초소형 IT 부품 조립을 위한 지능형 민첩 생산시스템

Agile and Intelligent Manufacturing System for a Small IT Parts Assembly

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Abstract : The tiny camera module used in a modern cellular phone requires precise assembly processes. To meet the requirement of high resolution and functionality, the number of parts used in a camera module becomes larger and larger. As the market grows rapidly, an automatic camera phone assembly process is required. However, diverse production line and short life cycle make it difficult to build an affordable assembly line. To attack this problem, a flexible and expandable lens assembly system is proposed. To save the manufacturing line set-up time, modular concept is adopted. Also, each module is designed to have intelligence to simplify the set-up process. The assembly system is built up on the standard flat-form that includes a vibration free base, air and electric supplies, and electronic controllers, etc. Furthermore, the assembly cell has the capability of handling tiny, thin, or transparent parts which are very difficult to identify without machine vision.

Keywords : manufacturing system, agility, intelligence, lens process, assembly

I. Introduction

The Agile and Intelligent Modular Manufacturing System (AIM) is a next generation intelligence production system featuring self- diagnostic and self-control capabilities. It is an adequate assembly system for the electronic components, which requires fast, precise, and flexible assembly process.

For the purpose of sharing component information with other systems in independent processing, the system utilized many techniques such as robots, vision guided control, virtual reality, sensing and self-training. The concept of system configuration is based on a fractal design.

In the case of traditional assembly systems, the cost of building a customized machine is high, and there are many difficulties in re-arranging the configurations to meet the ever-changing production models. Clear example is the miniature lens modules assembly in high-performance cellular phones.

Typically small lens modules have been assembled by humans. Furthermore, as the camera resolutions becomes higher and zooming capability is common in nowadays, the number of parts required have rapidly grown, in turn, making it complicated to build an automatic assembling system.

In this study, to attack these short-comings, we developed an agile and intelligent assembly system for the miniature products such as lens modules. The assembly process of small lens modules needs to have a flexibility in changes of the number of process steps as well as a capability of sequential/non-sequential process so that each of the unit cells can be a module with unique functions.

Therefore, we focused on developing standardized platforms and interfaces between the unit cells and the overall systems.

Firstly we analyzed the lenses to decide which models were the most suitable for the proto system and implemented a system that could be utilized for the various modules. In addition, we proposed a direction toward an agile system for diverse and small quantity production environment without loss of precision requirement of customers.

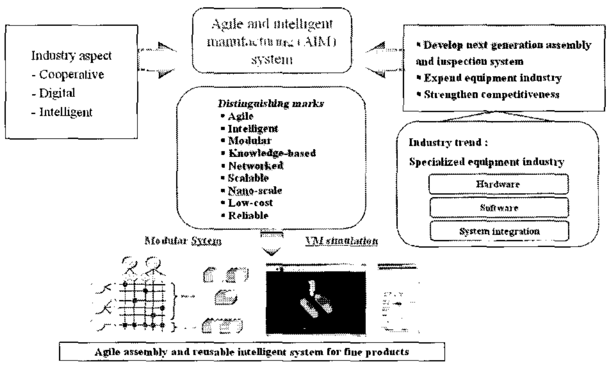

그림 1. 지능형 민첩 생산시스템의 정의.

Fig. 1. Definition of agile and intelligence manufacturing system.

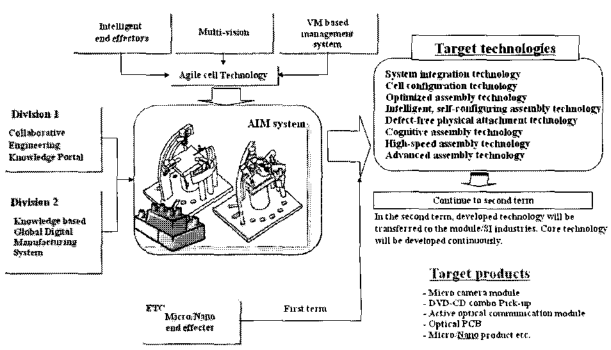

그림 2. 연구 계획.

Fig. 2. Research strategy.

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The requirements to implement an easy-to-use system under the situation as shown in Fig. 2 can be summarized as follows:

1.Standardized modules.
2. High-precision system for nano-scale manufacturing.
3. Miniature system to implement a micro factory.
4. Price competitiveness

II. Design of the lens assembly system using AIM

1. Analysis of assembly parts

Subminiature camera lens module applied to mobile phone is an assembly of precision and small parts. The numbers of elements is increasing as resolution becomes high and other functions are added such as zoom and AF. Also a clean manufacturing environment is required since the lens assembly is so vulnerable to the tiny dusts.

Fig. 3 shows the schematic and the exploded view of a camera lens module.

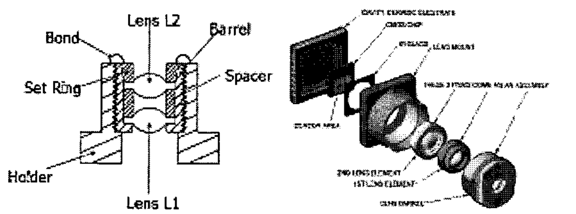


그림 3. 고정된 초점 렌즈 유닛.

Fig. 3. Fixed focus lens unit.

표 1. 초소형 렌즈 분석.

Table 1. Tiny lens analysis.

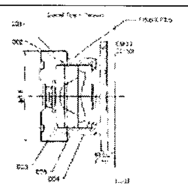
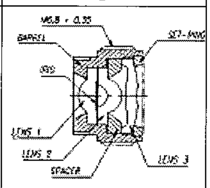
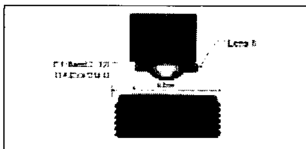
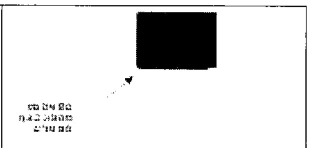
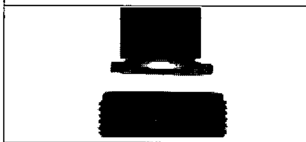
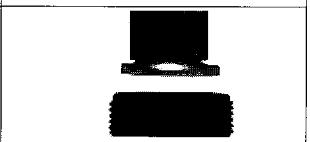
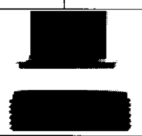
The number of lens	2	3
Composition		
Total components	5	7(Max 9)
Assembly tolerance	≤ 10 ㎛ ~ 20 ㎛	≤ 5 ㎛

표 2. 렌즈 부품 테스트.

Table 2. Lens components test.

	
Lens1	Iris
	
Lens2	Lens3
	
Spacer	

The lens module consists of lens accepting the object image, the spacer, the barrel and so on. For the efficient assembly process, it is need to grasp an exact internal structure of the module.

As the resolution of the camera lens increases, the number of the necessary components also increases. And with the addition of zooming capability, the number of mechanical parts also grows very rapidly. According to the Table 1, the number of the lens increases from 2 to 3. However, the total number of the components increases from 5 to 7(maximum 9). In addition, assembly tolerance is changed to less than 5 ㎛.

2. Lens assembly analysis using vision camera

For the case of lens assembly, a conventional alignment algorithm looks to give a reasonable assembly quality. However, actual measurement results shows that the tolerance of the component itself is over 5~15 ㎛. In this study we measured the iris of the lens with a common tool, but that is too thin to capture under the current measurement configuration.

3. Assembly work process analysis by parts

Fig. 4 is the assembly process of the lens module. The supply and exhaust of parts tray is attained through the vertical type manipulator robot. The lenses and components were transferred by a pick-and-place process with multiple gripper designed for holding various component with only one picker. When a component should be handled via vacuum chuck, a few vacuum sensors were employed to detect possible gripping errors.

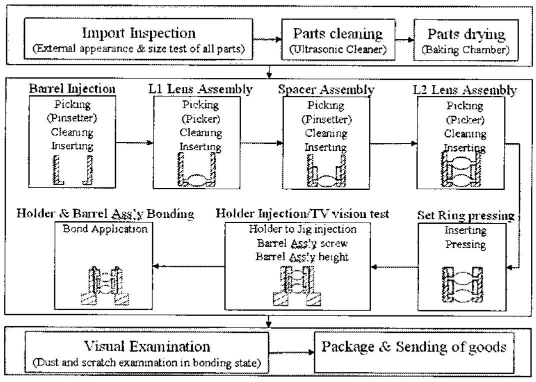


그림 4. 조립 공정 분석.

Fig. 4. Assembly process analysis.

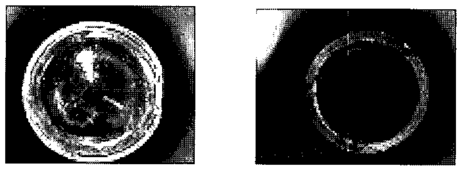


그림 5. 렌즈의 형태.

Fig. 5. Shape of lens.

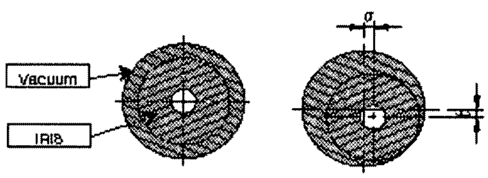


그림 6. 얼라인 공정.

Fig. 6. Alignment process.

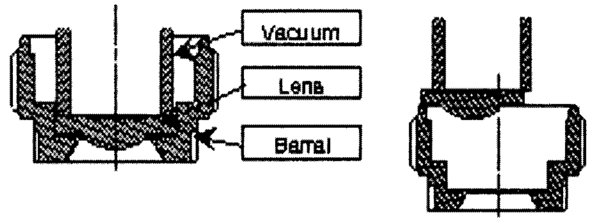


그림 7. 보통 삽입 상태와 삽입 에러.

Fig. 7. Normal insertion state and insertion error.

Several vision cameras are used to identify the gate cutting directions and the front- and back-side of lenses or parts. If there is no more part, the host PC issues alarm.

Because the iris were too thin to inspect from the side, it is difficult to align. Thus we inspected the parts in a separate process in which the direction and the front and back of the part are detected. Then, we measure the offset values a, b between the vacuum hand and the iris, and use the information in the following assembly process.

Before inserting a component in the barrel, we checked the alignment of barrel with an inserting component through vision camera. In that moment, insertion pressure and depth were monitored.

4. Configuration of lens assembly system

A block diagram of the proposed system for the lens assembly is shown in Fig. 8, which consists of vision system, force control system, and virtual reality system. The vision system is consists of vision camera, frame grabber, control PC, and so on. And the force control system consists of precision stage, robot, manipulator, feeder, bonding tool, actuator, and host PC.

The information from a vision camera module is stored and processed in the host PC and distributed to each AIM cells. Each cell sends the commands from the host PC to the core components, and the component executes the job. Each unit cells has own motion controller and a vision processing controller. System cell are comprised of multiple unit cells. In our design, the vision software used in a unit cell controller can be utilized in other unit cell controller of the system without change.

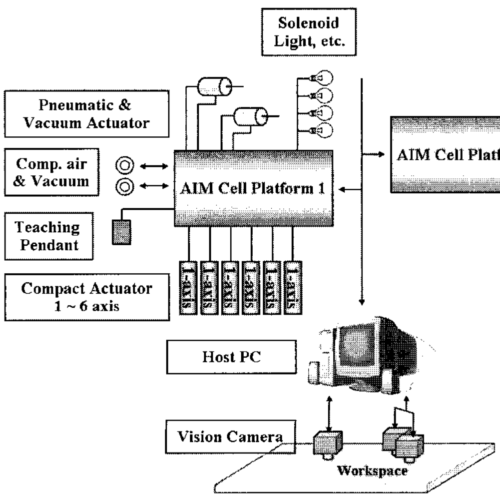


그림 8. 단위셀의 개요도.

Fig. 8. Schematic diagram of unit cell.

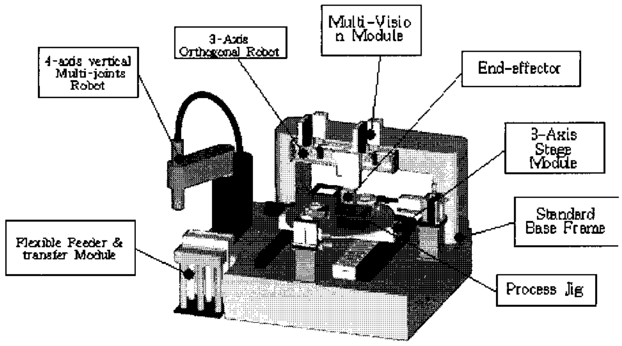


그림 9. 2½ 차원 조립 민첩셀.

Fig. 9. 2½ Dimensional assembly agile cell.

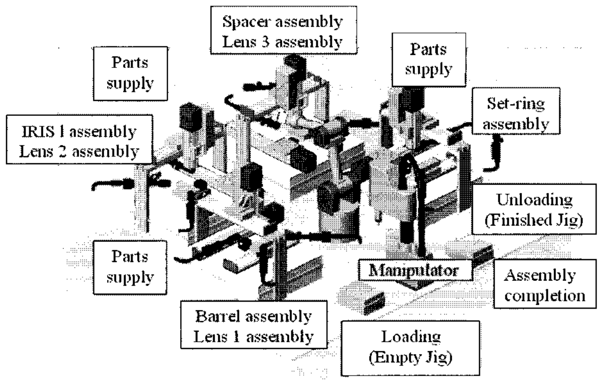


그림 10. 셀 구성도.

Fig. 10. Cell configuration prototype.

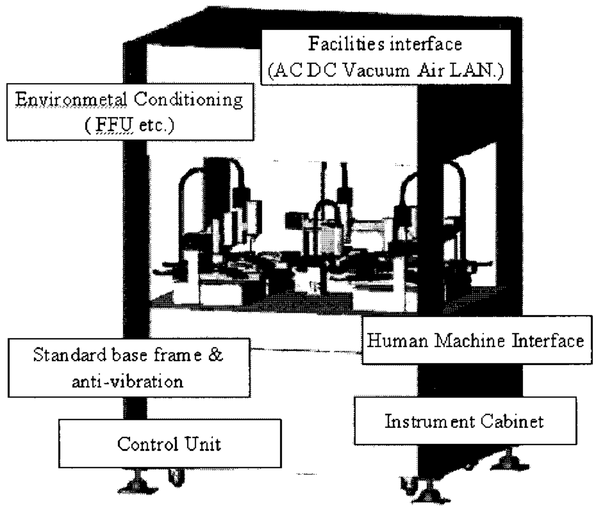


그림 11. 시스템 구성도.

Fig. 11. System configuration prototype.

Fig. 9 shows a prototype of assembly cell of 2.5 dimensions. This is the basic cell of the system. Also, depending on a process, cells with one or two functions can be mounted on the base frame resulting in the whole assembly system(Fig. 10).

We arranged whole system into an instrument cabinet for a clean assembly environment.

5. Lens assembly process

The flow chart of lens assembly is shown in Fig. 12.

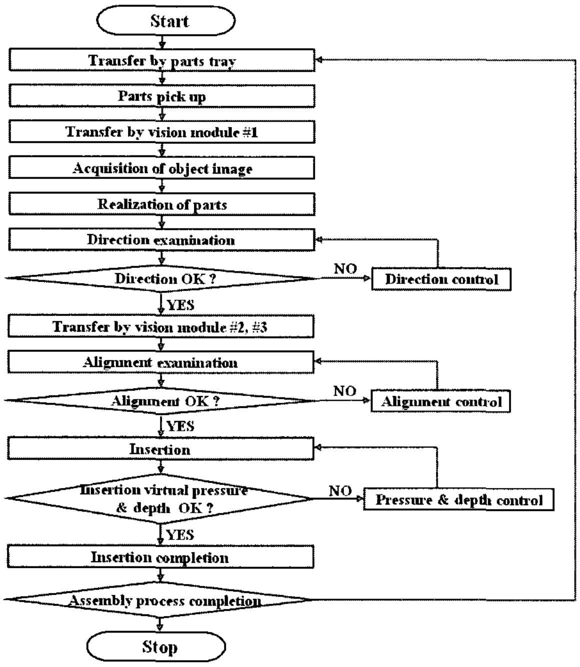


그림 12. 렌즈 조립의 공정도표.

Fig. 12. The flow chart of lens assembly.

III. Manufacture of lens assembly system

We designed the unit cell platform to expand and modify the flexible module assemblies through the standard modules.

The platform was equipped with a multi-axis position controller, 625Kbps high speed communication, and multipur- pose digital input/output capability, etc.

And the platform has a few standard features such a utility to control the peripherals, three valve ports for vacuum pads, and a customized vacuum pressure sensor to detect the holding status of components for robot control.

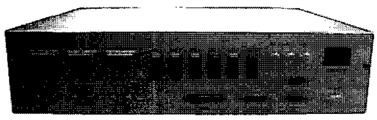


그림 13. 단위 플랫폼 패널.

Fig. 13. Unit cell platform panel.

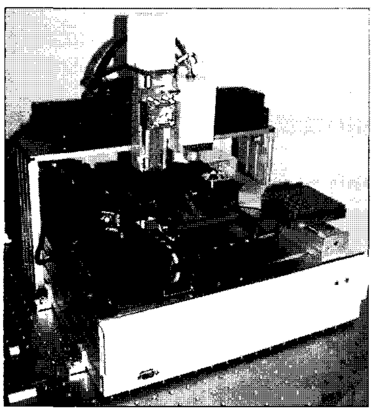


그림 14. 단위 셀 플랫폼.

Fig. 14. A unit cell platform with modules.

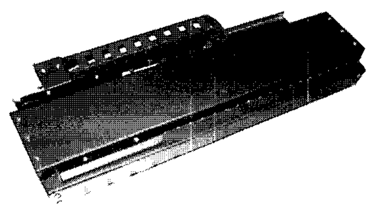


그림 15. 고정도 다이렉트 드라이브 스테이지.

Fig. 15. High-precision direct drive stage.

그림 16. 구동부 모듈.

Fig. 16. Cartesian module.

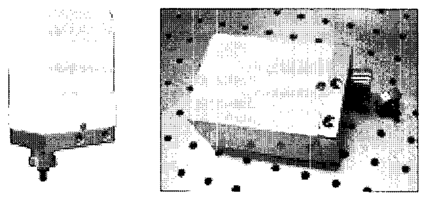


그림 17. 로테이션 모듈.

Fig. 17. Rotation module.

1. Actuator module

To build a system with high-speed and high-precision capability, precision direct drive stages were utilized through pulse control.

2. Cartesian module

For the general purpose, several Cartesian modules are used.

3. Rotation module

The rotation module was designed with simple, low-cost, light-weight pulley & belt reduction structure with a common rotational vacuum nozzle.

4. Parts tray

After cleaned and packaged so as not to be contaminated by dusts, each part is supplied on a customized tray. The trays are specially customized for each part. Sometimes a tray can contain more than two parts. In that case, the direction of the tray should be monitored. In assembling stage, jigs should have a sensor to detect the presence and direction of the tray.

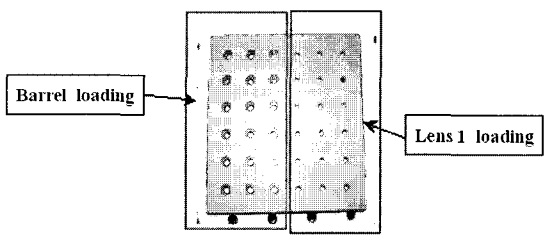


그림 18. 베럴과 렌즈 1 부품 트레이.

Fig. 18. Barrel & lens1 parts tray.

An assembled product is inserted in an assembly tray and stacked on the finished jig. The placement is made in a single row to inspect the position of the part with vision camera.

5. Jig Fixture

Both trays and jig-and-fixtures have magnets so that the magnets on a tray transferred by the manipulator stick to the jig-and-fixture, maintaining a certain distance between the two objects. Further, to adjust the gap between the magnet and magnetic metal, an adjusting screw is protruded from the jig-fixture.

6. Loader & Un-loader

The loader & un-loader are manually supplied and have a sensor to detect the presence and direction of a tray.

7. Force control module

With a combination of strain gage and flexure hinge, the insertion force is controlled during assembly. The control range is 0.5N~6.0N, and the resolution is 0.5N. The signal is amplified with two-stage OP-AMPs, and the sensitivity is adjusted by the internal constant voltage regulator.

8. Inductive sensor

Using sensors and flexure hinges, the insertion force is controlled during assembly. In this case, the control range is 6N~13N, and the travel range is 0.8mm.

9. Manipulator module

Manipulators are used for transferring trays. A gripper or vacuum is used to hold a tray.

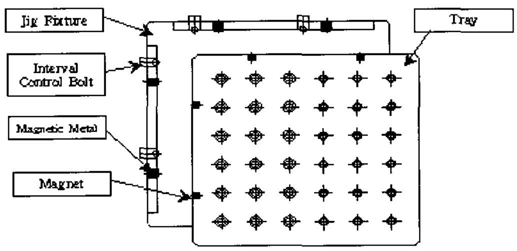


그림 19. 자석을 이용한 위치 결정 방법.

Fig. 19. Position deciding method using magnet.

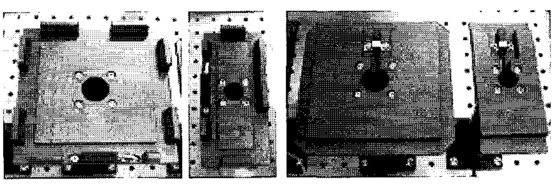


그림 20. 로더와 언로더.

Fig. 20. Loaders & unloaders.

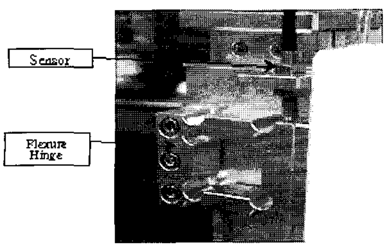


그림 21. 유접점 센서와 flexure hinge.

Fig. 21. Inductive sensor and flexure hinge.

9.1 Clean style horizontal type manipulator

The 4-axis horizontal type manipulator robot is used in this study. As an intermediate transferring system, this mani-pulator moves the manually supplied trays(parts/assembly) to the loader, and to an un-loader system. A transfer is done after checking sensor information from loader/un-loader. The manipulator's repeatability is ±5.0 ㎛(X,Y axis unidirec-tional) and maximum speed is 200 mm/sec.

9.2 Vertical type manipulator

We designed 5-Axis vertical type manipulator. This one supplies the part/assembly tray and unloaded trays with vacuum when a job was finished. The two vacuum ports can be separately controllable. And we achieved a relatively wide operation range though a slim, ligh-weight design.

9.3 Vision positioning module

Fig. 25 shows the motion control method through the acquisition of image using camera and image processing. It is possible to adjust minute x-y-z positions with the aid of vision cameras.

10. Lens assembly system operation software

Each assembly cell is dedicated for only one part assembly. We developed the expandable software that can be used for controlling n-component assembling system with the slight changes of parameters in the configuration.

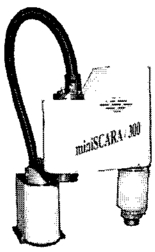


그림 22. 수평 다관절 로봇.

Fig. 22. Horizontal type manipulator robot.

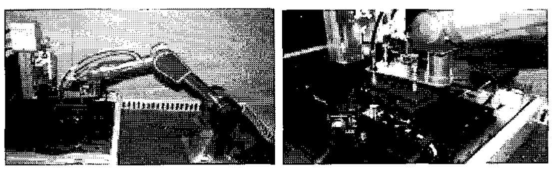


그림 23. 수직 다관절 로봇 작업.

Fig. 23. Vertical type manipulator robot works.

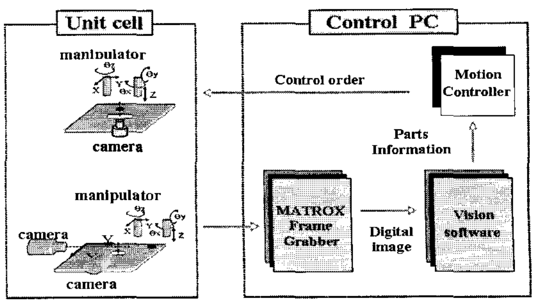


그림 24. 비전 시스템의 블록 다이아그램.

Fig. 24. Block diagram of vision system.

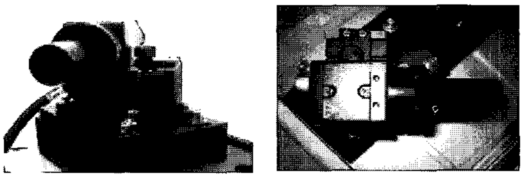


그림 25. 카메라 제어 유닛.

Fig. 25. Camera control units.

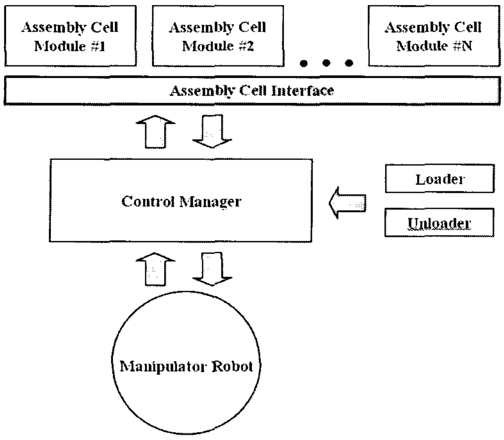


그림 26. 전체 소프트웨어 구성.

Fig. 26. Whole software composition.

When inserting a lens into the barrel, the robot's position is adjusted in each X-Y-Z axis in the distance between the barrel and lens by a visual monitoring system. For the case of inspecting lens alignment, the cutting direction is monitored before the inspection. And the lens unit is rotated in a constant degree so as for the cutting mark not to hinder the alignment measurement.

10.1 Software construction

The assembly cell for one part is a basic unit to build a production line. The controlling program is designed to make it easy to add and delete a process in the line. The Fig. 27 represent the overall configuration of the lens assembly system.

The Control manager program is the top module which checks the current status and issues the next work to each assembly cell module, manipulator robot and loader/un-loader. The Assembly cell conveys the commands of start/stop with indirect control. Controlling manipulator robot is directly managed by the Control manager program.

Assembly cell interface plays a role of intermediate communication between the Control manager and the Assembly cell module. Although the internal structure and function of each Assembly cell module are prominently different, Control manager can manage these modules if Assembly cell interface function is implemented in the managing program. Since each of Assembly cell modules performs their respective functions, the internal mechanical configuration and shape can be modified depending on the types of parts and the usage of visual inspection.

11. Vision inspection

A reason to perform visual inspection is to adjust the position of the Cartesian type X-Y robot to make it easy to insert lens smoothly into the barrel. In this experiment, we used a few CCD cameras with resolution of 640*480, FOV of approximately 10mm. Lighting was illuminated from back side.

Data from a camera has a unit of pixel. Thus it is need to convert those pixel data into the unit of milli-meter. The procedure to perform these steps is called camera calibration. In other words, it is the measurement to identify the relationship between each pixel on camera and actual size in mm. Assembly cell uses the lens holding grippers to calibrate, comparing the real width of gripper with the width on the image.

Calculation of the calibration data using above mathematical expression gives.

$$X_{cal} = 4.2/256 = 0.0164\text{mm}$$

We uses the Locator and EdgeLocator from HexSight co. The Locator carries out the function of finding a certain pattern from camera. To do this, the pattern needs to be registered before the inspection. EdgeLocator finds the borders of Edges from a specific image area. The EdgeLocator uses the two sides of barrel's position and recognizes the center of a barrel by taking the center of two sides.

We employed Locator to find a similar model and then used EdgeLocator to find an accurate center of the barrel. In reality, there is a discrepancy between Locator and Edge-Locator. To prevent this problem, the center position is defined when registering inspection pattern. In addition to this, a few visual error types were included such as upside-down lens and absence of lens etc.

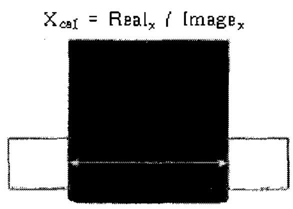


그림 27. 보정 영상.

Fig. 27. Calibration image.

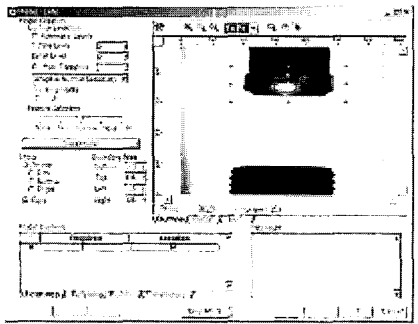


그림 28. 모델 기록 영상.

Fig. 28. Model registration image.

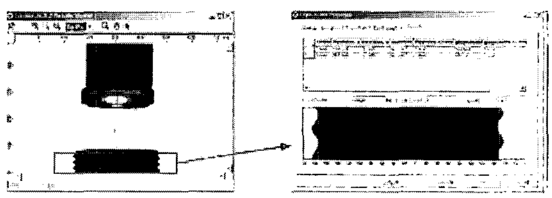


그림 29. Of Locator & EdgeLocator 의 응용방법.

Fig. 29. Application method of Locator & EdgeLocator.

IV. Conclusions

We have designed the Agile and Intelligent Manufacturing System for assembly automation of micro lens module to correspond to micro assembly.

By expanding a conventional concept, we were able to mix platforms with modules, giving an ability to handle a lens module with three-piece lenses. Precision measurement is achieved using a high-resolution vision system. Through combining control and management, we improved intelligence and completeness of the assembly system.

Although there is some limitation in applying the proposed system to the wide range of application, we could build a system that can be constructed in two to three weeks by adding and subtracting a few modules from the standard cells.

We will continue to develop the AIM systems for assembling other small IT parts, a system with six-degree of freedom and with more efficient methods. Lastly, the evaluation method of the performance of the completed assembly will be performed as well.

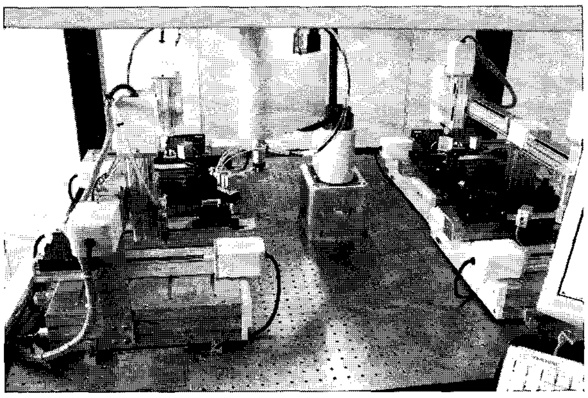


그림 30. 렌즈 조립 시스템.

Fig. 30. Lens assembly system.

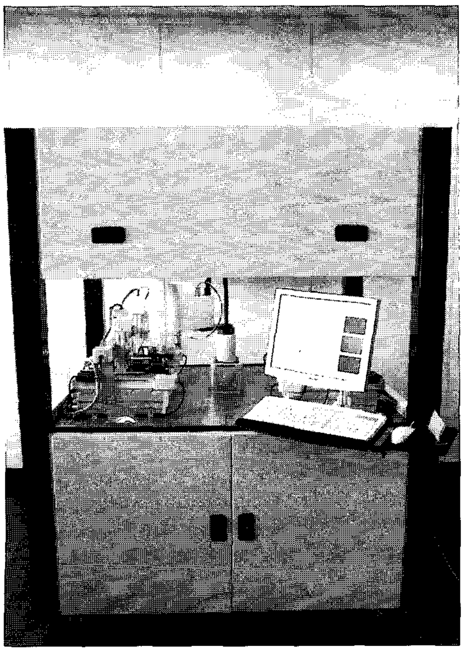


그림 31. 렌즈조립 시스템의 전체 모형.

Fig. 31. A whole form of the lens assembly system.

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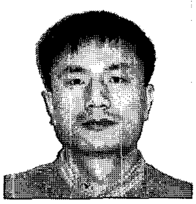

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