FORCE-GUIDED ROBOT IN MOBILE PHONE ASSEMBLY

by

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LIST OF ABBREVIATION

CIM	Computer Integrated Manufacturing
COC	Center of Compliance
FMS	Flexible Manufacturing System
P	Proportional
PI	Proportional integral
PID	Proportional Integral Derivative
RCC	Remote Center Compliance
RIA	Robotics Industries Association

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ABSTRACT

Assembly of mobile phone is currently carried out manually by human operation. Due to the labour intensive and labour shortage factor, the assembly operations are preferred to be automated. Assembly operation of mobile phone such as notch-locked assembly can only be performed using fine motion planning where force information is used to adjust the manipulator motion during the assembly. The objective of this research is to study and automate the assembly process of mobile phone using force-guided robot. This thesis presents the results of the study and implementation of force-guided robot in the automated assembly of a mobile phone. A case study was initially carried out to investigate the assembly operations and strategies involved in the mobile phone assembly. A force-guided robot was developed by upgrading an existing conventional industrial robot using a multi-axis force sensor and a custom-built low cost compliance device. Proportional-based external force control with computational of position feedback was developed and implemented in the force-guided robot to perform the compliant motions required for the assembly. In order to perform the mobile phone assembly operations, three basic force-guided robotic skills were identified. These are stopping, aligning and sliding skills in which the motions are guided by the force feedback. The proposed force control algorithm was tested to perform the force-guided robotic skills and the experimental results are presented. The basic force-guided robotic skills were combined and reprogrammed with fine motion planning to perform notch-locked assembly in the mobile phone. The approach was tested in the presence of component misalignment in multiple axes. Experimental results showed that the approach not only performs notch-locked assembly but also overcomes the

misalignment problems that may fail the assembly operation. The system was optimized for high assembly speed while considering the constraints and limitations involved.

ROBOT KAWALAN DAYA UNTUK PEMASANGAN TELEFON BIMBIT

ABSTRAK

Operasi pemasangan telefon bimbit masa kini dijalankan dengan mengunakan tenaga manusia secara manual. Walau bagaimana pun, operasi pemasangan secara automatik adalah lebih digemari disebabkan masalah faktor manusia and kekurangan tenaga operator. Operasi pemasangan seperti *notch-locked assembly* memerlukan pergerakan terancang (*fine motion planning*) di mana daya digunakan untuk mengawal pergerakan robot semasa proses pemasangan. Penyelidikan ini bertujuan untuk mempelajari and melakukan operasi pemasangan telefon bimbit secara automatik mengunakan robot kawalan daya. Tesis ini mempersembahkan laporan kajian dan implimentasi robot kawalan daya dalam industri pemasangan telefon bimbit secara automatik. Satu kajian kes telah dilaksanakan bagi mengkaji operasi and strategi pemasangan dalam industri pemasangan telefon bimbit. Robot kawalan daya telah dibangunkan dengan mengintegrasikan sebuah robot industri sedia ada dengan sensor daya dan alat pergerakan terpatuh (compliance device). *Proportional-based external force control with computational position feedback* telah dibangunkan dan diimplimentasikan dalam robot kawalan daya untuk melakukan pergerakan terpatuh yang diperlukan dalam tugas-tugas pemasangan. Bagi melaksanakan operasi pemasangan telefon bimbit, tiga pergerakan terpatuh menggunakan kawalan daya telah dikena-pasti, antaranya termasuk pergerakan terpatuh *stopping, aligning* dan *sliding.* Kawalan daya yang dibangunkan untuk melakukan ketiga-tiga pergerakan terpatuh diuji dan keputusannya

dipersembahkan. Pergerakan terpatuh menggunakan kawalan daya kemudiannya diaturcarakan menggunakan pergerakan terancang untuk melakukan *notch-locked assembly*. Operasi pemasangan dilakukan dan diuji dengan pelbagai kedudukan yang tidak tepat (*position error*). Keputusan menunjukkan robot kawalan daya bersama strategi pemasangan menggunakan pergerakan terpatuh mampu memasang telefon bimbit walaupun dalam kedudukan yang tidak tepat. Robot kawalan daya kemudiannya dioptimasikan untuk mendapat pemasangan yang cepat dan tepat.

CHAPTER 1

INTRODUCTION

1.1 Background

Automation systems, especially industrial robots, are preferred when compared to human operators because they are more consistent, reliable and have high repeatability especially in automated assembly (Du et al., 1999). Most industrial robots which are currently used for manufacturing purposes execute fixed programs by repeating a pre-set sequence of motions. Many application of robot manipulator are based on position control. The position control of manipulators is based on the information on coordinate and velocities of their links. However, such robots are inadequate for an assembly task (Gravel and Newman, 2001).

An assembly task can be performed by using sensor information to adjust robot motions (Gravel and Newman, 2001). Such information allows one to make judgements on the interaction between the manipulator and the environment and correct the manipulator motions. When a robot manipulator makes contact with an external surface, i.e. the environment, the robot motions can be handled by directly controlling the force of interaction between the manipulator and the environment. By installing force sensors at the wrist of the robot manipulator, it becomes possible to monitor and control small displacement of the manipulator end effector with respect to external objects or environment (Chiaverini et al., 1999). Force feedback provides information of stresses in the manipulator structure. Such information allows one to make measurement on the interaction between the manipulator and the environment and correct the manipulator motion. This is important to ensure that the manipulator always moves in a compliant motion in order to perform the assembly tasks. Therefore, force-guided robot can offer a very effective solution to the automated assembly problems.

1.2 Problem Statement

Manufacturing companies throughout the world are rapidly changing in order to survive in today's highly competitive market environment (Du et al., 1999). Industrial robots have played a very important role to improve flexibility, reliability and productivity, and to achieve competition-based technology development. However, implementation of force-guided robot in today manufacturing industry is still uncommon (Bruyninckx et al., 2001). This could be due to the complexity of the tasks involved in the real assembly line.

Real assembly tasks not only consist of simple mating processes but also consist of higher level assembly work using fine motion planning. Many concepts, methods and algorithms have been developed to accomplish compliant motion of the robot in generalized assembly tasks (Tsujimura and Yabuta, 1991; Zeng and Hemani, 1997). However, most of the past research and investigations regarding force-guided robotic worldwide were carried out to perform very general tasks, such as peg-in-hole insertion, contour tracking, screw fastening, and palletizing (Lange and Hirlinger, 1992; Qiao et al., 1995; Du 1998; Du et al., 1999; Erlbacher, 2000). Such general task may not be readily applicable in real applications due to the complexity of the real assembly tasks. Compliant motion has not yet made a real breakthrough in the field of industrial applications such as automated assembly, but rather remains mainly as a research tool (Tichem et al., 1999).

Many products manufactured today, including mobile phones, incorporate plastic components. These products are easily damaged if the assembly force is not monitored and controlled (Suarez et al., 1995). Assembly operation of typical mobile phone such as notch-locked assembly can only be performed using fine motion planning where force information is used to adjust the manipulator motion during the assembly. Therefore, application of force-guided robotic to perform more specific assembly tasks, with product design orientation, should be investigated using actual products before it can be implemented in a real production line.

With the high demand of mobile phone in the market today, mobile phones are manufactured in high volumes in the industry. Statistics shows that the number of mobile phones manufactured increases rapidly from year to year (source from Motorola) . Most assembly operations of these mobile phones are currently carried out manually. Due to the labour intensive and the labour shortage factors, the assembly operations are preferred to be automated. Furthermore, some parts of the mobile phone are generally fragile and have high complexity in part design. These make the automated assembly of a mobile phone more complicated and difficult. Therefore, implementation of force-guided robot to perform mobile phone assembly automatically is crucial to the mobile phone industry.

1.3 Objective

The objective of this research is to develop a force-guided robot to automate the assembly operations in mobile phone manufacturing. To achieve this objective, several sub-objectives were identified. These are:

1. To study and identify the various basic assembly skills necessary to perform the mobile phone assembly operation.

2. To developed a force-guided robot by upgrading a conventional pick-and-place robot.

3. To study, develop and implement the appropriate force control schemes used in the force-guided robot.

4. To demonstrate the assembly operation in the absence and presence of position error of component.

5. To optimise the assembly operation for real production.

1.4 Scope

The research covered the studies of the assembly strategy and implementation of force-guided robot in mobile phone assembly. This included the studies of assembly operation of mobile phone, development of force-guided robot with the force control scheme, performing the force-guided compliant motions, evaluate and analyse the force control scheme and finally to perform automated assembly of mobile phone. The research is only focused on the notch-locked assembly where this assembly operation requires the most attention and investigation on how force-guided robot can be used to perform the assembly operation automatically. The research is extended to test the assembly approach in performing the notch-locked assembly operation with and without the presence of position error.

1.5 Approach

In order to achieve the objective of this research, a case study on the application of force-guided robot to perform industrial automated assembly in a mobile phone manufacturing was carried out. This is to study all the manual assembly operations involved in mobile phone assembly and propose an automated assembly strategy based on the force-guided robotic skills. A low-cost force-guided robotic system was developed and implemented in this study. An existing conventional industrial robot, previously used for pick-and-place tasks, was upgraded by integrating a multi-axis force sensor and a custom-built compliance device. A force control scheme was developed and adapted to the conventional robot controller. The force control scheme was tested and evaluated to perform various kinds of force-guided motions. An assembly operation of the mobile phone using notch-locked assembly was selected and automated using force-guided robot. An assembly strategy and approach based on force-guided motions were developed to perform the notch-locked assembly. This assembly strategy was demonstrated and tested in the absence and presence of position error. The force-guided robot was optimised by improving the assembly speed and the robustness of the system within the allowable tolerance.

1.6 Thesis Organisation

This thesis is organised in such a way that it systematically leads to the research objectives:

Chapter 1 presents a very general introduction on the research work. The problem and the motivation of this research are discussed and the research objectives are identified.

Chapter 2 presents the literature review on robotic assembly, force control and fine motion planning which are related to this research. This covers the current and the past research that have been carried out worldwide.

Chapter 3 describes a case study based on an actual mobile phone assembly. This chapter investigates how force-guided industrial robot can perform the automated assembly tasks of a mobile phone. Two major factors are considered in the automated assembly planning: assembly system and assembly process. As a result, three force-guided robotic skills are identified and discussed to perform automated assembly of mobile phone.

Chapter 4 presents the hardware design and hardware interfacing of force-guided robot. This includes the discussion of the industrial robot, force sensor, end effector tool such as compliance device and gripper. The interface between computer, force sensor and robot controller is also presented.

Chapter 5 discusses the considerations involved in developing the force control algorithm. This chapter presents the modeling and the design of force control which is used to perform force-guided motions and assembly task

Chapter 6 presents the discussion and experimental result of the three force-guided robotic skills. The force control developed in Chapter 5 was tested and the performance of the force control is evaluated and discussed.

Chapter 7 presents the assembly strategy and approach based on the force-guided robotic skills. The assembly strategy was tested to perform notch-locked assembly using real mobile phone parts and experimental results are analyzed and discussed.

Chapter 8 discusses the position error problem and the assembly strategy to overcome this position error problem. The assembly strategy is tested with the presence of position error in all axes and the experimental results are analyzed and discussed.

Chapter 9 concludes this thesis with a short summary of the dissertation, an outline of the contribution and some direction for future research, which are mostly unsolved problems that remain open in this thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A robot is defined as a programmable, multifunction manipulator design to move materials, parts tools, or special devices through variable programmed motions for performance of a variety of tasks (Keramas, 1999). Robots originally were used in hazardous operations such as handling toxic and radioactive materials. Eventually, the use of robots is now extended to other applications such as exploration, medicine, military, entertainment and also for industrial assembly. With the rapid changes of product design involving higher assembly difficulty, researchers worldwide have extended their interest into higher level of robot control where the robot can perform compliant motion and interact with the surrounding environment. This motivation has brought to the development of force-guided robot. In order to understand more about force-guided robot, a literature review is presented covering the trend of robotics, the applications, the approaches, and the strategies of force control to perform compliant motion, which has been done so far.

2.2 History/Trend of Industrial Robot

Robots were first introduced to industrial in early 1960s. The jobs to which robots were assigned during that decade were primary repetitious and the robot responded only to simple input commands (Keramas, 1999). During the 1970s, many improvements in controls increased the flexibility and capabilities of robots. The first robots were introduced in the automobile industry for tending a die-casting machine (Keramas, 1999). Computer-controlled robots were commercialized in the early 1973. During the early 1980s, robots are used in assembly operations. The industrial robots were later integrated with external devices such as Remote Center Compliance (RCC), vision system and force sensors to perform simple assembly operation (Puskrius and Yuan, 1988; Yu and Paul, 1990). Robot applications and installation continued to grow but with increased emphasis on the integration of the robot into workcell, flexible manufacturing systems (FMS) and computer-integrated manufacturing (CIM) systems (Keramas, 1999). During the 1990s and early 2000s, the complicated design of the assembly parts involved tasks which are increasingly more complicated (Du et al., 1999). Fine motion planning is needed in order to perform the complex assembly tasks. Artificial intelligence was integrated into the robot controller to perform fine motions (Lin and Tzeng, 1999). More robots and sensoring devices such as vision and force sensory devices with motion control were merged in the integrated and automated production system to expand the capabilities of the robot in order to perform and adjust for new assembly jobs (Tsujimura and Yabuta, 1991).

2.3 Robotic Assembly

Assembly process consists of feeding, handling, and mating (Bruyninckx et al., 2001). Robots can be used in industry to provide these works and services. Robotic Industries Association (RIA) in USA estimates that 116,000 robots are now at work in United State factories, making the United States the world's second largest robotics user, trailing after only Japan (RIA, 2002). Figure 2.1 shows the robot application area as a percentage of total robot population for the year 2002.

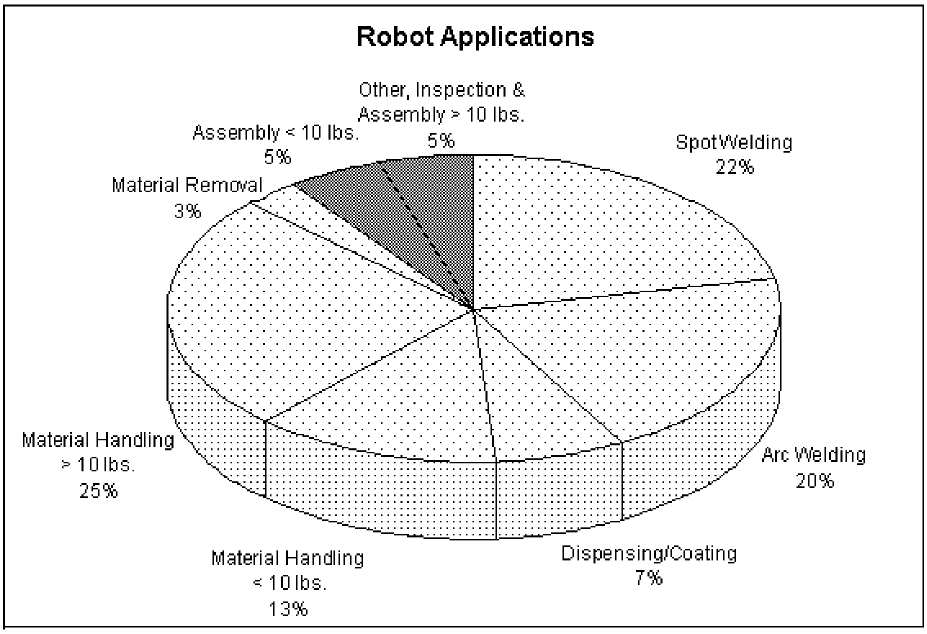

Figure 2.1: Comparison of leading robot applications in 2002. (RIA, 2002)

Over the huge number of robot population by application, less than 10% of the total is used in assembly application. This could be due to the complexity of the tasks involved in the real assembly line. Real assembly tasks not only consist of simple mating processes or pick-and-place applications but also consist of typical higher level assembly work, such as mobile phone assembly, furniture assembly by variety of fastening methods, and hip impact insertion in medical applications (Du et al., 1999).

Industrial robot controllers however do not yet offer built-in force control features (Bruyninckx et al., 2001). Bruyninckx (2001) describes the current conventional robotic system uses a position-based robotic control strategy, which is ineffective as an assembly tool in cases where the assembly tolerance is less than the positional uncertainty. Furthermore, compliant motion requires close integration of different software components that implement control, intelligent sensing and planning skills.

In order to achieve assembly performance comparable or exceeding humans, robot must use force and torque interaction to converge on a solution that produces a successful assembly. In these applications, force-guided robotic systems can offer a very effective solution.

2.4 Force-guided Robot and Compliance Motion Techniques

Robotic research group worldwide are moving towards doing research and designing generic system in force control motion planning to perform compliance motion over the past two decades (Ferretti et al., 1997; Yoshikawa et al., 1988; Mason, 1981, Raibert and Craig, 1981; Lange, 1992). Currently available compliant motion control techniques may be categorized into two basic types. One is passive compliance and another one is active compliance. This review is necessary as a guideline to determine the selection of compliant for current research in performing mobile phone assembly.

2.4.1 Passive Compliance

Passive compliance is inherent in the robot where an absorbable or elastic device is inserted near the end-effector. This can be force sensor itself or a compliance device. Whitney and Rourke (1986) and Robert (1984) showed that a soft force sensor could lead to stable behavior in a stiff environment. However, this kind of soft force sensor reduces the dynamic range of force response and the position accuracy. Goswami and Peshkin (1999) recommended an independent compliance device, which can be integrated to force sensor and end-effector as passive compliance. Basically, most of the compliance devices used in robotic application are the Remote Center of Compliance (RCC) (Joo and Miyazaki, 1998). The concept of RCC is preferred compared to Center of Compliance (COC) because the robotic joints providing the necessary articulation at the tip are generally at an appreciable distance from the tip.

There are many version of compliance devices, which have been developed in Belgium (Schutter, 1986), Japan (Asada and Slotine, 1986; Takuse et al., 1974), France (Merlet, 1987; Reboulet and Robert, 1985), Germany (Dillmann, 1982) and USA (Goswari and Peshkin, 1999; Cutkosky and Wright, 1982). The advantages of these compliance devices are: (i) provide efficient force control in a stiff environment, (ii) increase manipulator resolution, (iii) reduce the complexity of the active controller and (iv) prevent the damage of manipulator, end-effector and grasped object. A passive position-adaptive system does not need any change in a robot controller design. This provides a reliable, fast and relatively cheap solution. However, flexibility of compliance is low and accommodation error range is limited. Moreover, the robot must generate great power to press the peg into the hole during assembly. This method would reduce the repeatability of the robot. Therefore, passive compliance is not suitable for this current research as mobile phone assembly needs high flexibility of compliance and wide range of error accommodation for different assembly parts.

2.4.2 Active Compliance

The other category of compliant motion control is active compliance control. It involves proper programming of the control system to react to random tactile stimuli. Compliance can be achieved through joint-torque, either by setting a linear relation or equation between the force and displacement or force and velocity. The first force control presented is called active stiffness control (Salibury, 1980). The robot is considered as a programmable spring where the stiffness of the frame located arbitrarily in geometry coordinates can be specified to control the compliant behaviour of the manipulator. This force control is very simple but not suitable for most of the industrial controller where control at joint torque level is not allowed. Hybrid position/force control scheme combines force and moment information with position data to satisfy simultaneous position and force trajectory constraints (Mason, 1981; Raibert & Craig, 1981). This control exhibits two servo loops. In general, the position servo loop is already implemented in the original industrial controllers. The force loop must be implemented with an action at the joint torque level. Moreover, the algorithm is computationally extensive and can be incompatible with the computation power of industrial controllers. Hogan (1985) introduced impedance control, which attempts to establish a user-defined dynamics that includes the variables of position and velocity in Cartesian space. This control scheme is only useful for control in joint torque level that is for fast and gross motions involving nonlinear system and higher order dynamics system. De Schutter (1987) implemented external force control schemes where an external loop is enclosed to the robot position controller. This control scheme is widely used due to the flexibility to many kinds of robot positioning systems (Volpe and Khosla, 1993). Considering the high flexibility of compliance and wide accommodation range error, active compliance is used in this research.

In the process of improving the basic scheme of force control, research groups worldwide have proposed several control techniques in attempt to find a better solution and method to perform compliance motion. Panteley and Stosky (1993), Lopez-Juarez, Howarth M. and Sivayoganathan (1998) used adaptive control; Liu et al. (1999) used model-based adaptive hybrid control; Machado et al. (1998) proposed fractional control and fractional order hybrid control; Paul (1987) proposed hybrid control with passive compliance; Hace et al. (1998) proposed robust impedance control; Canudas and Brogliato (1994) used impedance control with adaptive estimation of the environment stiffness; Nagata et al. (1998) used position-based impedance control using fuzzy environment models; Moosavian and Papadopoulos (1998) used multiple impedance control (MIC) and Kwan (1995) and Parra-Vega et al. (1994) used a combination of adaptive and sliding-mode control technique.

There are also many advanced force control based on adaptive control, robust control and learning methods, which integrated or combined with the fundamental methods using artificial intelligence tools (Jung and Hsia, 1995). These intelligent control schemes overcome the nonlinear system effectively but it is hard to be implemented in real application due to the complexity and the longer cycle time. Therefore, a simple force control scheme combining external force control, stiffness control and position control namely external force control with computational position feedback signal is developed and used in this research. Details of the force control scheme will be discussed in Chapter 5.

2.5 Study/Investigation on Force-guided Robot

Besides the development of force controller, many investigations related to force control robot and compliance motion have been reported. John and Murphy (1991) presented a stability analysis for robot manipulator under the influence of external forces. Hoda and Payandeh (1989) have carried out investigation in extracting information about contact between two convex bodies from the measured force vector, which is a prerequisite for forming fine compliance motion control strategy. James and Goldenberg (1989) deal with force contact which results in a kinematics constrained imposed on the motion of the end-effector/manipulator. Krishnan (1999) has studied the effect of joint flexibility and actuator dynamic; Khatib (1987) has presented the operational space formulation for compliance motion.

There are few papers about the comparison of force control methods. Shaki and Shoham (1998) have investigated the comparison of explicit, implicit, stiffness and impedance control quantitatively using simulation software and Schutter (1986) has compared the Proportional (P) and Proportional Integral (PI) force control to perform compliant motion.

2.6 Force-guided Robot Hierarchy

Several decades of experience in sensor-based assembly control have led to the three-level hierarchy as shown in Figure 2.2 (Saridis, 1979).

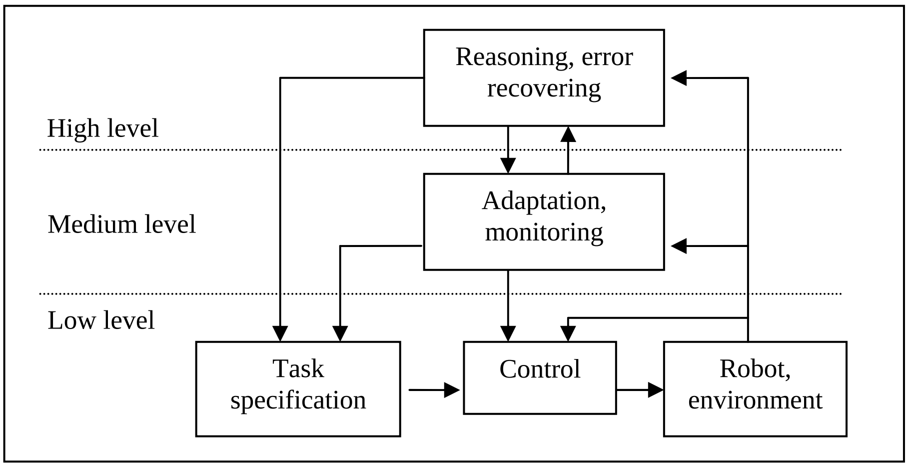

Figure 2.2: The classical three-level hierarchical control pattern for intelligent robot systems.

The lowest ("reactive") level deals with the dynamics of the robot and its environment (Schutter and Brussel, 1988; McCrragher et al., 1997; Raibert and Craig, 1981; Hogan, 1985). Most assembly systems still rely on passive force control using devices such as the RCC (Whitney and Nevins, 1979) because passive force control is much higher speed and robustness. The medium ("Sequencing") level comprises (i) estimation and monitoring, and (ii) automatic force-controlled compliant motion scheduling (Schutter et al., 1999; Hovland and McCarragther, 1998). The highest ("deliberative") level is responsible for decision making, re-planning and on-line error recovery. Only the lowest level in this hierarchy has been implemented industrially (Bruyninckx et al., 2001). Academic researcher realized some “proof-of concept” implementations in low and medium levels, but these lack sufficient robustness for industrial application. The medium level becomes necessary in assembly system whose uncertainties are too large to be compensated by an RCC. This research basically focuses on the low level sensor-based assembly but at the same time the medium level will be explored to monitor the mobile phone assembly operations and overcome part position error during the assembly operations.

2.7 Application of Force-guided Robot

Many papers have been published on the applications of force control in performing compliance motion. Kirad et al. (1999) presented the application of position/force control strategy to the calibration phase automation of weighing systems; Dubowsky et al. (1999) has applied the concept of force control in the multi-limbed robotic system (climbing robot); Nemec and Zlajpah (1998) has implemented force control in redundant robot.

Many concepts, methods and algorithms have been developed to accomplish compliant motion. However, most of the research and investigations related to force-guided robot worldwide are carried out to perform a very general task such as peg-in-hole insertion (Schutter, 1986; Naghdy and Nguyen, 1998), contour tracking (Lange and Hirzinger, 1992; Goddard et al., 1992), screw fastening, and palletizing (Lange and Hirlinger, 1992; Qiao et al., 1995; Du 1998; Du et al., 1999; Erlbacher, 2000). Such general task may not be readily applicable in real assembly tasks due to the complexity of such operations. Compliant motion still has not yet made a real breakthrough in the field of industrial applications such as automated assembly, but rather remains mainly as a research tool (Tichem et al., 1999).

The Ford Advanced Manufacturing Technology Development Center (AMTD) has implemented force-controlled robot technology to perform power train gear assembly (Gravel and Newman, 2001). Gravel and Newman (2001) have successfully performed the clutch hub insertion using force-controlled robot. The assembly parts are made of metal where the assembly force used is generally high (50-100 N). This assembly task is not suitable for fragile plastic component where assembly force must be accurately controlled. Many products manufactured today including mobile phones incorporate plastic components. These products are easily damaged if the assembly force is not monitored and controlled. Furthermore, most plastic parts are designed with snap fit features where the various parts can be assembled together without using adhesive or fastener. In assembly task involving snap fits, assembly force is extremely important to ensure the parts are well assembled without damaging them. The assembly task becomes more critical with the presence of position error. Therefore, this research will investigate the implementation of force-guided robot to perform mobile phone assembly in the presence of position error.

In order to study how force-guided robot can be implemented in industrial applications, Universiti Sains Malaysia (USM) has carried out research in this particular area for the past few years to investigate force control in automated assembly. The concept of force control in performing compliant motion was previously carried out in a simulated environment using a state-of-the-art dynamic simulation software (DADS) by research group in USM (Lai, 1999). A 6-DOF gantry robot with position and force controller was modelled and evaluated in DADS by using Proportional Integral Derivative (PID) control to perform one dimensional surface tracking. A 6-axis compliance device was also modelled in simulation environment to make the end effector of the robot comply with the contact force of a stiff environment. Research in force control robot is currently being carried out where a fine motion planning using fuzzy control of palletizing task is performed in simulation environment. The simulation result showed potential for application of force control in an industrial robot in real environment to perform compliant motion for assembly task.

2.8 Summary

Many researchers worldwide have developed different kinds of force control approach to perform compliant motion. Application of force-guided robot to perform automated assembly in manufacturing industries however is still very limited. This is due to the lack of understanding how force-guided robot can perform complicated assembly task in the presence of part position error. Many research carried out worldwide still focus on generalized tasks which may not be applicable in real industrial application. Problem regarding notch-locked assembly for example needs more attention to be studied and explored. An assembly approach based on compliant motion must be developed to make the automated assembly of real product possible. A study using real product and real environment is necessary to bridge up the gap between research and real application. In order to understand the mobile phone assembly operation, a case study is carried out to investigate how automated assembly of mobile phone can be performed using force-guided robot. Details of the case study are discussed in the next chapter.

CHAPTER 3

A CASE STUDY OF MOBILE PHONE ASSEMBLY TASK

3.1 Introduction

Integration of product design and assembly task is one of the major technology areas in assembly. Development of plans and strategies detailing the sequence of assembly operation in mobile phone assembly is necessary to perform automated assembly. This chapter studies all the consideration involved in the implementation of force-guided robot in automated assembly. A case study on the application of force-guided robotic to perform automated assembly in mobile phone manufacturing is presented. Existing human assembly operations in mobile phone assembly that can be automated by force-guided robot are identified and classified according to the assembly strategies and fastening method. Three force-guided robotic skills are recommended and discussed in order to perform these assembly operations.

The development, implementation and integration of force guided robot in automated assembly must fulfill the following requirements of flexible assembly as below (Boneschanscher, 1993):

- Reconfiguration flexibility.
- Programming/planning flexibility.
- Semi-random production capability.
- Fault tolerance.
- High production capacity.

- Good user interface.

The force guided robot must be able to be reconfigured or exchanged without great difficulty to perform a large number of assembly tasks. It must be easily reprogramable with user-friendly interface to perform ‘random’ production of products or new assembly tasks within the range of supported product families. Furthermore, the force guided robot must have limited automatic recovering ability after the occurrence of error, and sufficiently reliable and fast enough to enable industrial assembly tasks. Therefore, two factors are considered to implement flexible assembly in force-guided robotics: assembly parts and assembly process.

3.2 Assembly Part

In order to study the assembly operations involved in mobile phone manufacturing, all the parts of a mobile phone unit must be considered. Figure 3.1 shows the common mechanical and electronic parts found in a mobile phone.

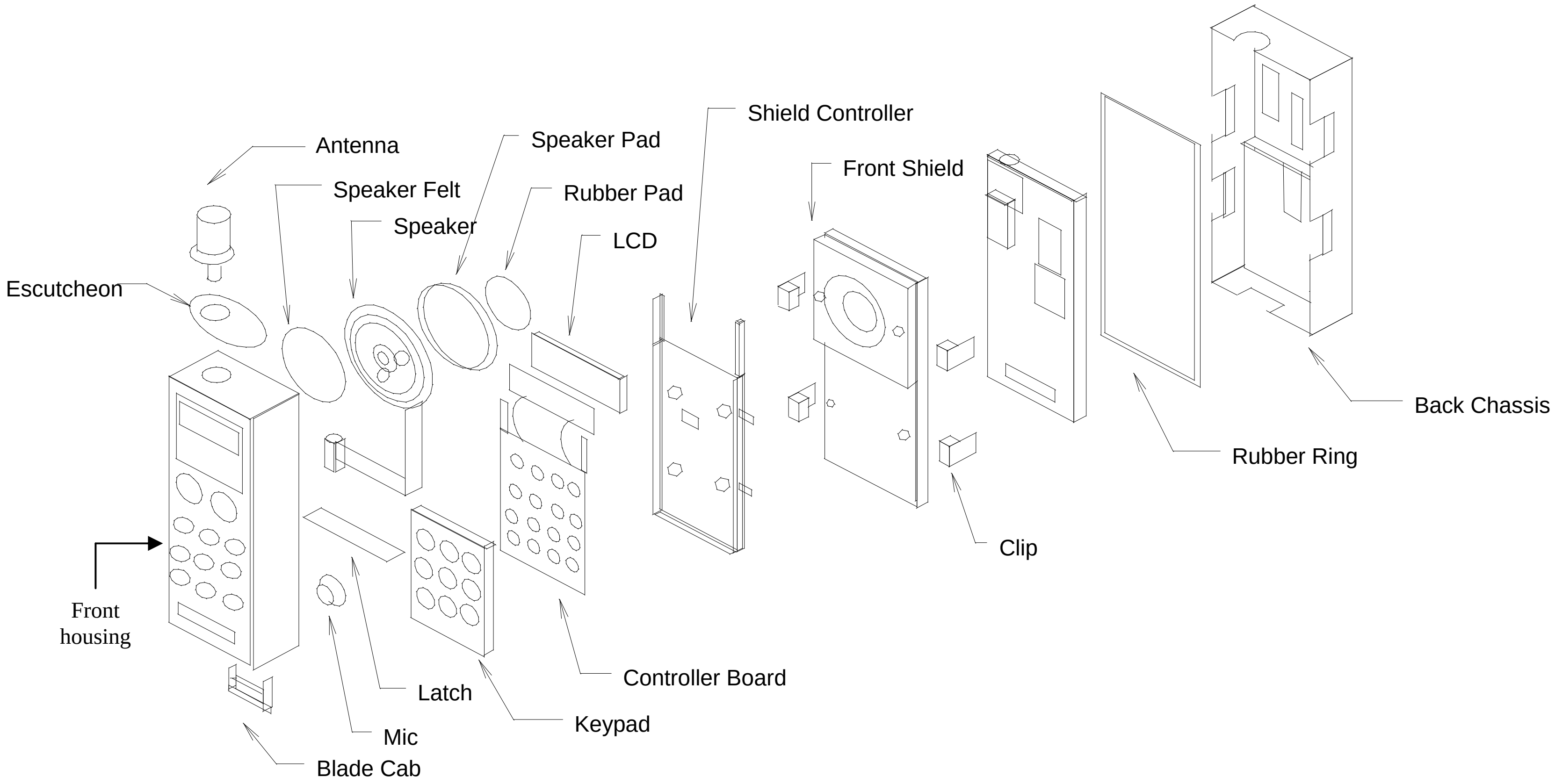

Figure 3.1: Assembly parts of mobile phone

There are 18 major parts in a mobile phone excluding the screws and clips. These mechanical and electronic parts are currently fully assembled by human operators in a local mobile phone manufacturing company.

3.3 Assembly Operation

In this section, an effort is made to point out the underlying general assembly process in mobile phone assembly. The sequences of mechanical assembly and its operations of mobile phone assembly are divided into three main assembly operations, namely front housing assembly, back chassis assembly and final assembly. The details of these assemblies are given in Table 3.1. Assembly sequence in mobile phone basically follows the part-oriented approach. Most of the parts in mobile phone must follow specific sequence to be fitted in. However, front housing assembly and back chassis assembly are performed independently. Therefore, they can be performed in parallel before the final assembly.

From the assembly operations listed in Table 3.1, the parts connecting assembly tasks of mobile phone can be classified as below:

(a) Peg-in-hole and male female insertion.

(b) Snapping and pressing.

(c) Screw fastening.

(d) Notch locked assembly.

(e) Pick-and-place.