

The up and coming technological idea of facial recognition can be applied to a plethora of areas in cyberspace. Not only are these applications used in professional fields to help identify specific people, but also in social media for efficiency and user-ease. Taking a look at one of the most popular social media sites in the world, Facebook.com, you might already be able to guess how facial recognition technology might be applied in social media.

Facebook.com is a social media networking site which allows you to search for your friends, celebrities, businesses and other pages while making use of different options to interact. One of the first things that you might do when setting up your user profile is uploading a picture of yourself so that others can recognize you. Not only can you upload pictures of yourself, there is an option to upload entire photo albums that may hold 200 pictures each. As of May 2013, Facebook has reached around 1.11 billion user profiles [1]. Even if none of these users have uploaded any pictures other than one of themselves, Facebook still has an enormous database filled with faces.

It still might be unclear how facial recognition technology plays into the goals of Facebook.com. At first, facial technology wasn't an option or applicable to Facebook photos. As facial recognition technology became more developed, and Facebook wanted to continue to improve user ease and efficiency, special photo features have been added for "tagging". In this case, "tagging" refers to identifying someone in an uploaded Facebook picture and associating their user profile with it. Once their user profile is associated with it, it will show up on their page as a photo of them.

The process of "tagging" in a Facebook photo has evolved over time to the automated facial detection that is seen currently. Originally, "tagging" was a manual task. This meant that you had to click on the face of a person, make sure the square marker was properly surrounding their head and then find their name from a list among the names of all your current friends. Not this this was particular hard to do, but for a photograph of more than a few people, it became very tedious. Facebook then added a controversial feature that was meant to make the "tagging" process easier which involved facial recognition technology.

On December 15, 2010, Facebook.com announced online that they were now using facial technology similar to what is found in cameras, to help take the monotonicity out of having to tag the same faces over and over in pictures [2]. This new feature would be tag suggestions. Facebook blogger explains that when you

upload new pictures, the facial recognition software is used to compare your newly added photos to existing photos that you are already matched in. When the algorithm finds similar photos, they are grouped together and a tag is suggested for you or your friends [2].



The facial recognition technology that Facebook.com implements is developed from Face.com. The developers at Face.com design applications using facial recognition technology to help users with uploading photos and tagging photos. The two apps that you can use for Facebook using Face.com's facial recognition technology are Photo finder and Photo tagger [3]. Although the two apps are a bit different in what they accomplish for Facebook, they are very similar in nature. They both use the “hybrid descriptor-based funneled” model to identify people in everyday photos. This includes photos that may be unfocused, contain poor lighting or unusual angles. Photo Tagger will take your newly uploaded photos and batch people together in groups by their faces and suggest a person to tag for the group of photos. Photo Finder will look through photos that have yet to be tagged and identify faces in them to suggest tags [3].

The hybrid descriptor-based funneled model that developers at Face.com use in their applications is a descriptor-based method for facial recognition algorithms [4]. In a descriptor-based method, face images are described by statistics derived from their intensities which serve template-based methods. These methods encode the appearance of each face image as a vector. The hybrid method is a combination of the direct distance method

and the one-shot model-learning method. The distance method is a very straight forward approach for pair matching. The goal of pair matching is to determine whether or not two given images are the same person [4]. The distance method will take the vectors of the encoded images and consider the distance between the vectors. For example, if we have two encoded images, $g(I1)$ and $g(I2)$, where g is the image descriptor function that encoded these images, $I1$ and $I2$ are considered a pair if $d(g(I1), g(I2)) < T$ where d is a distance function and T is a threshold [4]. In distance based experiments, a small amount of vectors are classified after the distance is taken. In a different framework, the pair matching problem is handled a different way. The “one-shot learning” learns the model of the face in the first image and tries to classify the second image and does this again except reverses. Then the average prediction of the two classifications is taken as the matching score [4]. To combine these two methods for the hybrid method, the 8 distances that the distance method will return are concatenated with the 8 scores that will be obtain in the one-shot learning method. With combining these two methods, a significantly higher recognition rate is obtained than each of the other methods alone [4].

One of the most used and researched facial recognition algorithms is the Elastic Bunch Graph Matching (EBGM) algorithm[5]. This feature-based identification method assumes certain fiducial point (facial feature) position points on the face and stores spectral information about the areas of facial features by convolving the images around the fiducial points with 2D Gabor wavelets [5]. For each fiducial point, a Gabor jet is formed from the convolutions. This recognition algorithm treats all images a graphs and each Gabor jet is a node on the graph. The model that is used for identification is the Face Bunch Graph (FGB) which consists of a stack of the training images [5]. The first step for a test image is to estimate the position of the fiducial points on this face image based on the already known points in the FBG. After the estimations, the Gabor jets are taken from the estimated points and a Face Graph is made for this image which is compared to all of the image in the FBG. The similarity of Gabor jets are measured to decided the identity of the person in the test image [5].

For the EBGM algorithm, the better the estimation accuracy, the better the identification performance. For the training step, the exact coordinates of the facial features are assumed to known. Images are then broken down by the algorithm such to be represented internally by information about specific regions of the face, and transformed into a Face Graph of Gabor Jet nodes and added to the system's model (FBG) of identifiable people [5]. For the testing step however, there is a lot less information available about facial features (maybe only the

eye pupil coordinates) which is where the estimation comes into play. The algorithm now creates the test image's Face Graph by estimating the positions of the facial features or fiducial points. This is done in an iterative manner using the known information from the FBG and previously estimated fiducial points. Once the test image's Face Graph is complete, it is then compared to the Face Graphs in the FBG to determine the closest match using a similarity metric [5].

One of the fundamental aspects of the EBGM algorithm is the Gabor wavelets. Wavelets are used to analyze frequency space properties of an image [5]. To process the images, the EBGM algorithms uses a two-dimensional form of Gabor wavelets. Each wavelet consists of a sine wave multiplied by a two dimensional Gaussian distribution. To obtain an accurate description of facial feature, the location should be convolved with many different wavelets with different frequencies and orientations. This will lead to the Gabor Jet for a facial feature [5]. The equation for a specific wavelength is as follow:

$$\text{where } x' = x * \cos\theta + y * \sin\theta \text{ and } y' = -x*\sin\theta + y*\cos\theta$$

$$W(x, y, \theta, \lambda, \Phi, \sigma, \gamma) = e^{-(x'^2 + y'^2) / 2\sigma^2} * \cos(2\pi x' / \lambda + \Phi)$$

Since the wavelet has five different parameters, there are many different wavelets to convolve the different facial fiducial points. θ specifies the wavelets orientation, rotating it around its center and can be a value between 0 and pi [5]. λ specifies the wavelet's frequency. Large wavelengths respond to gradual changes in the image intensity while short wavelengths are better suited for sharp edges and bars [5]. ϕ specifies that phase, made up of a real cosine wavelet and an imaginary sine wavelet. Therefore, the phase convolution will result in a complex number. σ specifies that Gaussian's radius and size. The area around the image's kernel center that is affected by convolution. σ is usually chosen to be proportional to the wavelength. γ specifies the aspect ratio of the Gaussian. This parameter can determine how round the wavelet mask will be [5].

Coefficients are generated by convolving the area around a facial feature and are then used as a collection to form a Gabor Jet to describe the local frequency of a landmark location . If 80 convolution masks are used, a Gabor Jet will be made up of 40 wavelets with a real and imaginary component. The following transformation is then used:

$$a = \sqrt{a_{real}^2 + a_{imag}^2}$$

$$\phi = \begin{cases} \arctan\left(\frac{a_{imag}}{a_{real}}\right), & \text{if } a_{real} > 0 \\ \pi + \arctan\left(\frac{a_{imag}}{a_{real}}\right), & \text{if } a_{real} < 0 \\ \frac{\pi}{2}, & \text{if } a_{real} = 0 \text{ and } a_{imag} \geq 0 \\ -\frac{\pi}{2}, & \text{if } a_{real} = 0 \text{ and } a_{imag} < 0 \end{cases}$$

and stored in an array such that a_i and ϕ_i correspond to the i th complex wavelet pair [5]. Now you have the internal representation of the a facial feature for an image.

The above parts of the algorithm only helped to identify and store information about fiducial points on the face image. There also must be a measure to figure out the similarity between two Gabor Jets. This is required for feature estimation and then for identification. Three Gabor Jet similarities are measured. The first and simplest is the Magnitude Similiary (MS) [5]. The phase information is not used here, but only the energy of the frequencies. The following formula is used for the MS calculation where N is the number of complex wavelet coefficients: [5]

$$S_a(J, J') = \frac{\sum_{j=1}^N a_j a'_j}{\sqrt{\sum_{j=1}^N a_j^2 \sum_{j=1}^N a_j'^2}}$$

The second metric that is measured in called the Phase Similarity (PS) and computes a similarity between -1.0 and 1.0. The result of the following function is based on the similarity of the magnitudes of the frequency response but are weighted by the similarity of the phase angles [5]:

This also means that high scores are only obtained when the magnitudes and phase angles are both

$$S_\phi(J, J') = \frac{\sum_{j=1}^N a_j a'_j \cos(\phi_j - \phi'_j)}{\sqrt{\sum_{j=1}^N a_j^2 \sum_{j=1}^N a_j'^2}}$$

similar. Even for small displacements, PS will correctly respond to the image's phase information and this measure will produce low similarity if the displacement between two compared jets come from a similar landmark location but are displaced by a small amount [5]. Other the other hand however, the MS will produce a high similarity for the same case. This means there is a possibility of false positives because of the fact that MS doesn't take any phase information into account [5].

The last similarity measure attempts to correct for the small displacements in the Phase Similarity metric in somewhat of a normalization step. It is called Displacement Similarity and will estimate the similarity as if jet J' was extracted from a displacement d from its current location [5]. The following function holds the phase information while compensating for small displacements: [5]

$$S_D(J, J') = \frac{\sum_{j=1}^N a_j a'_j \cos(\phi_j - (\phi'_j + \vec{d} \cdot \vec{k}_j))}{\sqrt{\sum_{j=1}^N a_j^2 \sum_{j=1}^N a_j'^2}}$$

where the displacement vector $\vec{d} = \begin{pmatrix} d_x \\ d_y \end{pmatrix}$ and

$$\vec{k} = \begin{pmatrix} \frac{2\pi \cdot \cos \theta}{\lambda} \\ \frac{2\pi \cdot \sin \theta}{\lambda} \end{pmatrix}$$

is a vector such that it points in the direction of the sin component of the Gabor wavelet and has a magnitude equal to the frequency of the sinusoid [5]. With this function measure of similarity, both magnitude and phase are considered with the compensation for phase differences.

There are other steps and functions involved in the EBGm algorithm, such as normalization of an image, landmark localization, displacement estimation methods, along with many other formulas to help image processing and facial recognition [5]. This algorithm is used and referenced frequently in

the facial recognition technology field because of the fact that it is featured-based, and this field is still going through tons of research trying to improve and build on preexisting algorithms.

Although the details and mechanics of facial recognition algorithms get very complex, the use of these algorithms are being applied to very weird and creative software. You can now find this technology as a basis of matching people on an online dating website, FindYourFacemate.com. Unlike other dating websites which match you with a potential mate based on personality chemistry, this website uses facial recognition technology to match you with a mate that looks similar to you [6]. The idea is that people that have similar looks are innately more attracted to each other. It doesn't stop there however. The website, DoggelGanger.com is a pet adoption website that uses facial recognition technology to match potential dog owners with a pet that looks similar [6]. Sticking with the idea of animals being incorporated into the facial recognition population, technology is being developed by scientists at Fraunhofer-Gesellschaft to assist researchers that study chimps in the wild. Now individual members of animal groups can be singled out. Last but not least, researchers and developers of facial recognition technology make a leap and branch out to develop a smart phone application that can analyze photos of leaves and determine the species of trees[6]. It seems as if facial recognition technology is branching out in all different directions, and will continue to be a hot topic of research in biometrics.

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