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Cyber Optics: Computing and Control using Vision Sensors

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ABSTRACT

Tremendous progress in computing, controls, and sensor technology has produced interest among engineers and scientists from multidisciplinary areas to develop systems and technologies that would help people and processes. Cyber Optics is an emerging technological development that utilizes vision sensors, computing, and control strategies to develop products or systems benefiting industrial and domestic users. The talk includes brief description of applications, fundamentals, an insight of the issues, and future directions in Cyber Optics.

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Keywords : Sensor network, Computer network, cyber optics, vision sensors

1. INTRODUCTION

Cyber is a product or technology that is related to computer or machine communication and control. Optics is the product or technology using vision sensor(s). Cyber optics has emerged as a new technological phenomenon of using vision sensor(s) for communication and control through computers or machines. Components of a Generic Cyber Optics System are (also refer Fig. 1):

a) Lighting source: Illuminating the object/scene
b) Camera: The optical lens
c) Sensor: Converting the scene into a signal
d) Processer: preparing and analyzing the signal

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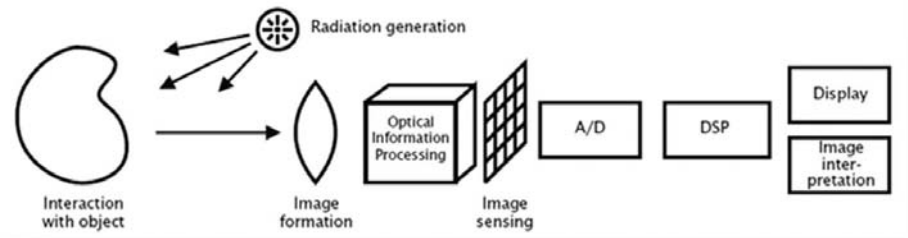
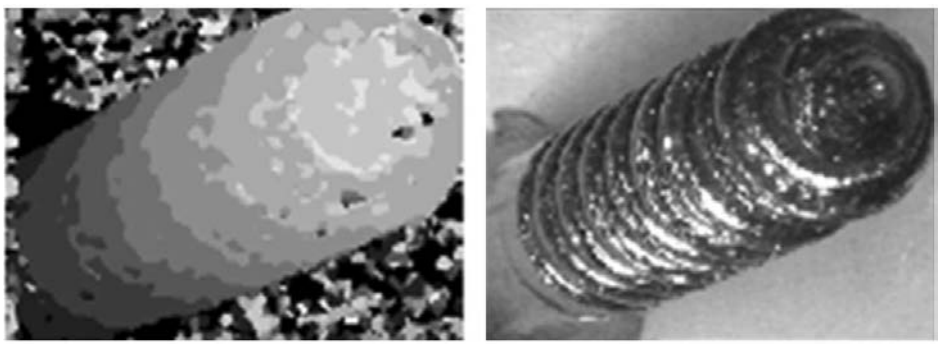
e) Knowledge-Base: data understanding/interpretation and finally
f) Action unit: responding the visual information that becomes part of control system not shown in Fig. 1.

Figure 1
Schematic of a generic Cyber Optics system



After getting the object from the scene in a signal form, the very first step of a Cyber Optics analytical system is the pre-processing of acquired data. This is essentially the preparation of data for detailed analysis (refer Fig. 2).

Figure 2
Actual Image (left), pre-processed image for analysis (right)



Following the pre-processing step(s), next is the segmentation process. Segmentation is the process of removing/obtaining the object of interests only from an image or image sequence(s). For example, if one is interested in extracting edges (corners) in an image, this could be done by employing different filtering techniques. Following the segmentation process, next is the image interpretation step. This is essentially the understanding the image scene or extracting information from image objects using either knowledge-base or other learning rules.

Consequent upon the image analysis and interpretation process, next is the controlling or responding the information. This functional unit is known as action unit. This may incorporate initiation of a process or some response in an appropriate form.

2. Application Scenarios

Cyber Optics systems are driven by a long laundry list of application scenarios. Some of the prospective application scenarios are listed below:

a) Visual surveillance (D. Ayers and M. Shah, 2001) (for safety & security applications),

b) Search & Rescue in Disaster (Xin Ran, Lei Ren, 2010),
c) Emotion Recognition (A.R. Abbasi, Matthew N. Dailey, Nitin V. Afzulpurkar and Takeaki Uno , 2010),
d) Whole body scanner (security applications),
e) Human motion/image analysis (M. Brand and V. Kettnaker., 2000) (T. Huang and S. Russell., 1997),
f) Face Recognition,
g) Face Database Creation,
h) Touchless Communications,
i) 3-D Processing,
j) Technology Marketing,
k) Virtualization,
l) Industrial Inspection/Quality Assurance,
m) Reverse engineering,
n) Object reconstruction,
o) Reconstruction from multiple views,
p) Scene reconstruction,
q) Motion tracking,
r) Weather pattern analysis,
s) Model-driven person detection,
t) Knowledge-based image retrieval,
u) Ocean Explorations,
v) Thermograph,
w) Geographic Information Systems (GIS), and many more.

3. Issues & Challenges

Major problem in development and successful implementation of a Cyber Optics system is perception of surrounding environment or object(s) for appropriate extraction of information. According to Dictionary, an object is defined as *"something perceptible by one or more of the senses, especially vision or touch; a material thing."*

Machine perception has several issues or challenges to face. These challenges are categorized as:

a) View point variation,
b) Lighting variation,
c) Occlusion problem,
d) Scale,
e) Deformation,
f) Background clutter
g) Intra-class variation among objects.

In all forms of machine processing, i.e. representation, modeling and classification, the above mentioned issues are a challenge to existing machine recognition and interpretation algorithms. For example, when representing an object, how many views (refer Fig. 3a) of an object may be considered for selection of features? What model will best suit the learning algorithm? What is necessary feature selection for classification purpose? These questions are posing great challenge to machine vision and learning researchers.

Another issue is varying lighting conditions under which an object(s) may be visualized/analyzed (Refer Fig. 3b). Sensors with built-in lighting functions are costly and inconvenient at times.

Figure 3a
View point variation due to viewing from different angle

Figure 3b
Lighting variation

Another significant issue is occlusion. Many times, the sensor employed are unable to retrieve full image of an object of interest (Refer Fig. 4a). This becomes very serious issue especially when working with unseen data. Few techniques are available such as Bayesian learning [6] etc, however, these do not work well. Identifying objects with varying size in an image frame is another important issue to address. This scale variation of objects may lead to misclassification.

Figure 4a
Loss of image information due to occlusion

Figure 4b
Scale variation cause difficulty

Next is issue of how to work with deforming objects (refer Fig. 5a) as they are difficult to represent by few number of features, difficult to model and similarly difficult to classify. Activities of human are also categorized in this class. Another problem is background clutter (refer Fig. 5b) which often obscures the object of interest. Finally, intra-class variation among the objects that may lead to lot of issues such as misclassification of actual object categories from the similar categories.

Figure 5a
Deforming objects are hard to model

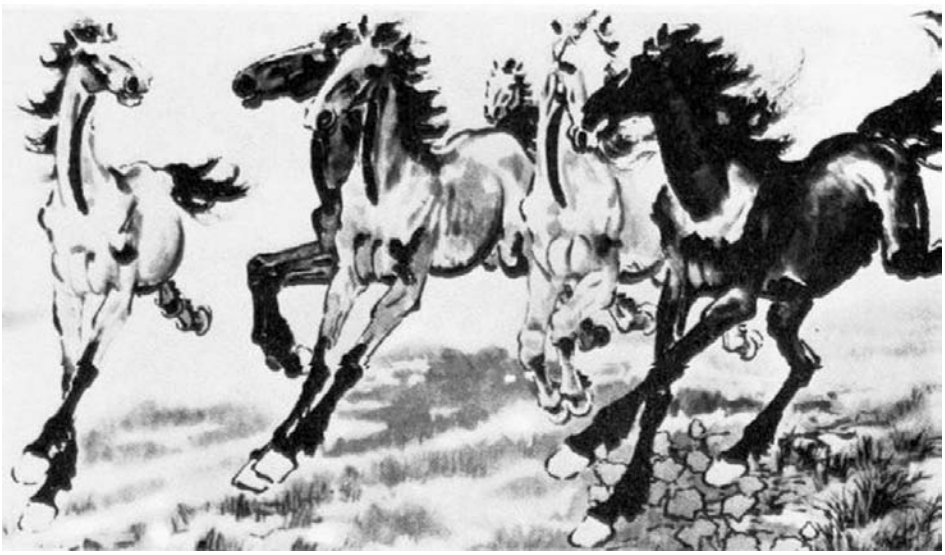


Figure 5b
Background clutter

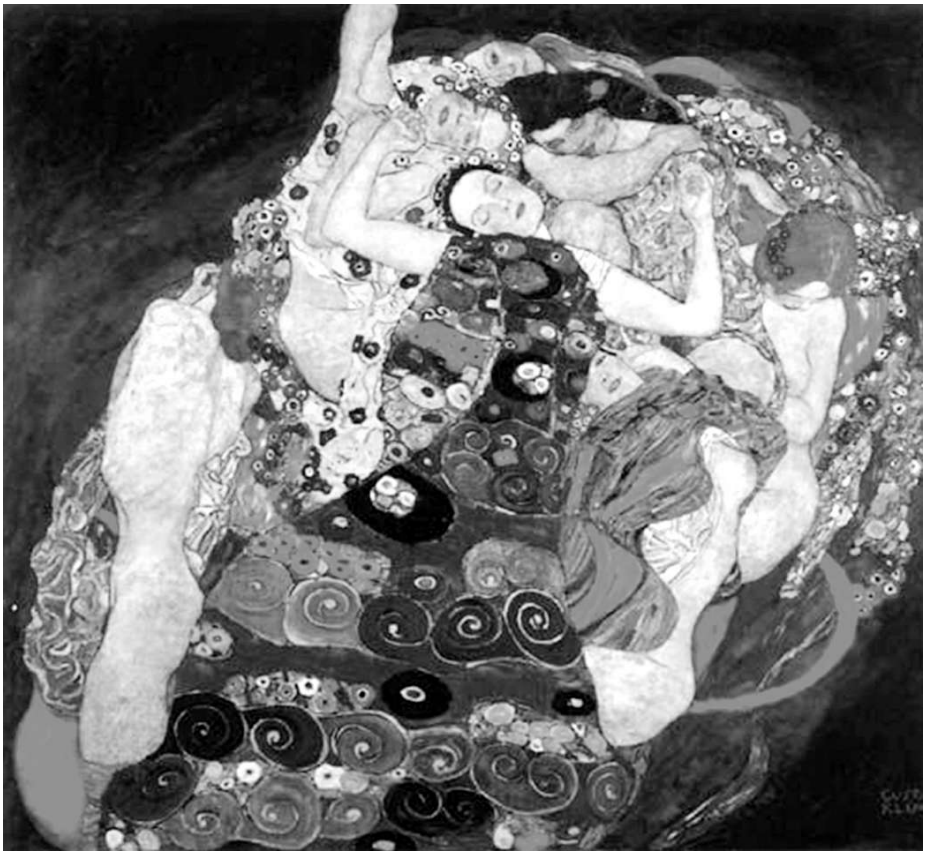


Figure 5c
Intra-class variations

In brief, all of the above issues are related to:

- Representation: Feature Selection: How to represent an object category
- Learning: Modeling: How to form the classifier, given the training data
- Recognition: Classification: How the classifier is to be used on novel data

4. Conclusion & Future Research

In this paper, we describe the challenges that should be considered as opportunities for future work. Many exciting areas including research and development of systems analyzing parent-child relationship, i.e. aiding in learning process of children through observing his/her behavior. Observing student behavior and learning, analyzing patient response to various therapies and consumer purchase and behavior trending, online gaming research, and sport science research are few areas of research that can benefit in progress in the described field.

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