Analysis of Relation between Entropy and Factors in Image Based CAPTCHAs

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Abstract- Image Processing is an emerging research domain in every walk of data in our life. As a part image retrieval and its analysis have its significance in identifying and measuring different factors in different images. In this research work, we have analyzed the semantic gap factors in different image based CAPTCHAs to define relation between usability issues and semantic gap. Different techniques have been literature reviewed in which a number of methods for measuring the semantic gap has been proposed. For evaluation different image based CAPTCHAs are considered to deal with. We shall also provide a designing factor requirement for the CAPTCHA designers as the prime objective of CAPTCHA includes robustness along with usability.

Keywords: Semantic Gap, Image Retrieval, CAPTCHA.

I. INTRODUCTION

Everyday huge amount of images are generated from different image capturing sources, shared over communication media and stored in database. Retrieval of required image that meets with user requirement from large image database is a big issue these days. We require some efficient techniques to search and retrieve user required image from big image databases. In literature following are the two major techniques proposed for image retrieval.

A. Text Based Image Retrieval

This technique is widely used by many image search engines such as Google, Flickr, Bing, etc. Result images are fetched on the bases of user's provided keywords.

B. Content Based Image Retrieval

This technique is based on visual feature of image such as color, texture and shape. Feature vector represent example image and compared with image database and result based on similarity are produced to user.

C. Semantic Gap

In the above mentioned techniques a problem is identified as semantic gap, which arise when the retrieval system produced results does not match with user perception. Techniques to bridge or lower down the semantic gap were proposed in the literature reviewed in next section.

II. RELATED WORK

Bahmanyar and Datcu (2013) have proposed a communication channel based method to quantify and measure semantic gap in [4]. Information carried by low level feature descriptors is quantified by communication channel using information theory. Mutual information of given image and provided result is considered as quantity of information. Author found relation between mutual information and semantic gap as the mutual information increases semantic gap decreases. In experiments results found that each feature carries particular amount of information, increase in mutual information will decrease semantic gap which leads to closeness of users' semantic to computers' semantic.

Saha and et al. (2012) have shown a gamification approach in [11] to analyze different usability factors related with different image based CAPTCHAs like negative CAPTCHA, geometric centre CAPTCHA, combo CAPTCHA, Assira, Claptcha. Their analysis have drawn a conclusion for the CAPTCHA designers to calculate different factors of images to design the image puzzles in a better way which can provide a usable way to gain access over a service with less complexity and more robustness.

Liu and Song (2011) have proposed a method to quantify information and measure semantic gap as shown in [6]. They shown relation between text based image retrieval and content based image retrieval and then they come up with a user centered definition of semantic gap defined as the semantic gap is actually a dynamic user-desired gap. The user inputs certain information/images with user-knowledge; the computer then outputs the setting results/images through the computer-intelligence method. But when the results/images don't reach the user's expectation then he desired gap occurs. They evaluated features using ontology theory divided features

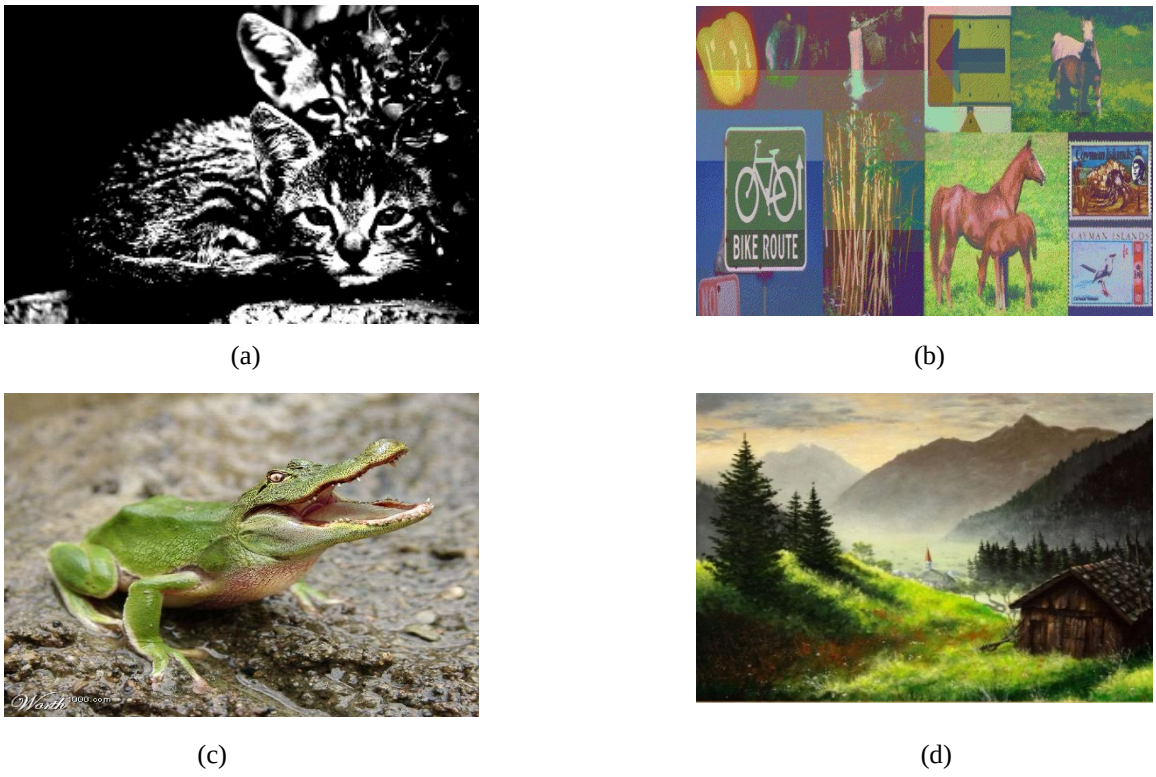
into: color, shape, position, size and then measured entropy of image to quantify information using information theory. From quantified information they come up with method to measure the semantic gap.

III. IMPLEMENTATION

A. Sources of Data

Different kinds of CAPTCHA images are collected shown in Figure-1 (a, b, c and d respectively) for implementation of proposed work:

- Negative CAPTCHA images [Fig.1-a]
- Geometric Centered CAPTCHA images [Fig.1-b]
- CLAPTCHA CAPTCHA images [Fig.1-c]
- Combo CAPTCHA images [Fig.1-d]



(a) (b)

(c) (d)

Fig 1. Data samples of image based CAPTCHAs

B. Method

We have used overall 20 samples 5 of each category stated above. We used them in MATLAB to vary the brightness and contrast values to check the associated entropy calculation. The output of entropy values have been analyzed in SPSS.

C. Entropy

Entropy of image is the amount of information that an image contains. Flat images have entropy zero and image containing heavy objects have high entropy value.

Formula for calculating image entropy

$$Entropy = -\Sigma_i P_i \log_2 P_i \quad \text{---------- [Eq.1]}$$

P_i is the probability between two adjacent pixel differences is i.

D. Brightness

Brightness of an image is the average over all pixel intensities. Brightness can be taken as arithmetic mean of red blue and green coordinates.

$$\mu = \frac{R+G+B}{3} \quad \text{---------- [Eq.2]}$$

E. Contrast

Contrast is the amount of difference between color and brightness to which different objects in the image can be visually distinguished from one another. Root Mean Square (RMS) Contrast is the standard deviation of the pixel intensities.

$$\sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\ \sum_{j=0}^{M-1}\ \left(I_{ij}-I'\right)} \quad \text{---------- [Eq.3]}$$

where MN is the size of two dimension image,

And I_{ij} is element intensity of i-th and j-th element, I' is the average intensity of all pixel values.

IV. RESULT AND ANALYSIS

A. Objective

To find out the effect of brightness and contrast of an image on the entropy.

B. Analysis of Objective

As we are not confident about the data distribution pattern of our testing data, we can move forward to analyze the effect of the parameters. For the purpose, we have created our hypothesis in the following way.

H_0: Brightness and contrast have no significant effect on entropy

H_1: Brightness and contrast have significant effect on entropy

To test this hypothesis, we have used linear regression in SPSS. From table I of Model summary, we can see that the R-square value is .689 which suggests that the overall regression model of our purpose can predict 68.9% significantly about the effect of brightness and contrast on entropy. The significance of the model can also be statistically proved with some hypothesis and ANOVA test.

H_0: The regression model is not significant

H_1: The regression model is significant

From the ANOVA results shown in table II, the significance value we have got is 0 which is < 0.05. Therefore we have rejected the null hypothesis and accepted the alternate hypothesis. This means that the regression model is significant.

From table III of coefficients helps to define the regression line which in turn helps to statistically prove the effect of the said parameters. Each of the significance value of constant, brightness and contrast has the significance value of 0 which is < 0.05. Therefore, we can say that the parameters brightness and contrast is individually significant for the regression model. The regression line of the model is defined as below.

$$Entropy = -1.085 - (.020 * Brightness) + (.606 * Contrast)$$

The above regression equation can be expressed as, the single unit change in brightness will reduce .020 unit of entropy and similarly, one unit change in contrast will increase .606 unit of entropy.

TABLE I. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.830[a]	.689	.688	1.3734948

a. Predictors: (Constant), Contrast, Brightness

TABLE II. ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1657.436	2	828.718	439.291	.000[b]
	Residual	747.049	396	1.886		
	Total	2404.485	398			

a. Dependent Variable: Entropy

b. Predictors: (Constant), Contrast, Brightness

TABLE III. COEFFICIENTS[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.085	.220		-4.929	.000
	Brightness	-.020	.001	-.632	-16.589	.000
	Contrast	.606	.021	1.116	29.307	.000

a. Dependent Variable: Entropy

V. CONCLUSION

From results it can be concluded that if all the other factors are constant, the increasing value of contrast will increase amount of entropy and as a result, semantic gap will be less. If all the other factors are constant, the increasing value of brightness will decrease the amount of entropy and as a result, semantic gap will be high. As semantic gap is related with usability and user interpretability, the increasing and decreasing amount of entropy or semantic gap also affects the usability aspects to solve the CAPTCHA puzzles. The previous work shown in the paper [11] has depicted different usability factors of image based CAPTCHAs. Our work of analyzing the entropy of the image based CAPTCHAs also lead us to conclude that entropy of the images affect the usability of CAPTCHAs.

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