機械系 博士研究專題

Spring 2013

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目前陳亮嘉教授可指導之碩士專題題目與內容如下:

1. Intelligent machine vision for robot automation and machine tool operation: (運用於自動化與工具機生產之智慧型機器視覺研究)

Machine vision systems are employed widely in industrial robot application nowadays for enhancing robot flexibility and intelligence and have been playing an important role in factory automation. A large number of two-dimensional (2-D) vision systems have been successfully applied for industrial robot manipulation. To meet for urgent demands in providing accurate 3-D information of industrial parts or achieving for more intelligent robotic manipulation, smart three-dimensional (3-D) imaging has emerged as even more important technology to pursuit, especially when dealing with complicated working geometry or condition. The existing 2-D imaging technology may be seriously impeded by its limitations in handling complicated part geometry. Thus, this research proposes a novel method by employing the developed 3-D optical imaging and processing algorithm for accurate classification of object's surface characteristics. In the method, 3-D geometry of industrial parts can be first rapidly acquired by the developed one-shot imaging optical probe based on Fourier Transform Profilometry (FTP) by using digital-fringe projection at a speed of 30 fps (frames per second) or higher. Following this, the acquired range image can be effectively segmented to three surface types by classifying point clouds based on the statistical distribution of the normal surface vector of each detected 3-D point and then the scene ground is reconstructed by applying least-squares fitting and classification algorithms. Meanwhile, a recursive search process incorporating the region growing algorithm for registering homogeneous surface region is developed. When the detected parts are randomly overlapped on a workbench, a group of defined 3-D surface features, such as surface areas, statistical values of the surface normal distribution and geometric distances of defined features, can be uniquely recognized for detection of the part's orientation. The homogeneous matrix of the pre-defined part major surface can be detected for identification of the orientation of individual workpieces. The integration of the developed 3-D vision system with an industrial robot system is presented. Some experimental tests were performed to validate the feasibility of the developed method for real robotic manipulation.

線上 3-D 視覺工件定位與辨識技術:

創新式三維影像光學量測探頭與核心技術 (Year 1):

第一年將著重於創新性三維影像光學量測探頭與核心技術之研發，發展包括光學量測探頭設計與製作、高速影像處理、探頭校正、量測原理與演算法以及量測軟體等核心技術之發展，具體發展出全域三維光學量測雛型探頭與核心量測技術。本子計劃所發展自動化三維光學量測系統，具全域特性，可進行物件精密表面輪廓之線上量測，為一深具創新發展與未來廣泛應用之技術發展，在深度偵測精度將小於全深度量測範圍的 5%，量測範圍可等於或大於 640x480 pixels/frame 點雲資料之輸出，量測速度可等於或大於 30 frames/minute, 量測空間解析 Rx 可等於或優於 $FOV_x/640$ 以及 Ry 等於或優於 $FOV_y/480$，量測系統具有對工件絕對定位之偵測能力，且不受有限階高(1/4 結構光週期)之限制。

對規則幾何形貌三維物件之光學定位與辨識核心技術 (Year 2):

以第一年之發展基礎，第二年將發展對規則幾何形貌三維物件之光學定位與辨識核心技術，主要發展工作步驟有二，其一在於具規則幾何形貌物件之三維影像進行與背景分離與單獨物件之萃取，進行三維影像物件分離與物件萃取演算流程時，以達到物件分離與萃取的即時影像，其二在於三維影像物件空間定位與辨識，針對已分離之工件三維影像，使用自動化演算法進行有效的物件定位與辨識，其中三維物件定位與辨識須考慮影像雜訊、量測視角、物件解析、和物件遮蔽與可能形變問題。預計可達成之工件定位與辨識速度可等於或大於 10 frames/minute，工件深度定位精度將小於全深度量測範圍的 5%，工件空間定位精度 Ax 可等於或優於 10* $FOV_x/640$ 與 Ay 可等於或優於 10* $FOV_y/480$.

對具自由曲面三維物件之光學定位與辨識核心技術 (Year 3):

以第二年之發展基礎,第三年將進一步發展對具自由曲面三維物件之光學定位與辨識核心技術，主要發展工作步驟與第二年相似，但對象將針對更複雜之自由曲面三維工件，其中三維物件定位與辨識亦須考慮影像雜訊、量測視角、物件解析、和物件遮蔽與可能形變等複雜問題。預計可達成之工件定位與辨識速度可等於或大於 15 frames/minute，工件深度定位精度將小於全深度量測範圍的 5%，工件空間定位精度 Ax 可等於或優於 10* $FOV_x/640$ 與 Ay 可等於或優於 10* $FOV_y/480$.

2. Research on automatic *in-situ* optical inspection machine for semi-conductor industries: (運用於半導體製程自動化線上光學檢測技術之研究)

The next generation of intelligent machine tools essentially demand smart *in-situ* optical sensing technology for in-process monitoring or in-cycle gauging of workpieces to minimize possible machining errors and thus to ensure high quality manufacturing optimally. For various kinds of materials machining or forming processes, traditional means using manual inspection as well as quality control cannot keep up with vast demands in high-speed *in-situ* three-dimensional (3-D) or surface profilometry. In this research, a novel composite fringe profilometry (CFP) method based on both of Fourier Transform Profilometry (FTP) and phase shifting principle (PSP) is newly proposed to achieve the measuring accuracy closely reaching to the same level by PSP, as well as one-shot imaging capability for achieving high-speed inspection. Multi sinusoidal colour fringe patterns are encoded to form a unique composite colour pattern for projecting onto the object's surface, and its reflected deformed fringe image is taken by use of a triple-colour CCD camera and rapidly processed by the developed CSP method employing an innovative band-pass filter. A newly developed 3-D surface measuring method is capable of performing surface dimensional metrology at a high speed up to 60 frames per second (ftp) or higher. To reconstruct a 3-D profile of an object, a new strategy is developed to wrap three FTP-derived phases by using the PSP method, in which surface reconstruction can be performed robustly for a production of high-quality optical information. The experimental results preliminarily demonstrate that the method has capability to acquire 3-D maps at a high speed while the measurement accuracy being reaching up to that of traditional three-step PSP method. By measuring standard step heights in a repeatability test, it is confirmed that a maximum measured error can be controlled less than 1.5% of the overall measuring depth range. The measuring bandwidth of surface inspection of workpieces can reach up to 60 ftp when a high-speed camera is employed.

3. Development of a new generation microscopic white light interferometric system with vast field of view for *in-situ* automatic optical inspection (AOI)

(具大視寬新世代線上白光干涉顯微量測系統之研發)

Scanning white light interferometry (SWLI) has the advantages of having a long measurement range and high vertical accuracy. The long measurement range can be achieved due to a short coherence length achieved in SWLI. Short coherence length enables absolute measurement without encountered by the phase ambiguity problem that inherently exists in phase shifting interferometry (PSI). However, the current SWLI technology has been significantly restrained from its potential application for *in-situ* automatic optical inspection (AOI) mainly due to its incapability in measuring objects having a low surface reflectivity, low measurement efficiency due to extremely limited measuring field of view (FOV) and being incapable of resisting *in-situ* measurement disturbances, such as vibration and air turbulence. Therefore, this project proposes to develop a new generation *in-situ* SWLI system for tackling on the above three technological challenges. With this project development, it is expected to perform *in-situ* high-speed 3-D surface profilometry on micro structures with a high lateral and vertical resolution as well in a high-speed measurement. The project aims to achieve the following three technological breakthroughs: (a) to perform high-accurate profilometry of an object’s surface with low surface reflectivity, in which the measurement accuracy can reach the standards from the traditional SWLI; (2) to obtain a vast measurement FOV up to 25 times to one covered by a traditional Mirau interferometer while the lateral resolution maintains the traditional Mirau objective; and (3) to be equipped with *in-situ* anti-vibration capability in against in-field vibration or disturbances.

顯微掃描白光干涉 (Scanning white light interferometry, SWLI)量測技術一般常應用於奈米等級之精密形貌量測，其優點為非破壞及非接觸性質，且可提供高密度之橫向量測解析能力與高深度之量測範圍，在表面垂直方向具奈米級之解析度與無斷高量測之限制等優點。但 SWLI 至今仍無法廣泛運用於半導體產業、液晶面板產業以及綠能光電量測產業等領域之線上製程自動化光學檢測，其主要之原因有下列三項: 1. 無法量測表面光反射率低的物件；2. 極受限於量測視寬狹小量測效率低，無法滿足線上量測速度需求；以及 3. 對於線上環境之振動、空氣擾動等極為敏感，量測系統需設限於嚴苛之檢測環境條件，無法應用於線上環境中。因此，本計畫以建立一套具大視寬新世代線上白光干涉顯微量測系統與關鍵技術，解決上述三項技術困難。計畫內容擬提出發展創新式 Mirau 物鏡，以銀奈米柱鍍膜為偏極分光之元件，使 SWLI 能夠量測表面光反射率低的物件與重建三維形貌，使 SWLI 能廣泛應用於更多物件之形貌量測工作。同時，基於主持人研究團隊近年在顯微色散物鏡之設計與製作能力，本計劃也提出以發展陣列式 Mirau 物鏡，配合陣列式 LED 光源與影像擷取感測器，構建之一個具有大量測視寬之 SWLI 掃描探頭與量測系統。在計劃第三年，為達到線上量測抗振之能力，擬架構線上即時位移偵測裝置於白光干涉顯微量測系統中，即時偵測出系統受到環境干擾時之振動位移量，以主動式回授控制對位移量即時補償，以達到線上抗振之能力，進而建構一套大視寬新世代線上白光干涉顯微量測系統，以利應用於生產線白光干涉量測之需求上。

4. **Development of multi-dimensional imaging, object detection and event monitoring technology by employing multi robots working within hazardous environment (智慧型機器人高速三維影像系統與形貌辨識技術之研發)**

Applications of high-speed machine vision to be equipped with intelligent robots for real-time multi-dimensional imaging (2D & 3D & radiation map) and object recognition are extremely critical for winning success in today’s globally competitive world. New generation machine vision systems having complicated optical image algorithms, electro-optic hardware and intelligent software systems are now capable of delivering on the simultaneous promises of high-speed and high-reliability 3-D object detection, especially for an intelligent robot operation in fields. The optical machine vision technology has thus become an essential method and expertise for developing intelligent robots. It also plays as a key to ensure success of effective operation within a dangerous working environment, such as nuclear power plants. The main objective of this project is to develop multi-dimensional imaging, object recognition and event monitoring technology by employing multi robots working within hazardous environment. The research proposes to employ multirobot integral optical detection for acquiring real-time multi-dimensional imaging in cooperation with environmental radiation distribution. Meanwhile, to develop object recognition capability using reconstructed 3-D information is also targeted as one of the main objectives for in-situ automatic object detection and recognition. A miniaturized optical vision system will be developed and integrated for intelligent robot operation. The system to be developed integrates an innovative spontaneous optical interferometric principle and a novel optical detection method to become capable of measuring dynamic 3-D surface characteristics with a measurement bandwidth up to few hundreds Hz level bandwidth. In addition, to satisfy spontaneous operation demands of an in-field robot operation, the project also includes the development of multirobot cooperative sensing methodology, to speed up fast object searching and accurate identification.

高速三維精密機器視覺為智慧型機器人之核心關鍵技術發展重點，即時三維資訊提供機器人行動能力極為重要之空間與物件訊息，可藉對時間與三維即時資料之整合成為 4D 資訊，對機器人在即時三維影像之偵測與辨識，提供不可或缺之核心資訊。因此，本計劃提出以三年計劃之多年期發展，研發即時三維動態影像偵測與重建之核心系統與技術，重點將包括即時三維影像之偵測與 4D 重建、微型化之即時三維影像偵測元件與系統、對物件之即時三維影像重建、以及對物件之形貌辨識技術，發展機器人之即時三維影像之偵測與重建、物件之精確定位與辨識、精確動作之導引與事件發展之監控能力。

計劃之第一年將著重於**創新性即時三維影像偵測雛型系統之研發**，發展高速影像處理、CCD 精度校正以及量測軟體技術，同時發展創新性之**同步光學干涉相移術與裝置**，以達成即時全域三維影像光學偵測之雛型系統。以第一年之發展基礎，第二年將發展**微型化之即時三維影像偵測系統**，以適應機器人在實際工作現場（高振動與雜訊干擾)之嚴格挑戰與需求，建立能獨立運作於現場之嵌入式系統，導入發展三維動態影像核心系統與技術。為達成機器人對空間與物件之精準與快速辨識能力，第三年將發展**對物件創新性即時三維影像重建與形貌辨識技術**，將研發三維影像疊合與特徵資料重建技術，高速構建物件與環境三維資訊。同時，將發展自動化三維特徵擷取技術，以獲得空間與物件之重要三維形貌特徵，達成**三維資料減容與關鍵特徵淬取**之目標，建立以物件三維型貌特徵為基礎之智慧型形貌辨識技術，使機器人具備自動化物件搜尋之精確辨識能力。