lines and figures on the background.

Figure 2 presents types of delimiters used on Brazilian bank checks. It is common to see one delimiter at the beginning of the courtesy amount and the same finishing the courtesy amount. However, variations are not prohibited, such as those listed here: no use of delimiters; many delimiters at the beginning and none at the end or vice-versa; different delimiters at the beginning and end of the courtesy amount.

Most Brazilian banks add a security line at the right side of the check. This is a sinuous and randomly generated line that crosses through different fields, such as the courtesy amount, legal amount, payees name, date and signature. The aim of these lines is to avoid falsifications. When one of these lines crosses through the courtesy amount, it compromises the performance of the recognition systems. After the binarization process, it is difficult to discriminate which part belongs to the security line and which part belongs to the courtesy amount sym-




```
if yit < (baseLine - h × λ1) and
   yib > (baseLine - h × λ2)
then "There is an invasion."
```
(c)

Figure 3. (a) CA image with invasion. (b) Zoom on the invasion subimage. (c) Condition to detect invasion.

bols. Due to binarization, the image may also contain spurious noise pixels and irregularities on the boundary of the components, leading to undesired effects in the system.

3. Detecting and Eliminating Invasion

Segment invasions derive of letters and lines from the legal amount field that cross the courtesy amount elements. There are cases of parallel lines that pass throughout the entire extension of the check and it is not uncommon for invasion to come from the signature field.

To eliminate possible invasions, the first step is to locate the courtesy amount area in the check image. In Brazilian checks, the courtesy amount is always on the right upper side of the check image. After the macro-localization of the field, the system needs to search for the limit lines of the courtesy amount: top line and base line, as shown in Figure 4. The amount of black pixels (foreground pixels) in the horizontal projection is used to find these lines.

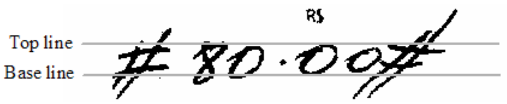


Figure 4. Courtesy amount base and top lines.

After the courtesy amount image is sharply located, all the connected components are labeled using 8-connectivity neighbor [2]. To analyze possible invasions, a larger image is needed that allows the visualization of an area greater than the courtesy amount area. Thus, a larger image with the courtesy amount in the middle is extracted from the original check image. The size of this image is defined based on a factor that expands the area of the courtesy amount image. Suppose that $imaCA(x, y)$ is the courtesy amount image with dimensions $m \times n$; the expanded image will have $(m + fv) \times (n + fh)$ dimensions, where fv and fh are factors for enlarging the image in the vertical and horizontal directions, respectively. The factors used in our experiments were: *(i)* fv, representing 30% of the m dimension and *(ii)* fh, representing 20% of the n dimension. These values were determined empirically after many experiments.

3.1. Detecting false invasions

The next step in detecting invasions is to identify the connected components of the expanded image ($imaCA_b$). For each connected component in $imaCA_b$, conditions are tested to determine whether the points represent an invasion. These conditions are based on structural heuristics. Figure 3 presents a sample of this heuristic.

A component in $imaCA_b$ is only identified as an invasion if it is bigger than a predefined size and if it has some part below or above the base line, as shown in Figure 3(c). λ_1 and λ_2 represent these percentage factors, which were adopted, respectively, as 0.2 and 0.8 in our experiments. y_{it} and y_{ib} represent the coordinates of the top and the bottom of the component. The definition of these boundaries is crucial to system performance. In Figure 5, some components of the image may not be considered an invasion and the system needs to detect these (false invasion). This is the case of commas and delimiters (such as ”#”, ”=”, ”x”, ”(”, ”)” etc.), which often cross the baseline, but do not come from the legal amount area.

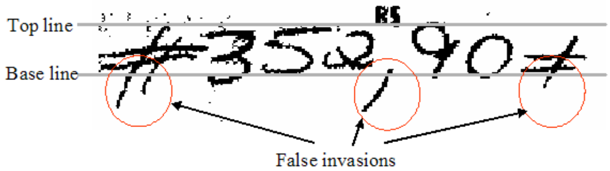


Figure 5. Example of false invasion.

3.2. Purging invasions

After detecting an invaded segment, it is necessary to remove the piece of this component responsible for the invasion. The main idea of our solution is to search points from where it is possible to break the segment into two subsegments, such that one subsegment has enough information to recognize the digit successfully. In order to do this, we adopt a depth-first search based on the “walk in the labyrinth” problem. One of the most popular solutions to this problem always works: choose a wall close to you (left or right), place your hand on this wall and go forward through the labyrinth without removing your hand from the wall.

Depth-First Search Algorithm

```
h1 = ∅ (h1 is the coordinate points of the first curve)
h2 = ∅ (h2 is the coordinate points of the second curve)
L = ∅ (L is the list of edges to be explored in our search)
Choose the start point of our search as Ps (the coordinates
beside of the first point in the bottom of the invaded image)
Search (Ps)
while(L is not full)
{
   remove edge (v, w) from end of L  (v and w are the
   coordinates of two points)
   if w not yet visited
   {
      Process (w)
      Search (w)
   }
}
```

In the labyrinth problem, the walk is only finished when the exit is reached. In our case, we stop the search when there is a significant change in the search direction. Figure 6 exemplifies this scenario. In Figure 6(a), the path is traced by the algorithm when the wall is on the left and in figure 6(b), the wall is on the right.

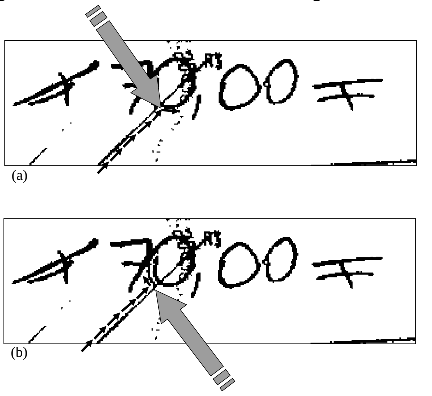


Figure 6. Coordinates: (a) Left wall. (b) Right wall.

The algorithm depth-first search presents the pseudo-code of the proposed method. The algorithm receives the image of the invaded segment as the input - the region of the image where the algorithm must test the interrupt condition and the wall chosen to place the hand (left or right). The algorithm gives the coordinates where it stops the walk as the output.

If the search is running and chooses the left wall to place the hand, it will return the coordinate illustrated in Figure 6(a). If it chooses the right wall, it will return the coordinate illustrated in Figure 6(b).

The algorithm is useful in locating the exact points of the imaginary line that divides the invaded segment into two sets: the set of pixels of the invaded segment and the set of pixels causing the invasion.

Process (***v***)

```
if |h1| < 10
{
   add v in the end of h1
   if |h1| = 10 then
   {
      h2 = ∅
      add the last 2 points of h1 into h2
   }
}
else if |h2| < 10
{
   add v in the end of h2
}
if |h1| = 10 and |h2| = 10    (there is completed both curves)
{
   if h2y < base cut          (the 2nd curve is inside the cut region)
   {
ψ1 = ∇h1 / ‖∇h1‖     (∇f is the gradient over the function f)
ψ2 = ∇h2 / ‖∇h2‖     (Ψ is the unit vector of the direction of the gradient)
      if |Ψ1 - Ψ2| > 15º
      {
         Let the cut point (Pcut) be the last coordinates in the vector h1
         and stop the entire process of the Depth-First Search Algorithm.
      }
      else
      {
         h2 = ∅
         remove the first 7 points of h1
         add (h12,h13) to the end of L, where h1 = {h11,h12,h13}
      }
   }
   else
   {
      clear h1 and put the last point of h2
      h2 = ∅
      add (h2,9,h2,10) to the end of L, where h2 = {h2,1,h2,2,h2,3,…, h2,10}
   }
}
```

Figure 7 presents an example of the images generated by the proposed algorithm. Figure 7(a) shows the original image with an invasion caused by a straight line. Figure 7(b) shows the base and top lines of the courtesy amount area. In Figure 7(c), it is possible to identify only the connected component that promotes the invasion and identify the point chosen by algorithm to cut the segment after erasing the invasion. Finally, Figure 7(d) shows the courtesy amount image without invasion. The procedure has removed the set of pixels that represents the invasion leaving the digits and symbols of the courtesy amount intact.

Search (***v***)

```
visit v
for each edge (v, w)
add edge (v, w) to end of L according to the following precedence:
   a) if the walk direction is left then:
      LEFT, UP_LEFT, UP, UP_RIGHT, DOWN, DOWN_LEFT, DOWN_RIGHT, RIGHT
   b) if the walk direction is right then:
      RIGHT, UP_RIGHT, DOWN_RIGHT, DOWN, DOWN_LEFT, LEFT, UP_LEFT, UP
```

Table 1. Accuracy rates using different databases.

	Database (Accuracy Rate)		
	without invasion	with invasion	Joint database
Default system	749 (65.02%)	63 (25.51%)	812 (58.04%)
System with invasion detection	749 (65.02%)	101 (40.89%)	850 (60.76%)
Total of images	1152	247	1399

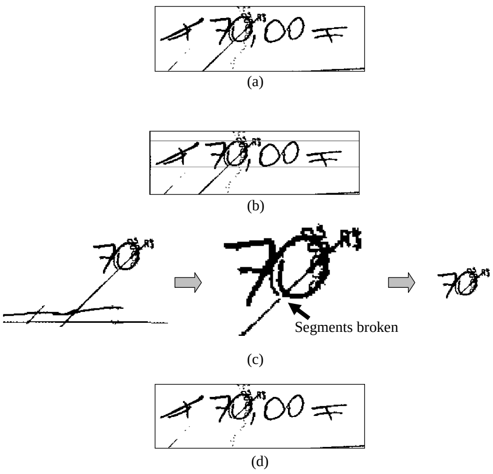


Figure 7. (a) Original image. (b) Base and top lines. (c) Separating the segments. (d) Final image without invasion.

4. Experiments

The database used in the tests was composed by real images of Brazilian bank checks, which usually contain very complex structures on the background. Samples of the courtesy amount fields are illustrated in Figure 2. A total of 1399 images of handwritten Brazilian bank checks were used in the experiments. From this amount, 247 images contained invasion in the courtesy amount field, representing approximately 18% of the image database.

Initially, the database was divided into two parts. The first part contained images with no invasion in the courtesy amount field (1152 images). The second part was formed by check images with invasion in the courtesy amount field (247 images).

The experimental results are presented in Table 1. The images were classified by an engine for automatic bank check recognition produced by AiLeader Technologies©[1]. The accuracy rates are based on a default system. The default system does not use the invasion detection procedure. The next experiment shows the performance of the system using the proposed invasion detection procedure. The analysis with the database without invasion in the courtesy amount fields achieved an accuracy rate of 65.02%, even when using the invasion detection function. This results is interesting, as it demonstrates that the proposed algorithm did not destroy non-invaded images.

When the database with invasion in the courtesy amount field was used as input to the system, system performance was highly increased after the invasion treatment procedure. Without the proposed procedure, the accuracy rate was 25.51%. Using the invasion treatment heuristic, the accuracy rate was increased to 40.89%. This result is, approximately, 15 percentile points higher than the result found not using the invasion treatment procedure on the database with invasion. This is a very good rate based on the fact that the quality of the images in this database was very poor due to the invasion curves from other fields. The images are in black-and-white, which is a more difficult scenario than gray-scale images, as it is easier to remove invasion based of the intensity of the line in gray scale than in binary images.

Table 1 also shows the impact when the function is integrated to the system and all images in the database are used to evaluate the system. As the amount of images with invasion represents approximately 18% and that the gain generated by the invasion treatment procedure causes an improvement of approximately 15 percentile points, when the database is completely evaluated, there is an expected gain of around 15% of 18%, which is approximately 3 percentile points. This is attested by the results achieved using the joint database: 58.04% (default system, i.e, system without the invasion detection procedure) and 60.76% (system with invasion detection procedure) accuracy rates.

There are no papers in the literature dealing specifically with digit invasion to compare with the proposed work. Most studies deal with segmentation of touching digits, but do not address the problem of invasion of information from other fields of the check [11, 1, 12]. This paper addressed the problems of invasion in courtesy amount fields and demonstrates the relevance of studies on this problem.

5. Final Remarks

In this paper, an approach was developed for dealing with invasion in the courtesy amount field. After an inspection in the real database of Brazilian bank check images, approximately 18% of the courtesy amount fields

[1]www.aileader.com.br

were invaded by other fields of the check. Detecting and eliminating this invasion is a challenging task that will certainly improve the performance of automatic check reading.

The tests performed on a real Brazilian bank check image database demonstrated that the proposed approach achieved very good rates when the courtesy amount image in invaded. The results also demonstate that the proposed approach does not interfere when there is no invasion in the courtesy amount field. This means that the procedure for detecting false invasion performed well on the database used.

Most Brazilian banks insert security lines in their checks, which are sinuous and randomly-generated lines that cross through many fields, such as the courtesy amount, legal amount, payee's name, date and signature. The aim of these lines is to reduce falsifications. However, when one of these lines crosses through the courtesy amount, it compromises the performance of the recognition systems. In black-and-white images, it is especially difficult to discriminate which part belongs to the security line and which part belongs to the courtesy amount symbols. We are currently working to minimize this problem.

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