A Face Characteristic Detection System Using Ontology and Supervised Learning

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***Abstract* - Describing a face characteristic is a task usually made by human experts for monitoring suspect in temporary checkpoints. In this work, we present a computer system capable to describe face characters from an image to assist on the task. Features of the face such as eyes, nose, mouth, and skin are extracted to create classification model for different types. The model is used to set up rules to work along with ontology based inference engine for generating human-understandable face description. From testing, our proposed system yielded impressive accuracy results about 96% in average. The main advantage of the system is the ability to apply supervised learning method to directly gain a rule set used in ontological inference from data-driven approach.**

***Keywords* - Face Characteristic, Ontological Inference, Facial Features, Supervised Learning Classification**

I. INTRODUCTION

Ordinarily, a human face is one of the best features to distinguish people apart. Aside from cloth that is changeable or a body size that is easily coverable with cloth, face characteristics are a crucial clue in several security controls such as finding a criminal suspect and conducting a crime investigation. In telling face characteristic, some parts of a face are greatly determined. The parts include eyes, eyebrows, nose, mouth, face shape, etc. These characteristic features are used in sketching a criminal suspect or to inform verbally in a radio channel for surveillance and checkpoint.

In rural area where an internet connection is scarce, two-way radio communication is a necessary tool in verbally informing face characteristic features of a suspect or wanted person to checkpoint and surveillance. However, human judgment in character features can inconsistently be varied from person to person; hence, the information may be incorrect in practical.

Previous researches on the facial recognition topic were mostly on identifying a face of a suspect in a digital image or video comparing to image corpus [1-3]. The works aimed to identify or verify a person for realize the person in both security and authorization domain. Those applications work well in their purposes, but none of the work has focused on describing a facial part into textual description for human communication.

In this work, we aim to systematically detect facial characteristic features from an image and describe the features in texts. Face recognition technique will be applied to detect face parts, and the detected parts will be inferred into description using semantic knowledge of face represented in an ontology schema and production rules associated to the ontology. The main objective of this work relies on to distinguish a different facial feature based on appearance of major face parts, i.e. face shape, eyes, eyebrows, nose, and mouth following police investigation guideline [4].

II. BACKGROUND

In this section, background of related technologies is mentioned. This includes ontology representation and Facial recognition

A. Ontology

In information science, Ontology [5] is a representation of knowledge in a logical structure of related concepts in domain knowledge that can help in human-system interoperation. The most famous and often quoted definition of ontology from Gruber is "An explicit specification of a conceptualization" [6].

In an ontology, a definition of concepts is defined with a common vocabulary for users or computational systems of concepts and their relations. Nowadays, ontology schema becomes a good resource to represent a network of concepts for intelligence system such as expert system and inference recommender.

In ontology, a schema of concepts in a domain is constructed and linked to each other by a relation. Types of relation [6, 7] are as follows:

- **Is a Relation:** This relation forms hypernym-hyponym (supertype-subtype) relationship between concepts to define a taxonomic hierarchy. As taxonomic hierarchical structure, all qualifications of a supertype must inherit into its subtype.

- **Property Relation:** This relation forms holonym-meronym (whole-part) relationship to define a possession or composition. For linking a concept with other concepts, Object property or Part-of (P/o) is called while Data property or Attribute-of (A/o) is used to mention a link between a concept and data.

By linking concepts together with logical relations in standard, ontology is claimed as one of the reliable knowledge representation useful and capable to understand knowledge as a knowledge base for computer system. With schema structure, semantic of concepts can be understandable such a subtype relation and similar structural concepts as semantic relevance.

For application usage, ontology is formatted in a computational logic-based language called OWL (web ontology language) designed by W3C [8]. OWL is built upon a W3C XML standard for objects called the Resource Description Framework (RDF) [9]. It is designed to represent rich and complex knowledge as a base for a machine to interpret and understand knowledge of things and their network.

B. Related Works in Face Recognition

A facial recognition system is an application aiming to identify a person from a digital image or a video frame from a video source. By learning features of human face, the system compares persons to the face image corpus [ref]. The main usage of the task is for security systems and authorization. Recently, it has become popular as a commercial identification tool.

Several techniques have been proposed to implement face recognition system. One of the major approaches is the use of machine learning algorithms. With the feature analysis of the face parts such as the relative position, size, and / or shape of the eyes, nose, cheekbones, and jaw, the system can differentiate individual identity [1]. By applying classification model from machine learning, many techniques can be exploited such as SVM [2], Gaussian [10] and Naïve Bay theorem [3].

The key for accuracy in face recognition, however, relies heavily on feature selection and image representation [1]. Various features have been proposed such as skin texture [11] and head shape, and several tools have been suggested such as applying 3D image for representing individual face [12] and using thermal cameras [13].

However, the existing works focused on face identification or verification. None has attempted to describe face characteristics from the face image for communication that will assist in police investigation or human monitoring in strict checkpoint. This work is the first face characteristic detection system aiming to make the face image into an understandable description for a face characteristic.

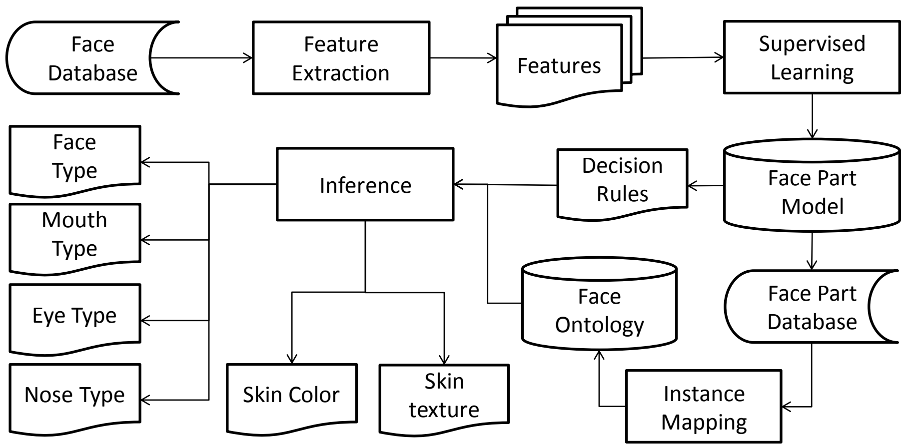

Fig. 1 An Overview of the Framework of Face Characteristic Detection Using Ontology and Supervised Learning

III. METHODOLOGY

This works attempts to analyze a human face in a digital image and to return a characteristic description of major facial features including face shape, eyes, eyebrows, nose and mouth according to the guideline of face characteristic informing for police investigation [4]. The framework consists of five main parts, i.e. 1) feature extraction of face image, 2) supervised learning to create face model for creating inference rules, 3) ontology development, 4) instantiation, and 5) inferring facial characteristic using inference engine. In this work, ontology is chosen to represent knowledge of face parts to work along with production rules in inference engine to semantically infer characteristic type. The overview of overall process is sketched in Fig. 1.

A. Feature Extraction

This process aims to extract face feature into parts. The parts of the face focused in this work are as follows.

- Face shape
- Eyes
- Eyebrows
- Nose
- Mouth

To recognize the face parts, we assign 32 points to detect parts in digital image files as shown in Fig. 2.

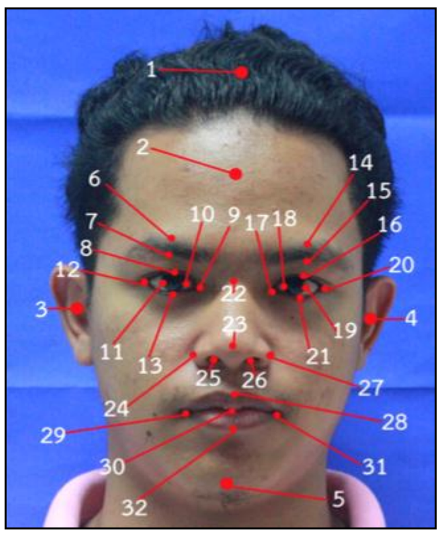

Fig. 2 Focused Points in a Face Image

These 32 points are utilized to mark on the straight face image to locate face composition as features of face. For each individual image, positions of these 32 points in total are different to represent one's unique characteristic.

Moreover, we aim to detect skin features of the face. It includes skin texture and skin color. For skin texture, local binary patterns (LBP) [14] are chosen to describe a texture feature of the face skin in the image. The LBP will classify a skin texture feature into two types, i.e. rough and smooth.

To detect skin color of the face from the image, HSV (Hue, Saturation, Value) model [15], which is hex-cone color model as demonstrated in Fig. 3, is applied. Hue (H) represents color based on an angle from 0 degrees to 360 degrees. Saturation (S) signifies the range of grey shade from 0 to 100% and is calculated in scale of 0 to 1, respectively. Value (V) is the brightness of the color and varies with color saturation in ranges from 0 to 100% where 0 value refers to pitch black and 100 value is the brightest in color. With the combination of hue, saturation and value, we decide to use HSV as feature to detect skin color in three shades based on majority of Thai skin into dark, normal and whiten.

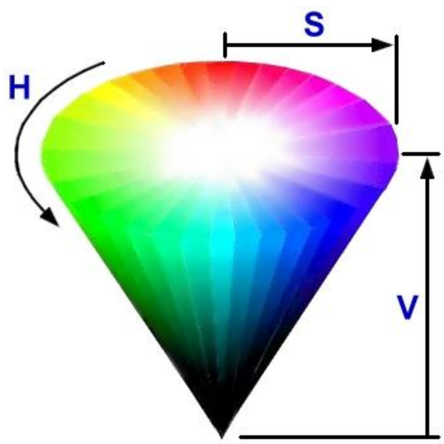

Fig. 3 Hex-Cone Color Model of HSV

In total, features for face characteristic are 7 parts including face shape, eyes, eyebrows, nose, mouth, skin texture, and skin color.

B. *Model Generation*

This process is to generate a model of each face part of each type. The parts and types of each according eyewitness guideline for face characteristic [4] are summarized in Table I.

TABLE I
THE FACIAL PARTS AND TYPES FOCUSED IN THIS WORK

Face Part	Types
Face shape	• Long face – Short face • Widen face – Narrow face • Normal Face
Eyes	• Narrow eyes – Big eyes • Long eyes – Small eyes • Squint eye (left, right, both) • Normal eyes
Canthus	• High-pointy canthus – Fallen canthus – Normal canthus
Eyebrows	• Thick-eyebrows – Thin eyebrows • Normal eyebrows
Nose	• Big nose – Small nose • Tilted nose • Normal nose
Mouth	• Wide mouth – Small Mouth • Big-lower lip – Normal lower lip • Big-Upper lip – Normal Upper lip • Normal mouth
Skin Texture	• Rough – Smooth
Skin Color	• Dark – Normal -- Whiten

The types given in Table II are a tag to signify each part for the individual face image. These tags are assigned for supervised learning [ref] to generate a face model. Actually, any supervised learning can be applied for the task, but this work selects Gaussian Classification [ref] approach (from simplicity in usage) as a representative method to gain a statistical model to classify the difference based on the given 32 features mentioned before.

C. Face Composition Ontology

In our ontology development, we carefully craft concepts of face composition into ontological classes and make a relation to link among the classes following an ontology development guideline [5, 7]. The knowledge of face composition is gathered with the focus on face parts and type mentioned in Table I.

An ontological class is created to represent a concept of each face part, such as face, eyes, nose, mouth, etc. Properties of the classes play a crucial role in this ontology to represent attributes and composition of the face part concept. Object property (part-of relation, p/o) gives knowledge of organ composition, such as a human mouth relatively contains two lips that are upper lip and lower lip. Moreover, Data property (attribute-of relation, a/o) shows that the concepts own specific data type to some certain roles. For example, the lip concept has width and height data in integer data type to determine a size of a lip.

Furthermore, concepts of types of each face part are also gathered as ontological classes. These classes are designed to work in association with inference engine as an inferred result to be retrieved if the conditions are triggered for some certain rules.

Once all classes and relations are conceptually connected, and rationally approved, we develop the face compostion ontology in the ontology editor tool called “Hozo” [16]. Hozo provides a user interface to visualize classes and relations into understandable graphic, and it contains a function to export the developed ontology to Web Ontology Language (OWL) format [8] to be used as RDF schema [9]. With limited space, we exemplify some parts of the face composition ontology in Fig. 4.

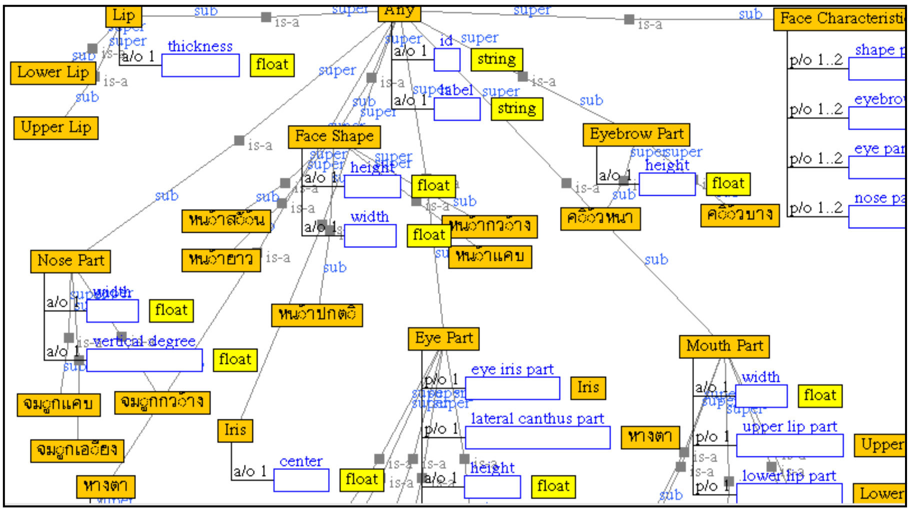

Fig. 4 Some Parts of the Developed Face Composition Ontology in Graphic form by Hozo Ontology Editor

In further usage, OWL of the face composition ontology is exported as a knowledge schema, and it will be assigned with instances.

D. Instantiation

An ontology is a schema of concepts and relation among concepts; thus, real data (instances and value) are stored in database. The task called ‘instanstiation’ is to inform that which ontology class and data property represent in database field. For instance-ontology mapping, a tool called ‘Ontology Application Management’ (OAM) framework [17, 18].

OAM is a tool to provide assistance in developing ontology-based application. One of the services is user-interface to manually map ontology with database field. With the given OWL format exported from the ontology editor and MySQL database schema, we successfully map all of our ontology classes and relations with the face feature database. By this process, we gain a configuration of concept to data mapping to create RDF format data [9] of face features.

E. Type of Face Part Inference

From the face composition model, we extract the classification rules of face parts and create a set of production rules based on the value of each feature. The production rules is a form of condition-result rules as:

If {condition(s)} Then {result}

In the condition part, two types of component are defined. The first component must be ontology class while the second part depends on the relation to the first component. There are two relations, part-of and attribute-of. In case of part-of relation, ontology class set as a class constrain to the first component. For attribute-of relation, the component requires operation and the value. Please see the example below:

If {the height of eye < 12.5}
then {eye type is a narrow-eye}

From the example, it can be interpreted that those who have the height of eyes less than a value of 12.5 are the person with narrow-eye type. Please be noted that the value is the distance based on the pixel of the image and gained through the classification model mentioned in previous section. We summarize some examples of the production rules in Table II.

TABLE II
EXAMPLES OF PRODUCTION RULE FOR INFERRING EYE TYPES USING WITH ONTOLOGY INFERENCE ENGINE

Condition	Result
height of eye < 12.5	eye type = narrow-eye
height of eye ≥ 18.25	eye type = big-eye
width of eye < 6.18	eye type = short-eye
width of eye ≥ 9.31	eye type = wide-eye
x position of lateral canthus > x position of medial canthus	eye type = pointy eye
x position of lateral canthus < x position of medial canthus	eye type = fallen eye
center of iris of eyes is not equal	eye type = squint eye

The inference rules, however, can be chained to give a complex semantic result such as combining narrow-eye with single eyelid can typically be inferred to Chinese style eye type. The inference chaining is the advance solution to provide more semantic to the face part classification. The inference engine is also available via OAM framework [17, 18].

IV. EXPERIMENT AND DISCUSSION

To test the potential of the proposed framework, we set up an experiment by comparing the inference result and the answer of types of face part given by human. 200 images of different persons were captured and assigned with the answer manually. An accuracy measure will be evaluated as the human answer being the correct standard. The result of inferring is separated based on face parts. The accuracy result is given in Table III. Moreover, we looked into the number of incorrect parts for each image and gained a statistic shown Fig. 5.

TABLE III
ACCURACY RESULT OF INFERRING BASED ON FACE PART

Face part	Accuracy
Face shape	98.50%
Eyes	93.00%
Eyebrows	98.00%
Nose	97.25%
Mouth	91.75%
Skin Texture	98.50%
Skin Color	98.00%
Average	**95.71%**

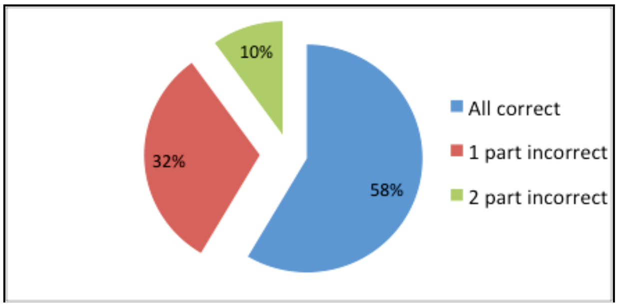

Fig. 5 Inferring Result Based on Number of Images and Incorrect Part

From the result, we can split inferring capability into two groups based on the accuracy. The first group is a group of face parts with very high accuracy including Face shape, eyebrows, nose, skin texture, and skin color. These facial parts impressively obtained over 98% accuracy. From observation, we found that the feature detection and model of these parts are very accurate, and that directly affects in determining a value for inferring rules.

However, parts of eyes and mouth obtained lower but acceptable accuracy results as 93.00% and 91.75%, respectively. We found that the incorrect results came from the complexity of the parts themselves. For the eye part as example for explanation, there are several aspects in consideration such as shape of the eyes, position of iris, and eye canthi including lateral canthus and medial canthus. With various features to consider in classification, generated models cannot find a good distinguishing points to differentiate the types.

Furthermore, we found the advantage of the usage of ontology schema. Combining two different types of a certain part can describe more specific characteristic in semantic of the face part. Instead of telling of low-width eye type for example, ontological inference can assist on generating a result of human understandable description into a relative term such as narrow-eye. In addition, it can help to infer more specific type of different aspect of the same part as combining pointy eye (known by positions of canthi) with narrow-eye (recognized with width of the eyes) into an eye characteristic of a Chinese descendent.

From the view of accuracy, the proposed system shows a great capability in telling face characteristic. The total accuracy result is about 96%.

V. CONCLUSIONS

This work presents a face character detection system using supervised learning with ontological inference. To assist in security control and police investigation, this work aims to read human face in a digital image and describe characteristic of the face for verbal communication. Features to be considered are position of specific face parts, skin texture and skin color. Supervised learning generates classification model from the given features. The ontology is developed to gather knowledge of face composition and is used along with inference engine and rules gained from the generated model. From the experiment, the accuracy of the system impressively reached 96%. The advantage of this work is to apply supervised learning method to directly gain a rule used in ontological inference. With ontology power, the result is a face characteristic in semantic description understandable for human in verbal communication.

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(Arranged in the order of citation in the same fashion as the case of Footnotes.)

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