

Bibliography of Works Done on CAPTCHA

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Abstract

Nowadays, a great amount of information is circulated through the Internet. Some of them exclusively belongs to a special group of users and requires protection and safeguarding against unauthorized access. To this end, a category of systems called HIP (Human Interactive Proof) have been introduced to distinguish between various groups of users.

CAPTCHA (Completely Automatic Public Turing Test to Tell Computer and Human Apart) methods are one of the important branches of HIP systems which are used to distinguish between human users and computer programs automatically. These methods are based on Artificial Intelligence (AI) topics. The goal of these systems is to ask questions which human users can easily answer but current computer programs cannot.

During past years, many researchers worked on HIP and CAPTCHA systems. In this paper, we try to collect different works which are done on HIP and CAPTCHA systems and create a complete bibliography of published works. We collect 87 published works and classify them into a number of categories. This paper contains different works which are done for creating CAPTCHA methods, attacking CAPTCHA methods and applications of CAPTCHA methods. We think that this paper can help new researchers in CAPTCHA domains to quickly find the works which are done previously.

1. Introduction

Many aspects of human life are affected by the expansion of the World-Wide Web (WWW). In particular, in developed countries, many daily affairs from daily shopping to education and commerce can be done using the Internet. A common action which is done in most websites, especially those belonging to commercial and administrative applications, is to fill out registration forms for certain purposes. After filling out the

forms by entering the required information, the individuals are allowed to login into that website and carry out certain jobs. Unfortunately, there are persons who abuse web services by writing programs which do automatic false registration in websites. These programs automatically fill out forms with incorrect information in order to enroll in the site. This wastes a large volume of the resources of the site in favor of the profit-seeking programmers and reduces the performance of the system.

Various methods have been presented in order to prevent such attacks, aiming at distinguishing human users from computer programs. The main characteristic of these methods is their automatism so that they can be implemented automatically by computers; because the examination of a large bulk of registrations on the Internet websites by human requires a great deal of time and expense and in some cases, such as email services websites, may even be practically impossible. Therefore, it is necessary to use automatic systems to distinguish human users from computer programs.

In artificial intelligence (AI), a test known as the Turing test [76] is proposed for proving the intelligence of a computer. In this test, a human person and a computer are put in two different rooms and a human interrogator in a third room asks them questions. If the interrogator cannot recognize which room the computer is in and which one the human, it is said that the computer has passed the Turing test. A similar method to the Turing test can be used to distinguish human users from computer programs with the difference that the human interrogator is replaced with a computer. The computer interrogator asks questions from the applicant to distinguish between the human user and the computer program. These methods are known as CAPTCHA (Completely Automated Public Turing test to tell Computers and Human Apart), after the CAPTCHA project which is done at Carnegie Mellon University [79]. Therefore, the main focus of these methods is on questions that the human user can easily answer but the present computer programs are hardly likely to be able to answer.

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CAPTCHA methods can be generally divided into three groups: OCR-Based, Visual Non-OCR-Based and Non Visual. Optical Character Recognition (OCR) programs are used for automatically reading the texts, but they have difficulty reading texts printed with a low quality and can only recognize high-quality typed texts that use common standard formats. However, the defects of the OCR systems can be taken as an advantage by changing the picture of a word so that it can only be recognized by a human and not by any OCR system.

In OCR-Based methods, the image of a word with distortion and various pictorial effects is shown to the user and he must type that word. Due to presence of various pictorial effects, the computer will encounter problems in the recognition of the word and only a human user can recognize the word. We explain these methods in section 2.1. But these methods usually result in dissatisfaction of users. On the other hand, efforts have been made for breaking these methods such as [43]. In section 4 we discuss some of these attacks.

In contrast, we can talk about Visual Non-OCR-Based and Non Visual methods which are easier to pass for users than OCR-based ones. These methods are studied in sections 2.2 and 2.3. For example, in Collage CAPTCHA method [57], the image of some objects with distortion is shown to the user and he is asked to click on a certain object.

CAPTCHA systems are usually used to prevent fake registration by computer programs in websites, but can be applied to other applications such as anti spam applications. We explain these applications in section 3.

CAPTCHA is one of the important branches of HIP systems. HIP is the abbreviation of Human Interactive Proof and is used to call systems in which human users prove their membership in a special group through a challenge/response protocol. Some examples are: human versus machine, himself versus any other person, adult versus a child, etc [7]. Most of HIP works have been done in field of CAPTCHA and few works have been done in other fields of HIP such as distinguishing between a special group of users and other users. We also survey some of these HIP.

In this paper we try to collect different works which are done on CAPTCHA during past years. The main goal of this paper is to create a comprehensive bibliography of works done on CAPTCHA. Because of the lack of space, we only group similar works and describe the main ideas of some method.

In section 2 we will briefly survey the different CAPTCHA methods proposed. Then we will survey the applications of CAPTCHA methods in section 3. Section 4 contains attacks and analysis which are done on CAPTCHA methods. The last section is the conclusion.

2. CAPTCHA Methods

The method designed in AltaVista in 1997 is known as one of the first CAPTCHA methods [7].

von Ahn defined CAPTCHA method formally in [78]. Their CACM paper [79] is a brief description of methods created in the CAPTCHA project.

Baird had a survey of some the CAPTCHA methods in [2]. His paper in DAS 2002 workshop is one of the first papers which introduces the CAPTCHA problem [7]. His preface on the HIP 2005 workshop proceedings also describe the status of CAPTCHA methods at that time [5]. Another survey of CAPTCHA methods is [47]. All of these surveys are not broad and mention a small number of methods. So we think that a comprehensive survey on CAPTCHA methods is required.

2.1. OCR-Based Methods

Pessimal Print [4] is one of the first OCR-Based methods. Another early work on OCR-Based CAPTCHA methods is [83]. BaffleText [20] is another OCR-Based method which generate meaning less pronounceable words. ScatterType [6] is another method created by authors of BaffleText method. The authors of [9] discuss how to generate random words which are easier for human users. Another similar paper is [81]. The method which is currently used by Microsoft web services is described in [17, 16, 18, 19].

A special method for using in console applications is presented in [23]. Method [38] uses visual patterns as foreground and background for displaying the text which the user must type. Rusu proposed Handwritten CAPTCHA, which uses scanned handwritten words for generating CAPTCHA images [49]. The majority of works done on CAPTCHA are for English CAPTCHA methods. There are a few CAPTCHA methods for other languages such as [62, 85, 66, 65, 63].

2.2. Visual Non-OCR-Based Methods

In addition to OCR-Based methods, there are another visual methods which do not use OCR software weaknesses. These methods usually uses the drawbacks of computer vision systems such as their difficulties in identifying the type of an object in an image. PIX method is one of the first Non-OCR-Based methods. More information about PIX and EPS-Game which is used for creating the required image database can be found in [77]. Bongo which is another Non-OCR-Based method which is created in the CMU CAPTCHA project is described in [12] in 2001.

The authors of [24], who are working on Content Based Image Retrieval (CBIR) systems, proposed a method which uses the problems of CBIR methods. Another examples of Non-OCR-Based methods which are based on object recognition are [26, 57].

The method presented in [31] uses the idea of rendering 3D scenes for creating CAPTCHA images instead of using a bank of images. The idea of method [39] is to exchange a number of blocks in an image and ask the user to click on that blocks. ARTiFACIAL is a method developed at Microsoft research and ask the user to found the complete human face among a number of imperfect faces [48]. A number of Non-OCR-Based methods are described in [3] such as the method which asks the user to click on a certain object in an image. Similar methods are proposed in [21].

Most of visual Non-OCR-Based methods require a database of labeled images. Creating a database of labeled images is costly and time consuming. An approach for solving this problem is creating games such as EPS-Game [77]. Another idea is using image search engines for this purpose [58, 53].

Movies can also be used instead of images in the CAPTCHA methods. In [1] an animated CAPTCHA method is proposed. Another method which uses small movies is [61]. The face recognition method proposed in [41] asked the user to match the two face images which are similar in a set of images.

A hybrid method which has both OCR-Based and Non-OCR-Based parts is described in [40]. CAPTCHA methods are usually designed for using with computers and are not suitable for other devices such as mobile phones and PDAs. A number of methods are designed especially for devices such as mobile phones [52, 54].

2.3. Non Visual Methods

One of the main categories of non visual methods are sound based CAPTCHA methods such as [35, 14]. In these methods, a word is said and the user must type the word. These systems are usually used beside other CAPTCHA methods, especially OCR-Based methods, for disabled people.

CAPTCHA in text domain was desired from the beginning, but there are few works done in this field including [10, 82]. As the authors of these paper said, it seems that designing a Text Domain CAPTCHA is very difficult. A new type of CAPTCHA methods are proposed in [22] in which there is no specific answer to the question asked from the user.

Disabled people usually have problems with CAPTCHA methods, because most of CAPTCHA methods are designed for and tested by normal persons

(e.g. see the test group description in [18]). So special methods can be designed for disabled persons or persons with special needs such as [56, 64, 69, 70].

Another group of methods uses questions which need reasoning to be answered such as [60]. This idea can be extended to create HIP systems which can distinguish between different groups of people, such as method explained in [72].

3. Applications

CAPTCHA methods were originally designed to prevent spammers from registering free accounts in the free email services [7]. But they are used in a number of methods to prevent email spam sending or identifying spammers such as [34, 68]. In addition to email spam problem, CAPTCHA methods are used for other types of spams such as [30, 51].

Another main application of CAPTCHA methods is in bot detection. Bots are computer programs which simulate human behaviours. CAPTCHA methods are used in different applications to identify bots. These methods identify bots to ban them from using services such as [28, 86] or to block them in automated attacks such as Denial of Service (DoS) attacks [32, 33].

Spammers are also using CAPTCHA techniques for sending undetectable spams [37]. A method is proposed for filtering this type of spams in [11]. CAPTCHA methods are widely used to block brute-force attacks in different applications such as [13, 71, 55, 45, 74, 84]. They are also used for detecting Phishing attacks [15, 25, 50]. Other special applications are [73, 27, 67, 59]. Most of these applications try to improve the security.

4. Attacks and Analysis

One of the first and well known attacks to CAPTCHA methods (Gimpy method) is [43]. Another attacks on Gimpy method are [44, 75, 42]. In [46] authors described two attacks on two OCR-Based CAPTCHA methods and discuss about the security which CAPTCHA methods can provide. A more recent attacks on OCR-Based CAPTCHA methods are reported in [87]. A series of in depth works on analysis of CAPTCHA methods are done in Microsoft Research labs. In [16] they show that computers are more successful in some parts of solving OCR-Based CAPTCHA methods. They also report their result on attacking a number of OCR-Based methods which are used in websites such as Yahoo and Google in [19].

Reference [78] have a formal definition of CAPTCHA methods and further analysis. Another paper which analyses the limits and security of

CAPTCHA method is [8]. There are another papers which analyse the CAPTCHA systems and their efficiency such as [36, 80]. There is a detailed discussion on the spam problem and using CAPTCHA methods to stop spams in [29].

5. Conclusion

CAPTCHA systems are used to distinguish between human users and computer programs. Today they are used widely in web servicies to offer better services to human users. In this paper we collect a great part of the works done on CAPTCHA during last year. It includes different methods designed, applications of CAPTCHA methods and analysis done on robustness of CAPTCHA methods to attacks. We hope that this paper can assist the researchers who works on the CAPTCHA methods to find previous works done in this field.

Most of the works which done in design and analysis of HIP was focused on CAPTCHA systems, which aim at distinguishing between human users and computers programs. But other fields of HIP have potential uses. A few works have been done in proofing membership in a special group [72]. But we did not find any work on distinguishing children from adults, which is needed in sites which are for adults only. We think that other areas of HIP systems are open fields for further researches and during next years, we will see practical systems for them, such as systems which can distinguish between child users and adults.

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