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Global IT Research Institute

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- Is the paper clearly written and well organized?
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- Does the introduction state the objectives of the manuscript encouraging the reader to read on?
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Please supply any information that you think will be useful to the author in revision for enhancing quality of the paperor for convincing him/her of the mistakes.

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Design and Implementation of Vision-based Structural Safety Inspection System using Small Unmanned Aircraft

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***Abstract*—Safety inspection for high-rise structures should be done regularly for follow-up test. However, as it is very dangerous job and direct manual examination takes a lot of time and money, its correct diagnosis is difficult. In this paper, computer vision-based structural safety inspection system is proposed to be designed. The proposed system is an image recognition monitoring system through wireless transmission of sensor data by loading multiple sensors for facility monitoring in UAV platform. The system loads various sensors such as temperature sensor, humidity sensor, smoke sensor, illuminance sensor, CO2 sensor, ultrasonic sensor, and infrared thermal imaging sensor and can achieve stability inspection. So, It can reduce inspection time and building's maintenance cost**

***Keyword*—small unmanned aircraft, Multi -Sensor, Monitoring facilities, Safety inspection, Image Processing, Sensor Fusion, openAPI**

I. INTRODUCTION

In domestic construction industry field, as number of facility that was constructed more than 20 years ago is increased, accident by facility damage and collapse is taken place frequently and its occurrence frequency is showing a tendency of being increased due to facility deterioration and negligence of safety check-up. Therefore, sustained safety inspection and management are required but inspection of high-rise buildings with its height over 10-100m by inspectors with directly carrying inspection equipment is too dangerous and requires lots of time and cost.

Therefore, in order to perform integrated inspection of several structures of which access of inspector is limited and confirm damage status of structure to be inspected based on time difference by each season and day, inspection method using unmanned aerial vehicle (UAV) that is effective for shortening inspection time and reducing maintenance cost is urgently required. In this study, computer vision-based structural safety inspection system is proposed to be designed

Proposed system is an image recognition monitoring system through wireless transmission of sensor data by loading multiple sensors for facility monitoring in UAV platform.

This system has an advantage of being able to perform more accurate, precise inspection and diagnosis through image processing on the ground by identifying problems after approaching high-rise structures through remote control using UAV equipped with video camera.

II. RELEVANT STUDY

A. Definition of UAV and its Utilization Field

UAV is a small aircraft on which pilot is not boarded and it has a separate remote control operator on the ground and it is also called as drone meaning that it looks like a buzzing bee. In the past, it was mainly used for reconnaissance target or military purpose but recently, its usage has been diversified including private and research survey purpose. [1]

At present, in order to apply UAV control technology to diversified fields including documentary shooting or pesticide spraying, diversified researches are under progress [2] and in case of image analysis level, technology development for substituting physical sensor including fire watch-out, behavioral watch-out has been advanced to a considerable level. [3]

In overseas case, mainly Japan, Germany and U.K. show unusual concern over maintenance and safety inspection of structures and Fraunhofer ISE, Germany and Cyberhawk, U.K. have developed and commercialized UAV for safety control of wind power structures.

Recently, DHL, Germany started parcel delivery using drone and Amazon and Google, USA are preparing unmanned home delivery service.

B. Computer Vision Technology and Algorithm

In order to extract information contained in image by

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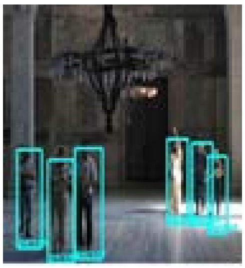
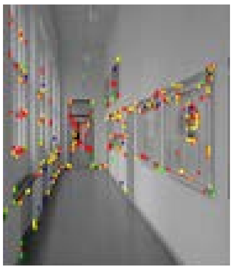
analyzing it photographed from camera mounted in UAV, computer vision technology is required. Computer vision technology is widely applied to diversified applications including text recognition, biometrics, positioning, 3D image restoration, augmented reality [4]. Its utilization example is as shown on below Fig. 1.



(a)Object recognition



(b)SLAM

(c)Augmented reality

Fig. 1. Example of computer vision utilization

In this study, a system of identifying damage part of building using edge detection algorithm by converting photographed image to grayscale using light intensity(illuminance) after tracking ground structure in the air by mounting image camera in UAV is intended to be developed. In addition, structures could be managed efficiently by having inspector recognize facility condition and information without difficulty through UAV equipped with diversified sensor

III. Main Subject

In this study, in order to supplement disadvantage of existing systems, development of a system that enables internal, external defect detection of high-rise facility and diversified inspections using UAV based diversified sensors and HD camera is proposed.

A. Total System Configuration and Hardware Specification

Total system configuration to be proposed in this study is as shown on below Fig. 2.

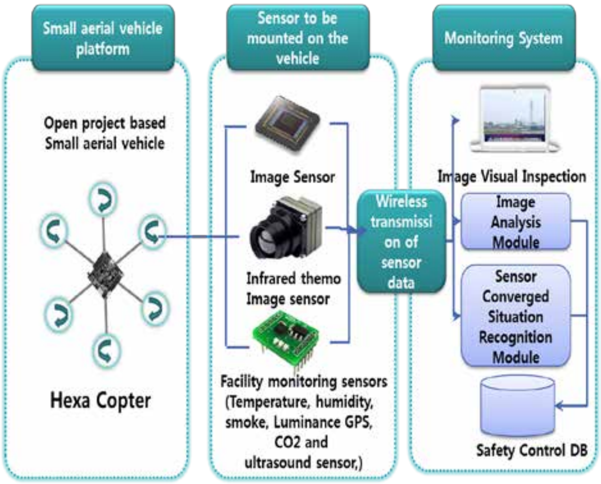


Fig. 2 System Configuration

In order to perform safety inspection of structures, Mikrokopter based open-sourced UAV, Germany is used. Mikrokopter was developed into quardcopter (4), hexacopter (6) and octocopter (8) based on number of blade [5]. As a system of controling flight depending on altitude-hold (acceleration sensor), horizontality-hold (gyro sensor), posture stabilization function (pressure sensor), GPS is mounted in FC(Flight Control) board that controls flight and so, it is suitable for basic aircraft of UAV for safety inspection of structures [6]. By mounting image camera in UAV, image frame of UAV is supplied to tablet PC on the ground through a synchronization proces and tablet PC on the ground processes image of each entered frame. In addition, by mounting diversified sensors, more accurate safety control of structures could be ensured. General system outline is as shown on below Fig. 3.

Fig. 3. System Outline

Detailed hardware and functions of UAV to be equipped with multiple sensors are as follows

TABLE I
DETAILED HARDWARE SPECIFICATION OF UAV

Item	Specification
Diameter	800mm
Frame	Aluminium
Weight (Battery excluded)	3Kg
Propeller	14 inch
Motor thrust	1.5Kg/motor
Operation time	Over 30 minutes
Gimbal	300mm(W)×300mm(H), Internal dia. 200mm

MCU (Main Control Board) in which sensors will be mounted comprises multi Wii open-source base.

B. Sensor Convergence for Posture Control of UAV

UAV to be used in this study is STM32 bit processor mounted Black32 board based hexacoper and it comprises 6 motors, 6 ESC (Electronic Speed Controller) that controls motor speed and 6 propellers. Fig. 4 shows Black32 board mounted with sensors.

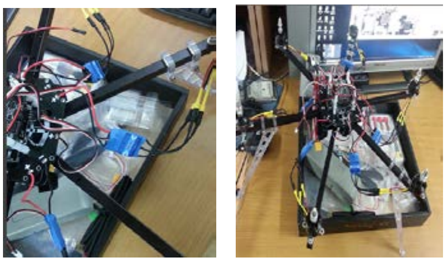


Fig. 4 UAV internal sensor mounting

In order to ensure flight of hexacopter by taking stabilized posture at the time of take-off and landing, balancing of blades facing with each other is very important.[7]

In order to measure posture of hexacopter, sensor is required and for exactly measuring roll, pitch, acceleration, gyro sensor are required and for measuring yaw, geomagnetic sensor is required. Acceleration sensor is a sensor measuring acceleration and its size is expressed in figure by dividing gravity acceleration into vector world of x, y, z axis. Gyro sensor is a sensor detecting angular velocity and as exact gradient measurement is difficult by accelerometer only in case that acceleration sensor measures other acceleration than gravity, it measures rotation angle. Therefore, gyro and acceleration sensor are used in convergence. Row, pitch value could be obtained by acceleration sensor but yaw value could be calculated by mounting geomagnetic sensor that measures global magnetic field [8].

Operation mechanism of gyro sensor is as shown on below Fig. 5.

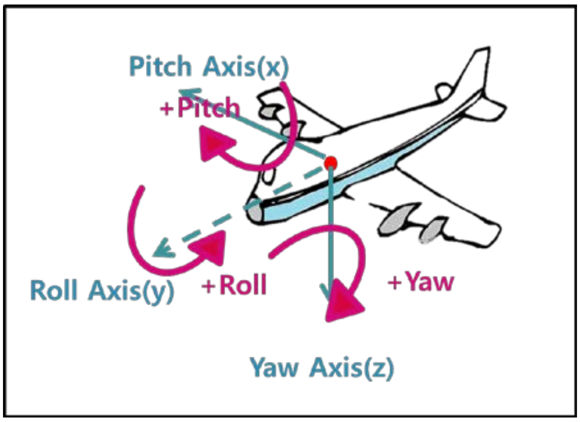


Fig. 5. Operation mechnism of 3-axis gyro

In this study, Kalman filter was used in order to obtain exact value by efficiently converging information acquired so far from sensors in posture stabilization of UAV.

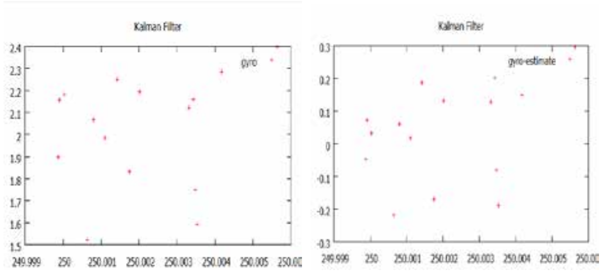


Fig. 6. Measurement of sensor data value through Kalman filter

Kalman filter developed by Rudolf Kalman in early 1960s is an algorithm being widely used in computer vision, robot, rocket, satellite, missile and control field [9]. This algorithm is estimating a new result after removing noise included in data by using past and new measurement data [10] and in this study, more exact image was intended to be processed through UAV positioning and posture control by using this Kalman filter.

C. Design and Development of multiple sensor mounted module

Actually, inspector may require a lot of time and cost and experience a lot of difficulties due to exposure to risk if he wishes to check visually in order to confirm damage status of inspection site based on time difference by each season and day but by performing inspection through UAV mounted with sensors, such risk factors could be reduced and structures could be managed efficiently.

Therefore, in this study, by using diversified sensors including sensor of temperature, humidity, CO, CO2, Ozone, dust, VOC (detection of organic compound), safety of structures is intended to be inspected. In order to mount sensors in UAV, as large or heavy sensor module is detrimental to flight, flight stability is ensured by using small, light sensor module.

D. Development of multiple sensor data transmission technology

Multiple sensor data collected from UAV is required to be transmitted to monitoring personnel on the ground and in order to ensure transmission distance over min. 100m, IEEE 802.11n based wireless transmission module and 7dbi antenna are required to be composed. By visualizing sensor data being obtained from diversified sensors including sensors of temperature, humidity, CO, CO2, Ozone, dust and VOC (for detection of organic compound), data shall be processed.

By developing meta data management module that controls data type, unit, validity range of sensor data, sensor data of diversified forms are processed. Information could be managed more efficiently by implementing visualized module by each sensor data and displaying it in tablet PC monitor of the worker.

E. Design of video camera mounted module

Visual inspection is the most basic inspection method performing structural stability inspection but inspection of high-rise building facility by inspector with directly carrying inspection equipment is too dangerous and it requires a lot of time and cost. In this study, through more clear and precise photographing of video camera mounted in UAV, precision and efficiency of structural safety inspection are intended to be increased. Camera image is obtained by projecting dots of 3D space in 2D image plane. Therefore, conversion, movement and rotation of world coordinate to camera coordinate are taken place and in order to explain this coordinate conversion nature, a process of finding out parameter value is required and this is called calibration.

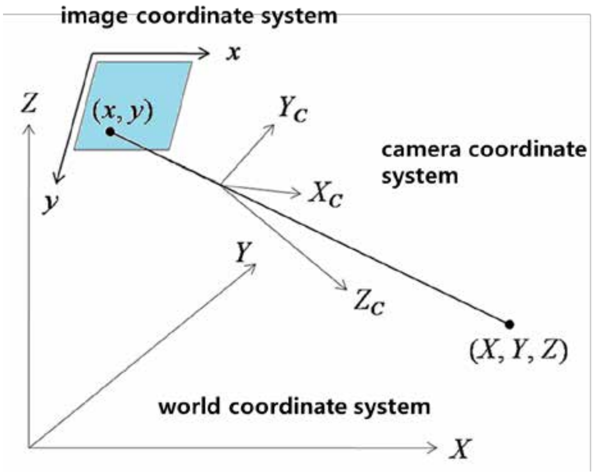


Fig. 7. Camera and image coordinate

As video camera to be mounted in UAV has to identify position of ground facilities in the air and perform inspection of external damage status and cracking, more precise and delicate image acquisition is required. Calibration is performed in order to correct camera distortion. Result of performing camera calibration is as shown on below Fig. 8.

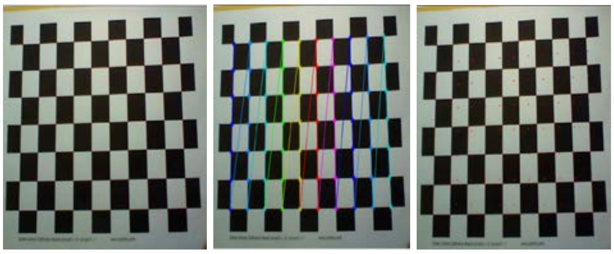


Fig. 8. Camera calibration

As a result of performing experiment with two image files, focal length was [762.873 766.547] +/- [26.743 26.669] and main pointer [298.977 231.074] +/- [3.814 6.803]. distortion [0.024516 -0.243971 -0.005740 -0.000509] +/- [0.030206 0.361247 0.000665 0.000902] and pixel error [0.26 0.22].

In order to transmit acquired image to the ground from video camera, IEEE 802.1x based wireless transmission technology was used. Motion JPEG video compression that may transmit clear image at every scene was used and safety of structure was identified promptly by transmitting image with transmission speed over 20-30fps and resolution of 4CIF/2CIF

F. Development of image acquisition and processing technology

In order to process images acquired from UAV, image processing technology is required. Image transmitted by video camera may be sometimes damaged and not clear and if interested area is desired to be observed, data could be managed more effectively by using image processing technology. In addition, as acquired image shows difference depending on climate or surrounding environment, image is required to be improved to be fit for intended purpose. As a technology of improving image, there are smoothing, sharpening and noise removal.

A work of extracting a specific area is called image analysis and it is mainly used for finding out size, form and contour line. In addition, in order to recognize image, following processing stage is required.

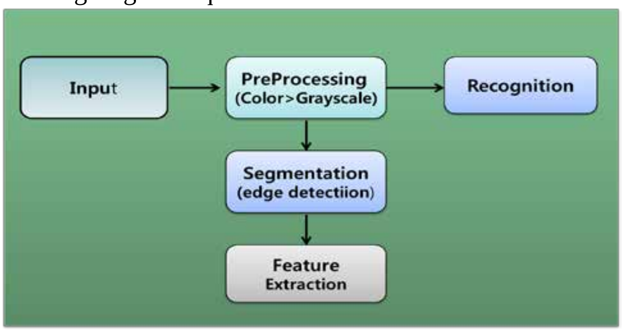


Fig. 9. Image recognition processing stage

In detecting internal, external damage status of structures by receiving input of color image being photographed by UAV, it is hard to process color image immediately and so, pre-treatment process of converting to grayscale is required. In order to change RGB color image to grayscale, it is required to change color information to light intensity information.

Various methods are available for changing RGB colour value to light intensity value and in this study, NTSC

(National Television System Committee) method that is mainly used in analogue broadcasting system in our country and the USA is used. Required formula could be obtained as follows.

$$Grayscale = 0.2999 * \text{Red} + 0.587 * \text{Green} + 0.1114 * \text{Blue} \quad (1)$$

(a)RGB Color (b)Grayscale Conversion

Fig. 10 PreProcessing

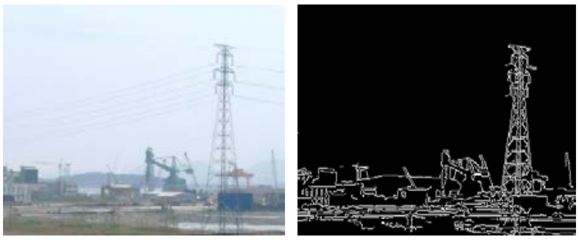
Image acquired from UAV requires more precise image processing through pre-treatment process and at this time edge detection method is used for removing noise of image. Edge is taken place at boundary between image object and object or object and background and it means boundary of object in image [11].

Detection technique using edge does not require many operations and such noise is usually identified by brightness change at edge that is boundary with background around image being entered. Edge information is used for detection of first differential function such as operators of Prewitt, Roberts, Sobel, second differential function such as Laplacian operator or many other methods. [12]

In most cases, as edge extraction mask is sensitive to noise, even small noise is frequently extracted by regarding it as noise. As a method of supplementing this disadvantage, there is edge extraction method using Canny mask and its objective is to extract strong edge by actually making such mask not to be sensitive to noise.

This algorithm presents a method of finding out edge that satisfies good detection, good localization and clear response.

In this study, Canny edge detection technique that is resistant to noise is used.



(a) Original image (b)Canny edge

Fig. 11 Segmentation

Image processed like this uses extraction algorithm through image segmentation and its processing speed is fast and storage capacity could be saved as well. It has an advantage that after extracting characteristics using segmented image and comparing it with existing photographed image, its normality status could be determined without difficulty. Image processing technology like this is effective for identifying and managing structure condition.

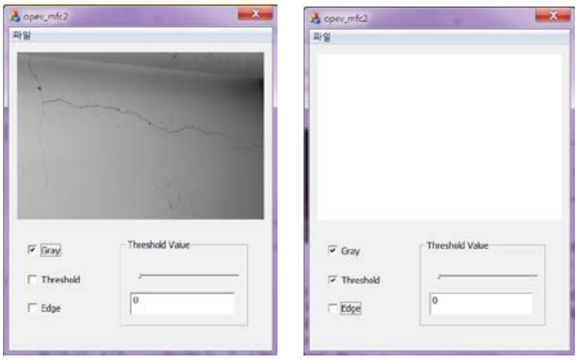
Pixel is basic unit of image and image is composed of numerously gathered pixels. Therefore, as the quantity of image data is relatively larger than that of general text data, considerable loss of time and data may be taken place during transmission. As the quantity of image being transmitted by video camera using UAV is relatively larger than that of general data, this feature is required to be considered.

In this study, image compression technology is used for removing overlapped or unnecessary data in order to store or transmit data efficiently. Image compression technology is usually classified into loss technique and lossless technique. As Loss technique reduces resolution at the time of compression and data is wasted, its quality is decreased. In order to restore image again, linear interpolation is used but it is hard to restore to original image. On the contrary, lossless technique makes no difference even though image is restored again after compression. In order to ensure fast image transmission in this study, Motion JPEG (M-JPEG) video compression is performed.

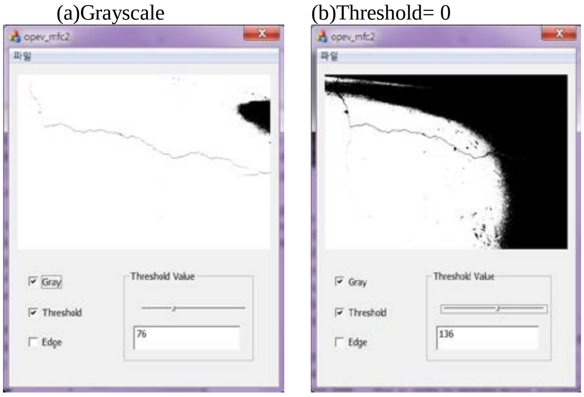
IV. Experiment And Implementation

In this study, in order to perform inspection for cracking detection status of internal structures by importing video image photographed by UAV as a part of safety inspection of structures using UAV, window application program was implemented. Implemented image acquisition system is a program of identifying cracking status of internal, external structures by detecting contour line in order to obtain required information in screen after importing colour image file and converting it to Grayscale.

As a result of extracting cracking image of internal, external building, cracking image was extracted relatively well but very fine cracking image was not extracted as intended.



(a)Grayscale (b)Threshold= 0



(c)Threshold= 76 (d)Threshold= 136

Fig. 12 Result of cracking extracting

V. Conclusion

In this study, system design for structure safety inspection using UAV was suggested and a system processing photographed image was implemented. It could be realized that in order to process image acquired by UAV, noise was removed by using image processing algorithm and through more clear image, appearance of structure could be discriminated.

By providing more convenient working environment after visualizing data by mounting video camera and diversified sensors in UAV, more safe and objective inspection process and result could be obtained compared with existing method.

Based on future design, it is intended to be applied to safety inspection of T/L tower, plant smoking stack, bridges and piers, wind power generators of which access to workers is difficult and dangerous. In case of T/L tower, inspection of its corrosion and cracking by using UAV rather than manual inspection would be more safe and fast.

As inspection of plant smoking stack should be performed manually after stopping plant operation, a lot of cost is required but in case of safety inspection method using UAV, its inspection could be performed while operating plant continuously and analysis of gas being emitted during operation is enabled.

Besides, UAV could be utilized for safety inspection including exfoliation, cracking of concrete structures such as high-rise buildings and apartments and by mounting thermo-graphic camera in UAV, UAV could be used for detection using thermal sensing in wide area including forest fire watch-out. Therefore, it is expected that a system suggested in this study could be effectively utilized in safety inspection of diversified industrial fields in the future.

ACKNOWLEDGMENT

This work was financially supported by the Ministry of Education (MOE) and National Research Foundation of Korea(NRF) through the Human Resource Training Project for Regional Innovation under Grant 2013H1B8A2032217, and the MSIP(Ministry of Science, ICT and Future Planning) and the CITRC(Convergence Information Technology Research Center), Korea supervising by the NIPA(National IT Industry Promotion Agency) under Grant NIPA-2014-H0401-14-1008 .

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Efficient 3D Design Drawing Visualization Based on Mobile Augmented Reality

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***Abstract*—Recently, in manufacturing, machinery, construction and shipbuilding industry, diversified researches of visualizing design drawings without difficulty utilizing augmented reality technology have been performed. In this paper, we propose efficient 3D design drawing visualization technique based on mobile augmented reality. Proposed technique first recognizes design drawing region, and only performs image tracking in its region. Through performance analysis, it could be seen that in technique being suggested in this paper, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.**

***Keyword*—Augmented Reality, 3D Structures, Drawing recognized**

I. INTRODUCTION

As augmented reality provides users with enhanced immersion and a sense of reality, it has been applied in diversified fields including broadcasting, shopping, medical service, education, military, game, architecture, shipbuilding and manufacturing business[1-6].

As design drawing is 2D plane and it expresses relevant data numerically, it is hard for construction manager, engineer and users to understand solid form of structures. In order to solve this problem, diversified researches visualizing design drawing without difficulty by utilizing augmented reality technology have been performed.

In this paper, 3D model visualizing technique of augmenting virtual 3D structures on 2D drawing utilizing augmented reality technology is suggested.

Suggested visualized technique recognizes design drawing through smart phone camera without marker and displays it out on camera image by augmenting 3D model.

First, in order to recognize design drawing, edge point is extracted from camera image and it is set as design drawing region by calculating rectangular region. And as feature point for total image is extracted by performing matching for design drawing region only, its calculation volume is less than existing matching method.

Through performance analysis, it could be seen that in technique being suggested in this study, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.

II. AUGMENTED REALITY 3D MODEL VISUALIZATION TECHNOLOGY IN INDUSTRIAL FIELD

A research on introduction of augmented reality for site support of 3D design data utilized augmented reality technology for a system in which 3D design data could be supported to site workers in terms of operation and maintenance after ship hand-over in order to ensure sustainable performance of ship[7].

Augmented Reality Technology based plant piping construction management plan aimed at efficiency of piping construction management through real time confirmation of piping information in plant piping construction site and confirmation of 3D piping model based piping installation error being overlapped in actual environment by utilizing augmented reality[8].

In a research on application of augmented reality for inspecting rebar arrangement of civil works, its application could increase understanding of rebar workers by visualizing 3D modeled rebar in actual site in an overlapped form and by utilizing it even to construction inspection stage, suppress cost increase by defect and rework that may be taken place in rebar fabrication work effectively[9].

In a research on application of augmented reality technology for operation and maintenance education for ship building/marine equipment, in order to ensure sustainability of ship building/marine equipment, material and support product sustainability by introducing augmented reality technology at the site, a system that enables education and maintenance support for the system that may support workers more effectively at the time of operation and education for marine equipment/material was provided[10].

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III. EFFICIENT 3D DESIGN DRAWING VISUALIZATION

Augmented reality has been used in diversified fields including construction, machinery, ship building industry as communication tool between managers and engineers because structure of 3D model is visualized on 2D design drawing so that design process of structures to be manufactured could be explained to the users without difficulty and exact user's requirements could be identified. "Fig. 1" show structural diagram of visualizing 3D model of design drawing.

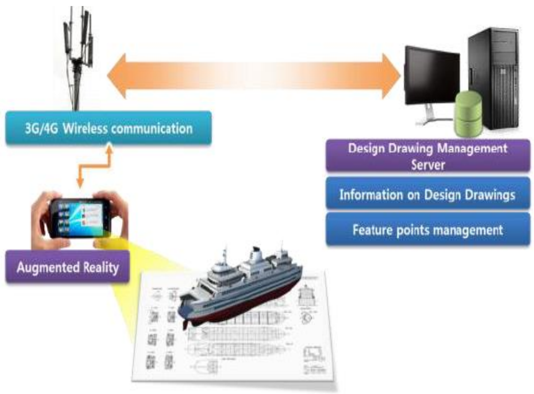


Fig. 1. structural diagram of visualizing 3D model of design drawing

A. *Design drawing management server system*

Design drawing management server includes configuration of design drawing management server, design drawing information management module and feature point matching and search module.

Configuration of design drawing management server: Design drawing management server system play a role of saving image, feature points and 3D model of design drawing, searching relevant design drawing by receiving feature point data transmitted from smart phone and transmitting design drawing information and 3D model.

Design drawing information management module: Design drawing management module is to manage design drawing information in design drawing image registered in server. System manager is able to manage overall side information and authorized user is able to manage permitted information only after approaching module through user authentication. In total natural image being used in augmented reality system, each main information and additional information are managed.

Feature point matching and search module: Feature point matching and search module receive information request if image entered from smart phone is available and search information in DB management system. Searched result is printed out in a form of XML.

B. *Recognizing Design Drawings*

The mobile augmented reality system for design drawing proposed by this paper is implemented using non-marker based AR technology which enables to recognize existing design drawings without inserting specific marker into the drawing. The processes in which design drawings are recognized is shown in "fig. 2".

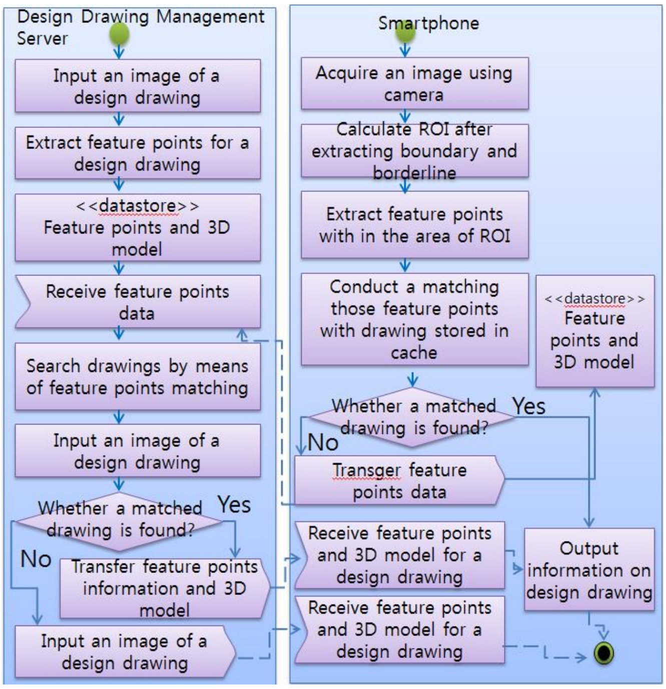
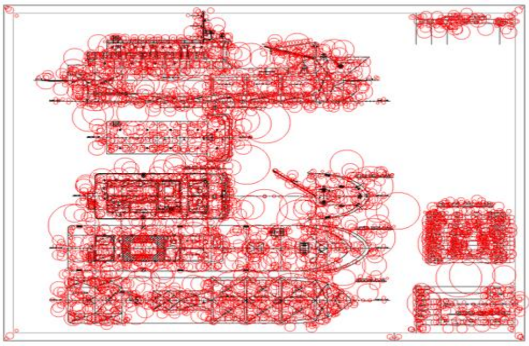
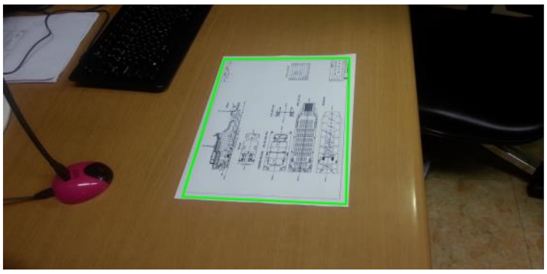


Fig. 2. Design drawing recognition process of design drawing recognition

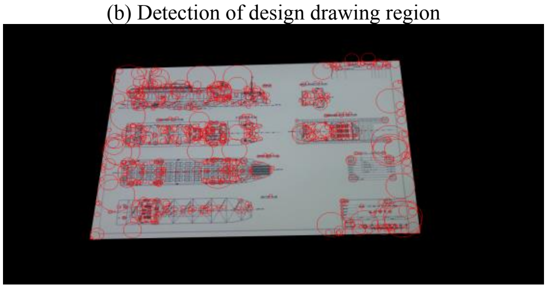
Firstly, design drawings are entered to the server by using scanner. Feature points are extracted from the drawings using feature points extraction algorithm. The extracted feature points are stored in database together with 3D model. Subsequently, drawing image is acquired by taking photo using a camera embedded in a smartphone. From the obtained image, boundary and borderline are extracted. Then regions of interest (ROI) for a rectangle area of the drawing are calculated. After extracting feature points within the ROI, a matching operation is carried out by comparing between extracted feature points and the feature points of drawings stored in a cache. If there exists the drawing with matched feature points, fetch the information about the drawing from cache memory. Otherwise, send the feature points to the server in order to search data stored in server. Once the server receives the feature point data, it retrieves the design drawings stored in its data-base using the method of feature point matching. In this case, the drawings with highest similarity are searched using SURF(Speeded Up Robust Features) algorithm. When the search is completed, the found feature points and 3D model would be transmitted back to cache memory in a smartphone. The smartphone shows the message to the user, so that the user recognizes that the drawing data with matched feature point now exists in cache memory. However, if the server couldn't find the matched drawing in its database, it returns failure message back to the smartphone. Then smartphone displays failure message to the user. "Fig. 3" shows matching process after setting design drawing region based on suggested region setting.



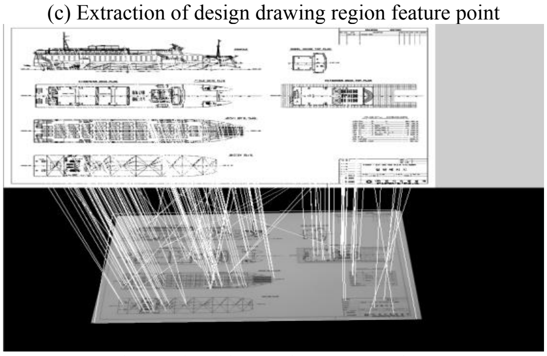
(a) DB of design drawing feature point



(b) Detection of design drawing region



(c) Extraction of design drawing region feature point



(d) Result of design drawing matching

Fig. 3.Matching process after setting design drawing region

DB of design drawing feature point: First, design drawing management server saves design drawing image, feature point data, 3D model as DB and extracts feature points by using SURF algorithm after converting to image size similar to resolution of smart phone.

Detection of design drawing region: Generally, design drawing is rectangular shape and by utilizing this feature, design drawing region is detected. First, unnecessary noise is removed by performing Up-Scale immediately followed by Down-Scale in camera image of smart phone. And then, contour line is detected utilizing inter-regional contour algorithm by changing threshold. After approximating these pointers, whether it is rectangular shape is determined. Coordinate of rectangular vertex is calculated by determining whether line is 4 and it is rectangular shape utilizing edge angle, region.

Extraction of feature point of design drawing: After extracting rectangular drawing region, feature points in region only are extracted. In order to recognize design drawing as marker, after detecting rectangular shaped drawing region in previous stage, features points are extracted for only relevant regions.

Feature point matching of design drawing: Data that extracted typical feature points by its compression and feature points of DB are matched. In system resources such as smart phone or tablet PC and mobile devices having frequent processing speed limit, feature point is matched by applying SURF algorithm.

C. Design Drawing 3D Model Visualization

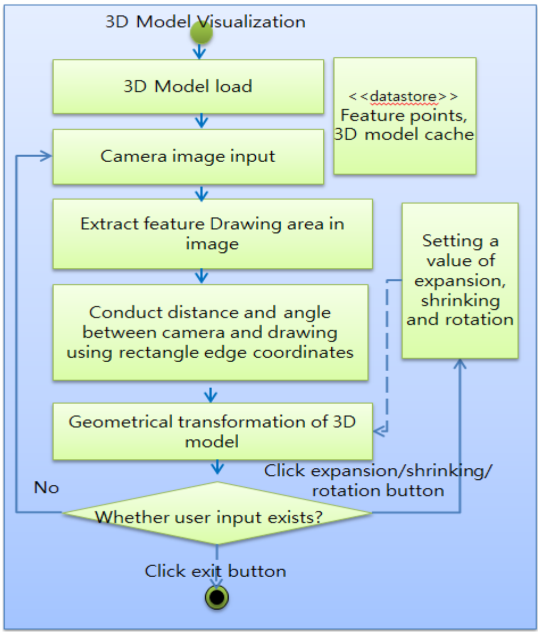
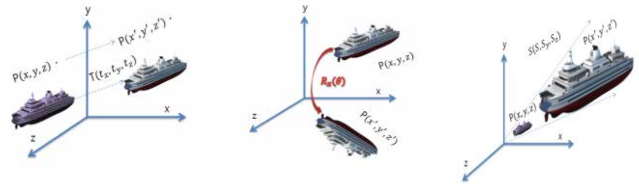


Fig. 4. Process of 3D Model Visualization

Once a drawing is completely recognized, the process to augment 3D model on top of the 2D drawing is being conducted as illustrated in “fig. 4”. 3D model and the feature points for the design drawing stored in cache memory are loaded into a smartphone visualization module. Then camera takes a photo of a target drawing. Based on the photo image, ROI coordinates are detected for the rectangle area of the drawing. The edge coordinates of the rectangle are tracked and then a distance and an angle between a camera and a drawing are estimated. Corresponding to an estimated distance and angle, 3D model would be adjusted like moving, expanding, shrinking or rotating. Finally shading effect is added to 3D model. The resulting 3D model is visualized on a screen of the smartphone. In the meanwhile, if there is no user input, all of the above processes are executed under an iterative loop starting from getting input of a camera image. When a user input occurs, correspondent events are handled such as expanding, shrinking, rotating and terminating.

Geometric conversion of 3D Model: If four vortex coordinates of design drawing is known, rotated position and posture of design drawing could be calculated based on camera coordinates system. In this study, camera coordinates system is obtained from vortex of design drawing ROI using a method suggested in geometric conversions. “Fig. 5” shows movement, rotation, enlargement of 3D model



(a) Movement (b) Rotation (c) Enlargement

Fig. 5. Movement, Rotation, Enlargement of 3D Model

Conformity of design drawing 3D model: Image conformity is a process of making two images to be exactly coincided when actual drawing and virtual 3D model are shown in overlapped form. By receiving video image data in Frame buffer of graphic system, 3D model is expressed in overlapped form in setting position. After matching 3D model including its depth value on 3D design drawing, it is displayed.

IV. IMPLEMENTATION AND PERFORMANCE ANALYSIS

A. System Implementation

Developing environment: To analyze feasibility of the proposed mobile AR system for design drawing visualization, android-platform smartphone application and a drawing management server were developed. For a design drawing management server, hardware specification is as follows: INTEL i7 3.40GHz, 16GB Memory and SSD 256GB. As for smartphone, hardware specification is Qualcomm Snapdragon S3 Dual Core 1.5GHz and 1GB memory. Android 4.1.2 Jelly-bean is used as platform. Screen resolution is 1280×800.

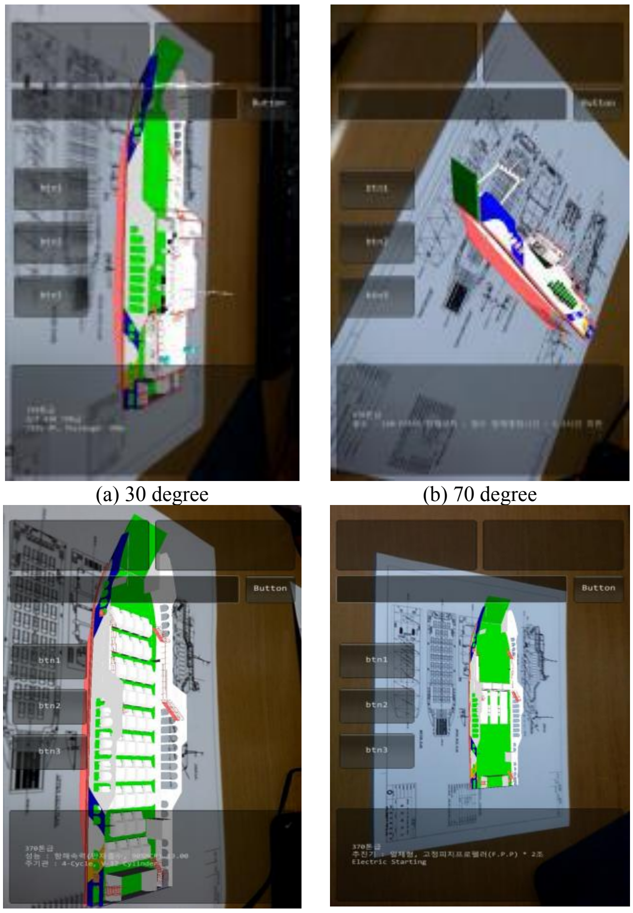
Design drawing and 3D model database: For implementing the proposed system, management server for dealing with design drawings were developed. In conjunction with the server, database was also developed. The database was de-signed to be used for storing 20 types of design drawing images, feature points and correspondent 3D model. The 20 types of models were generated using Catia modeling tool.

Implementation result: The implementation result is explained here. Total 20 models were entered to the system as an input. The system supports to expand, shrink and rotate the image as user wants. Each part comprising the whole image can be displayed. "Fig. 6" shows a demonstration of running mobile AR-based 3D model display system. "Fig. 7" shows screens where an augmented 3D model is presented as rotated image and as partial display.

B. Performance Analysis

Performance regarding recognition of design drawing: To estimate system performance, a comparison between the proposed technique and an existing technique was conducted by measuring a recognition rate and recognition time duration for the design drawings. In the proposed technique, ROI is firstly detected within the drawing image and then matching is done by using only feature points extracted from ROI. In contrast, the existing technique extracts feature points from an entire region of the drawing image. For carrying out the sys-tem performance analysis, 20 different types of design drawings were taken pictures using a rear camera of the smartphone which was used in this study. When taking pictures, camera angle and distance to the drawings were varied. Those pictures were entered to the system as inputs. "Fig. 8" shows a scene how a design drawing is taken a picture using the smartphone which is a component of mobile AR 3D model display system.

Fig. 6. AR execution demonstration



(a) 30 degree (b) 70 degree

(c) Car loading (d) Truck loading

Fig. 7. Rotation and Partial display screen of an augmented 3D model

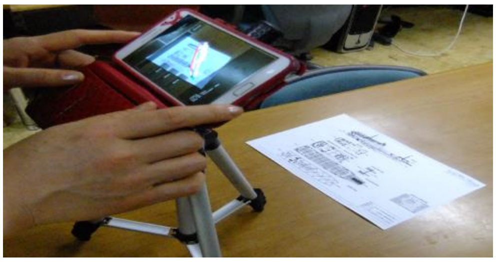
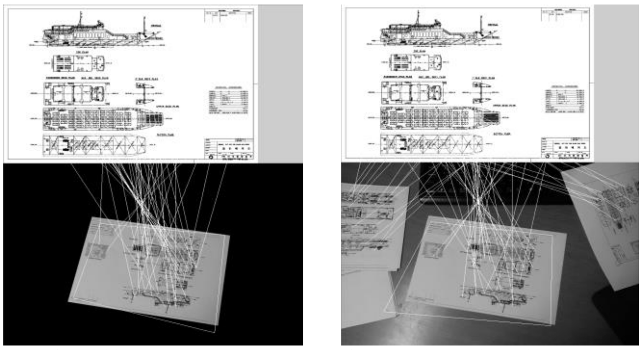


Fig. 8. Drawing test process

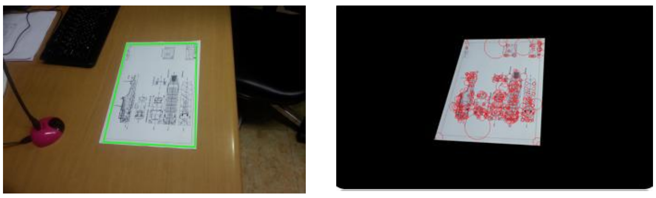
Total 20 tests were carried out. In each test, the design drawing was taken from a different direction, for example, front, side and diagonal direction. For each angle and direction, tests were conducted for the pro-posed method and an existing method. Therefore, total number of tests conducted is 180. In this test, measurement items are two: recognition rate and recognition time duration. To get rid of any effect of a lagging time which might occur in communicating between the server and the smartphone, feature points and 3D models were stored in a cache memory of the smartphone prior to conducting tests. The process to detect feature points by extracting ROI from the design drawing is shown in “fig. 9”. The technique pro-posed in this study detects and extracts ROI first as illustrated in (a). Secondly, remaining area except for the ROI is marked to be black as presented in (b). Finally, feature points are extracted using SURF algorithm.

“Fig. 10” (a) and (b) shows a matching result for the proposed method and an existing method respectively. In case of Fig.10(a), matching process is carried out only for ROI region. It implies that time to be taken for matching can be lower and matching accuracy can be better than that of an existing technique. In case of Fig.10(b), however, matching needs to be conducted for an entire region of a drawing. It indicates that time to be taken for matching would be increasing. Furthermore, other objects surrounding the core part affects and distracts the matching task.



(a) only within ROI region (Proposed method) (b) an entire region of image (traditional method)

Fig. 9. Feature Points Extraction from Design Drawing



(a) Drawing Region ROI detection (b) Feature points extraction

Fig. 10. Feature points matching for design drawings

Recognition results for the drawings are listed as table 1. According to the figures in table 1, the proposed technique shows higher recognition rate than a traditional method by 5~15%. In terms of recognition time duration, the proposed method shows 23~32% lower than a traditional method. These results come from the fact that the proposed method excludes remaining region by detecting ROI of rectangle area for the drawing prior to carrying out feature point matching. The total number of feature points to match becomes less than that of a traditional method. Therefore, calculation amount would be decreasing.

Table 2 shows a test result of design drawing recognition rate. In case of suggested technique, its recognition rate is app. 95-85% in side and diagonal and it shows difference depending on each angle but in most cases, it recognized almost accurately. However, existing technique showed relatively low recognition rate in side and diagonal and it is understood that in side and diagonal direction, as design do cements backdrop or surrounding objects occupy more regions in camera image, it lowers exact recognition. In 70° angle, suggested technique showed recognition time shorter than existing technique by app. 4-7% and in 50° and 30°, recognition time was represented to be shorter by app. 24-33%. The reason of this result is that in existing technique, as more backdrop or surrounding objects occupy most part of image in low angle, number of extracted feature point is plenty. Table 3 is 3D Model visualization test Results

TABLE Ⅰ.
DESIGN DRAWING RECOGNITION RATE TEST RESULTS

Test Item	Angle	Proposed technique			Traditional technique		
		Front	Side	Diagonal	Front	Side	Diagonal
Recognition Rate(%)	30	95	90	85	80	75	70
	50	100	95	90	90	90	75
	70	100	100	100	100	95	95

TABLE Ⅱ.
Test result of recognition time of design drawing

Test Item	Angle	Proposed technique			Traditional technique		
		Front	Side	Diagonal	Front	Side	Diagonal
Recognition Time(%)	10	410.2	424.6	426.7	548.4	562.3	569.8
	45	427.3	432.5	420.9	530.0	541.1	547.3
	80	410.5	423.1	426.3	478.7	492.6	491.2

TABLE Ⅲ.
3D Model Visualization Test Results

	The number of frames per second
Traditional Method(Tracking an entire region And then performing image registration)	14~20 Frames
Proposed Method (Tracking ROI Rectangle. And then performing image registration)	21~28 Frames

C. *Performance Analysis for Design Drawing Visualization*

To estimate the performance especially for image registration technique used in the proposed visualization method, time to be taken for augmenting process was measured by the number of frames per second. In case of a traditional method, feature points are extracted first. Secondly, a distance and an angle between camera and the design drawing are calculated by matching the feature points. And then, 3D model is geometrically transformed for performing image registration. In the process of feature point matching, a significant amount of calculation is required, so that the image registration cannot be performed in smooth way. In contrast, the proposed method firstly detects ROI of rectangle from a camera image. A distance and an angle between the smartphone and design drawing are to be calculated only within the ROI. Then image registration is performed after geometrically transforming 3D model. An amount of calculation necessary for each frame would be lower. Hence image registration can be performed smoothly. Model visualization test results are presented in table

V. Conclusion

In case of visualizing 2D design drawing as 3D model using mobile augmented reality technology, understanding for each design drawing could be enhanced and exact and efficient design and manufacturing process control are enabled.

A system suggested in this study recognizes design drawing based on non-marker by limiting entered image. In particular, as matching is made by recognizing design drawing region and extracting feature point in this region only, its recognition rate is high and calculation volume is marginal. And by tracking once recognized rectangular shape only, 3D model could be visualized on drawing based on limited calculation volume only.

Through performance analysis, it could be seen that in technique being suggested in this study, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.

For future work, it is necessary to generate 3D model for an internal structure of specific part of a design drawing as panoramic images and to display them efficiently.

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First A. Author (M'76–SM'81–F'87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year degree was earned. The author's major field of study should be lower-cased.

Study on Access Permission Control for the Web of Things

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***Abstract*—The Web of Things (WoT) research is exploring ways on the interoperation among the smart things, since the Web has proven its potentials as open communication environment for accommodating a variety of Web resources. The Web technologies has enabled the Web-enabled devices to publish and exchange their resource information over the Web, whereas the Web-enabled devices should cope with the security threat regarding the information exposures over the Web, particularly, access permissions for the resources about the things. Thus, in this paper we analyse access permission control mechanism considering both the WoT characteristics and the REST-compliant resource-oriented Web architecture. In contrast to existing access control logics, the proposed mechanism utilizes not only the requester information such as the typical identity and the internet addresses, but also the context of the thing itself. Based on this mechanism, we present web-resource structure for access permission control, and describe an exemplary procedure in detail. This research contributes to the flexible and decentralized access permission control for WoT.**

***Keyword*—Access Control, REST, Security, Web of Things, Web Resource**

I. INTRODUCTION

THE number of smart things connected to the Internet even exceeds the population of human beings nowadays. As more smart things are capable of data communicating over the Internet, the concepts of the "*Internet of Things* (IoT)" or "*Machine-to-machine* (M2M)" are having been realized in many fields, as in [1]–[8], including smart home, smart meters, remote healthcare, and logistics process automation. Different sources predict that by 2020, as in [9] and [10], the number of connected things would be more than 25 billion, even up to 50 billion with an optimistic view, and the IoT market size will grow up to $7 trillion according to [11] and [12].

Whereas many IoT researches mainly have focused on how to establish connectivity among the networked devices, the *Web of Things* (WoT) or the Web-based IoT have been extensively studied for integrating these smart things with the well-known Web technologies, as in [13]–[15]. The Web-enabled things can interoperate freely over the Web utilizing the open Web standards, since the World Wide Web (WWW, Web) can provide flexible, scalable communication channels for any web clients to share web resources. Also, the scope of the traditional web services can be broadened into the physical-world, not only cyber-world. Moreover, the Web-enabled things can reuse and adopt the proven Web mechanisms such as discovery, searching, browsing, linking, and caching, as in [16]. Further, REST (Representational state transfer) architectural style with URIs (Uniform Resource Identifier), HTTP, and standardized media types, is very promising to make these things to share their data and resources over the Web.

A pressing open problem in this WoT environment is how to allow smart things to grant clients access to their own resources, since the Web-based open environment often leaves information vulnerable to disclosure resulting in security threats such as:

--Malicious clients and unwanted data sharing
--Attacks in any time and from anywhere
--Unpredictable work load and availability risk

Unfortunately, there are few studies on these concerns and several system prototypes just have shown inadequate functionality for security. In particular, from a security point, the existing access control mechanisms for the web resources, as in [17]–[18], are used to require either rigid access policy enforcement or dependency on the pre-configured access management procedures like a central authentication service (CAS) system. And these ways have limitations for dealing with the dynamic interactions and the scalability in the WoT.

Thus we analyzed the access permission control for the resources of web-enabled things, as in our previous research [19]. And a decentralized access permission control mechanism for Web resources for WoT is proposed. The proposed mechanism adopts REST-style resource-oriented architecture for things, in order to enable a thing itself (or its owner) to manage access permissions to its own information resources by means of simple CRUD (Create, Read, Update, and Delete) actions. To explain the mechanism in detail, we described the prototype module of resource access control as

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well as resource structure XML.

The remainder of this paper is organized as follows: Section 2 presents the related researches and the basic concept of access permission management. Section 3 proposes access permission control mechanism considering both the WoT characteristics and the resource-oriented Web architecture with the exemplary cases in detail. Then, concluding remarks are provided in Section 4.

II. Related Study

This section introduces the basic model for providing access control and discusses the existing researches on access permission management, with describing research challenges coming from the WoT characteristics.

A. Access Control Model

The rudimentary form of access control model in a computer security system suggests that an active subject requests a specific access operation to a passive object, then a reference monitor between them decides whether to grant the access request or not, as shown in Fig. 1.

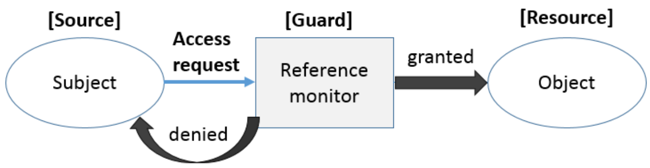


Fig. 1. Basic access control model including subject, object, and reference monitor

In order to protect the information system against malicious actions which could damage data and resources, it is essential to control access requests from subjects [17]. So, the reference monitor as a guard should perform two types of tasks; 1) to identify the subject who made the request, and 2) to decide who is allowed to do what to the object.

Traditional access control systems have usually relied on a local database which can maintain either user passwords, group membership, and/or access control matrices. Then, several modifications have been adapted for the Web security environment, including 1) SSL usage for securing the user channels, 2) checking host information for authentication, and 3) centrally managed database for a domain access control. However, the centralized Web security architecture often imposes limitations like a single point of failure as well as a dependency on the dedicated security configuration.

To assure access control in a distributed system environment considering an ad-hoc security domain for the thing-to-thing communication, as in [20]–[21], it is necessary to handle all the access requests even without asking to the central security manager. Likewise, the number and/or diversity of subjects/objects in the web of things make the access control issues more challenging [13].

B. Existing Access Control Logics in Computer Network

With the advancement of information security, in order to facilitate the management of access permission, many security models for computer network systems have been coming up as the followings, to name just a few:

--Subject/object access control matrix [22],

--Multilevel security using information flow [23],

--Role-base access control (RBAC) [24]–[25], and

--Attribute-based access control (ABAC) [26]–[27].

Here, RBAC represents the concept of *role*, in order to logically relate users and permissions. That is, the RBAC model assigns permissions to roles, and roles to the users. However, this model mainly focuses a kind of 'static' authorization assignment a priori, whereas many practical information systems require more flexible ways to update the subject's permissions. In the meantime ABAC can support changing needs much easier, since only subjects with valid set of attributes are permitted to access the data and this approach do not rely on the pre-defined roles for the specific sets of attributes. Also ABAC supports the notion of distributed access control enforcement, called policy enforcement point.

In addition, in consideration of environmental and context information, a concept of context-aware authorization model has been suggested as in [28]–[29]. And it is recognized that these semantic information can help to specify access control measures and to provide machine-interpretable description of security requirements [30], as the WoT environment enables things to communicate over the Web with disparate parties and users.

III. Access Permission Control for WoT

A. WoT Access Control Requirements

In the WoT environment a thing is expected to have a dynamic connection with other things over the web. That is, each thing may be either subject or object interchangeably in order to perform its own task. Further, according to the REST-style web architecture, each thing may represent itself as web resources which can be identified with unique URIs. According to the aforementioned properties, the access permission control for WoT should meet the following requirements:

1) Each thing may publish its information as one or more web resource(s) over the web.
2) Resources for a thing can be accessed by the basic HTTP/REST request from a subject (e.g. a HTTP client), as outlined in Fig. 2. Since each thing may communicate with other things in the WoT environment, Thing A can request access for the specific resources about the hosting entity, Thing B. Then, Thing B needs to assure the access permission about the requested resources against the Thing A's access request.
3) Permission assignment can be described as a web resource representation, then the decision to grant access for a given request to the specific resource should be made with referring to this type of resource.

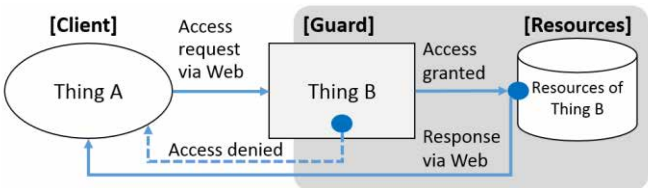


Fig. 2. Control flow about access request and response between two web-enabled things in WoT

B. Resource-oriented Architecture for WoT

Since the WoT makes use of the current resource-oriented Web architecture, a web-enabled thing can exchange a specific resource with the HTTP/REST methods about the CRUD (Create, Read, Update, and Delete) operations. Also, the given resource and its attribute(s) information, if any, can be identified with unique URI, of which situation is described in Fig. 3. The resource representation contains three resource objects ('a', 'b', and 'c') and the relative contents can be accessed with the usual HTTP/ REST CRUD methods. For example, in order to retrieve the content information of object 'a', which is hosted at 192.168.0.1, a HTTP request for GET operation should specify the URI of the given object as following: 'http://192.168.0.1:8080/things/a/contents'. Like any web page or image file which might be linked using URI, WoT resource information could be accessible via Web.

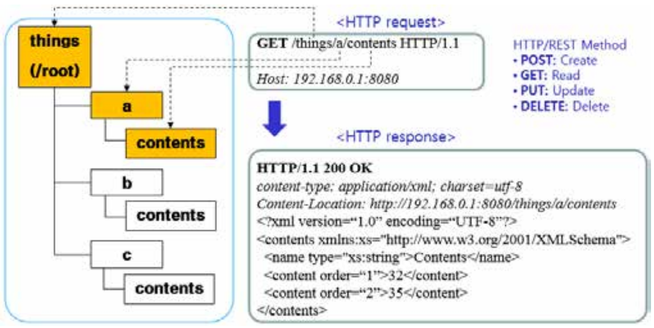


Fig. 3. Exemplary resource representations about Web-enabled things and the associated HTTP/REST request and response

In this situation, we considered that the hosting entity might accommodate a number of resource objects, even resources from the other thing (e.g. /things/b/contents and /things/c/contents) which do not have a HTTP server capability. It is because many smart devices practically provide constrained features as well as limited powers, so these constrained things may exchange its resource information through the support of much powerful entity, called WoT Gateway or WoT Broker [16]. Thus, in this case, the way to make each resource configured with different access permission should be provided.

C. Proposed Mechanism for WoT Access Control

Fig. 4 outlined the detailed steps (i.e., from the Step 1 through the Step 6) to process a request for accessing resources in the WoT. Each steps aims to filter out any incomplete or ambiguous access request, as summarized in TABLE I. Even though it seems the advanced secure channels as well as cryptographic algorithms improve the entire security level for the HTTP protocol communication, we presumed the participant things in the WoT at least supports the standard HTTP protocol basically. For example, if the request could not be interpretable in Step 2 due to any malformed syntax, then the original requestor should receive HTTP response with a 'Bad Request (400)' status code according to the HTTP protocol [31]. Likewise, if the requested resource is not found at the hosting entity, 'Not Found (404)' HTTP response should be generated.

We recognized that the matter of granting an access request to the specific WoT resource is very closely associated with the Step 5. Here, as shown in Fig 5, we considered that there might be several resource objects (Object 1 to Object N) and each object could be dealt with different access permissions. Particularly the request handling function is required to check the suitability for access permission to the corresponding resource objects in the Step 5, just after the existence of the requested resource has been checked from the Step 4. Then, access operation to the requested resource should be executed in the Step 6, and the relevant HTTP/REST response would be sent back to the requester.

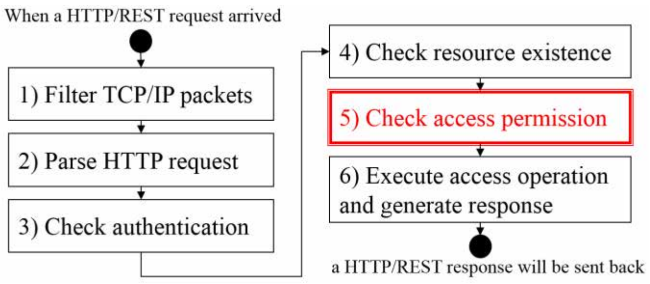


Fig. 4. Process flow from the arrival of a HTTP/REST request to sending the relevant HTTP/REST response back

TABLE I
STEPS TO ASSURE WOT ACCESS CONTROL

Step	Purpose	To filter out
1	To filter TCP/IP packets	Unallowable transaction
2	To parse HTTP/REST request	Invalid request, usually with abnormal parameters
3	To check HTTP header for basic authentication	Unverified client
4	To check whether the requested resource exists or not	Requests for the expired/outdated or irrelevant resource
5	To check the assigned access permission for the request operation	Unassigned access permission for the requested operation

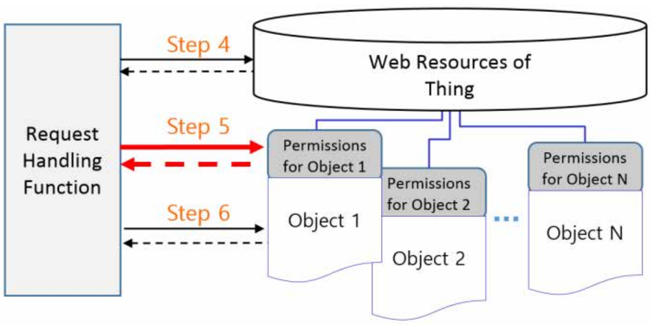


Fig. 5. WoT request handling function handling secure access control using the steps described in Fig 4 and TABLE I

Fig. 6 describes an exemplary case for assessing a HTTP/REST requests using the typical access control matrix, where a thing may have N resources (i.e. Object 1 to Object N) which can be requested from the other M things (i.e. Subject 1 to Subject M). The access permissions about Object 1 should be simply assigned for all the subjects, but this model do not provide scalability due to the overhead for maintaining the M by N matrix. That is, if a web-enabled thing has 10 resources and other 10 things are expected as subjects, the 10 by 10 matrix should be maintained and searched through. So the access permission about a resource object 'Object 1' can be specified for every subjects (Subject 1 to Subject M). Then, the hosting entity checks the matrix if the subject of the access request has the enough right to access the given resource object. For example, Subject 1 have all the C/R/U/D access rights to Object 1, whereas Subject 2 has only R access rights. Here, C means Create, and likewise R for Retrieve or Read, U for Update, and D for Delete. Though additional classification of subjects into several associated groups based on Role-based Access Control (i.e. the role of 'SuperUser' may be assigned to several subjects like {Subject 1, Subject 2, …}) might alleviate this burden, but each thing still needs to maintain the lists of roles and compare the assigned access permissions against each HTTP request about CRUD operation to the specific resource object.

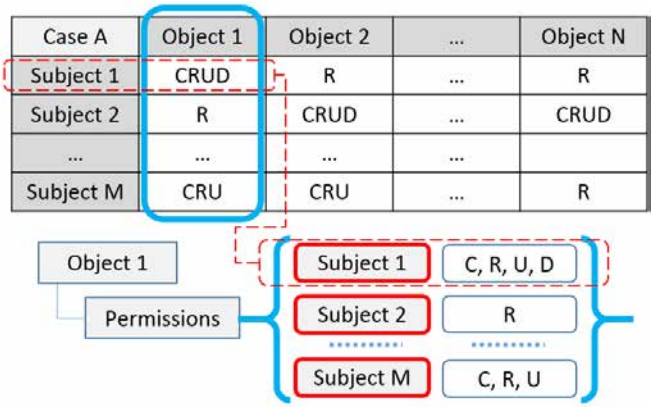


Fig. 6. Naive form of access control matrix specifying the Subject-Object relationship

As all the access operation can be categorized into the four types among C, R, U, and D, then we concentrated on the each CRUD operation with a modified access control matrix as shown in Fig. 7. When compared to the naïve form of access control matrix, now the 4 by N columns should be searched through. That is, the access permission for each specific CRUD operation can be assigned to the given subject(s) in the form of 'permission flag'. The permission flag value 1 of the specific operation means the corresponding subject is allowed to access the given resource object. For example, the Read operation to Object 1 is allowed to all the subjects (so, the permission flag R includes Subject 1 to Subject M), whereas only Subject 1 is assigned to have rights to the Update operation. We also noticed that a specific permission setting can be applied to more than one REST requests, for instance, the two operations, Create and Update, for the resource 'Object 1' in Fig. 7 can be specified identically. Likewise, more than one resource object, Object 1 and Object 2, may have the identical access permissions for Read operation.

Moreover, regarding the third WoT access control requirements, the set of permission flags can be represented as a web resource, a specific access permission rule could be applied to the multiple resources synchronously, as far as there exists a reliable web connection. Fig. 8 conceptualizes that resource objects of Thing A are referencing the same set of permission flags (i.e., 'Local Permissions A1' and 'Local Permissions A2'). And Object 1 and Object 2 have configured with Access Right A1. Since web resource can link other web resource readily using URI. Meantime, Object N of Thing A is referencing the external access permission rule, 'Global Permissions B1' which is managed by other host. Here, we assumed all the Retrieve access operation to this permission rule resource should be allowed for interoperability.

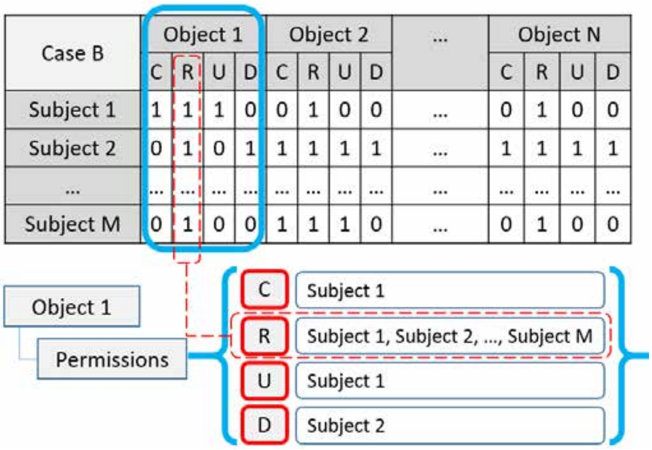


Fig. 7. Modified access matrix focusing on the each CRUD operation instead of the original subject-object relationship shown in Fig. 6

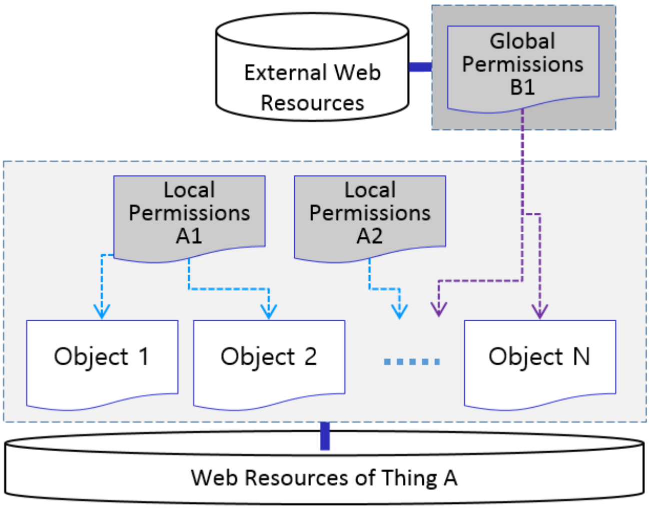


Fig. 8. Linking the set of permission flags as a type of web resource object

D. Access Permission Abstraction for WoT

Now we generalized the access permission by replacing the subjects with the generic conditions, which aggregate not only the subject information like typical identifiers for the requester (i.e. IP address, hostname, and domain information), but also context and environmental information related with the web-enabled thing itself (i.e. point of time, time schedule, location, device hardware state, and configuration limit value). Therefore, we can express a permission flag for each CRUD access operation as the following:

Permission Flag C [/R/U/D] = {Condition about subjects} + {Condition about the context of the requested resource object}

For example, as presented in Fig. 9, a web-enabled thing as the hosting entity for the resource objects may allow the 'Create' operation by judging from the combinative results throughout the several conditions (e.g. C1 to C3) as followings:

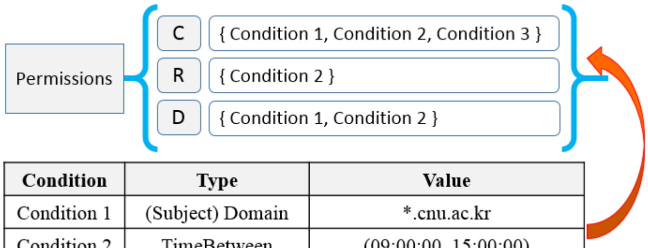
C1) if the requester is from the specific domain like '*.cnu.ac.kr',
C2) if the current time is between 9 AM and 3 PM, and
C3) if the CPU usage of the hosting entity is less than 90%.

In addition, an internal policy should be settled in order to deal with more than one condition. For instance, a policy have to be determined considering the following two situations:

--Situation 1: Permission should be granted only when all the conditions meet.

--Situation 2: Permission should be granted if any of the conditions meets.

Here, we considered the case of Situation 1 and all the conditions have the equal level of priority or weight for simplicity. So, in Fig. 9, only if the specified conditions are satisfied, access permission for each CRUD operation can be passed. For example, the permission flag C of the given resource object includes three conditions C1 to C3, whereas the flag R includes only C2.



Condition	Type	Value
Condition 1	(Subject) Domain	*.cnu.ac.kr
Condition 2	TimeBetween	(09:00:00, 15:00:00)
Condition 3	(Thing) State	(CPU, LESS-THAN, 90%)
…	…	…

Fig. 9. Exemplary representation of permission flags specifying various combination of conditions

E. *Proof of Concept for WoT Access Control*

We implemented a request handling function as a proof of concept with the example of Fig. 9, with two Java framework libraries, Jersey RESTful Services Framework (Available: https://jersey.java.net/) and Grizzly Web Framework (Available: https://grizzly.java.net/). The implementation accepts the HTTP request for accessing the example resource, '/root/object/', and checks the set of permissions related with the given resource, as shown in Fig. 10.

Fig. 10. **(a)** HTTP request to retrieve a web resource located at '192.168.219.106:8080/root/object/'; **(b)** HTTP response with successful retrieval of the requested resource; **(c)** HTTP response with a status code 401 ('Unauthorized')

We used Postman REST client utility to send HTTP request in order to retrieve a web resource located at '192.168.219.106:8080/root/object/', as shown in Fig. 10 (a), and receive the responses, as shown in Fig. 10 (b) or (c) accordingly. Since the retrieve access operation from (a) do not violate the condition about 'TimeBetween', the requested resource was successfully retrieved. The response payload presents the set of permission flags described in the example of Fig. 9. (c) If the request do not satisfy all the relevant conditions regarding the given access operation (in this case, the request time was beyond the time range), the requestor might get the HTTP response with a status code 401 ('Unauthorized'). The implementation showed that the web-enable thing as the hosting entity for the requested resource can control access permission as far as the relevant conditions are being checked well, apart from centralized authorization procedure.

F. *Elaboration on Specifying Access Permission*

For the more elaborated access control, we noted that a binary true-function can be adopted for processing the multiple conditions, then each condition can be classified into two types, i.e., inclusive and exclusive. For example, we set a rule about 'access permission would be granted only if any of inclusive conditions meets and if any of exclusive condition does not meet at the same time'. Then, the regarding permission flag might be expressed as the following:

Permission Flag C [/R/U/D] = {inclusive-type conditions}
- {exclusive-type conditions}

Fig. 11 outlined an access permission rule (<permissions>), in XML document format, including the permission flag about 'Retrieve' operation (<permission type="R">) which consists of 3 inclusive and 3 exclusive conditions. That is, the resource object referencing this permission rule can be accessed, only if any of 3 inclusive conditions (i.e. conditions about Subject id, Subject IP address, and Subject domain) can be satisfied, and at the same time if any of 3 exclusive conditions (i.e. conditions about Thing operation duration, Thing CPU usage, and Subject domain) is not applicable at all. Likewise, other three operations (i.e. C/U/D) can be listed as the other elements of this access permission rule.

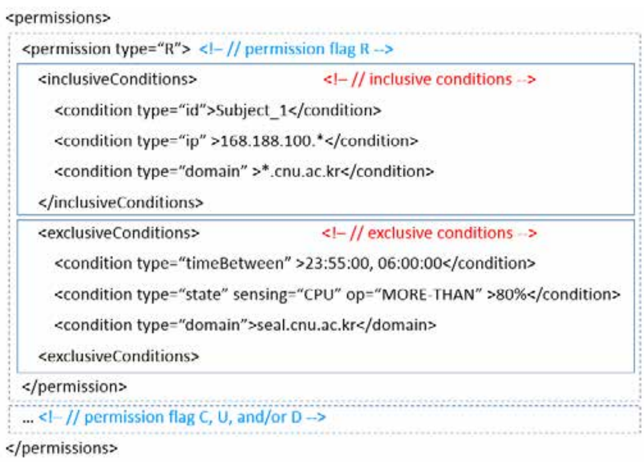


Fig. 11. Exemplary structure for expressing the access permission

Fig. 12 describes the resource structure of a web-enabled thing using the web-based access permission mechanism, illustrated in Fig. 8. In order to configure resource objects with the specific access permissions, each resource object within the web-enabled thing needs just a reference link to the appropriate permission rule resource, for example, '/root/permission_A1' or '/root/permission_A2'. Here, these permission rules include one or more conditions following the way specified with the example of Fig. 11. Thus, the web-enabled thing can authorize any access operation to resource object (i.e. '/root/object_1') by referencing a permission rule resource (i.e. '/root/permission_A1') and checking the access conditions.

Also, the permission rule resource '/root/permission_A1' might be referred by two resource objects, '/root/object_1' and '/root/object_2', so these objects could be accessible by checking the identical sets of access conditions. The object '/root/object_N' refers to the external permission rule '/permissions_B1' maintained by other hosting entity. Eventually, through the inter-linking among the web resources, a web-enabled thing manages access permission without any external authorization server's support. Besides, as far as the external web connection keeps alive, a number of things can be managed under the identical access permission policy when configured to adopt a global access permission rule resource.

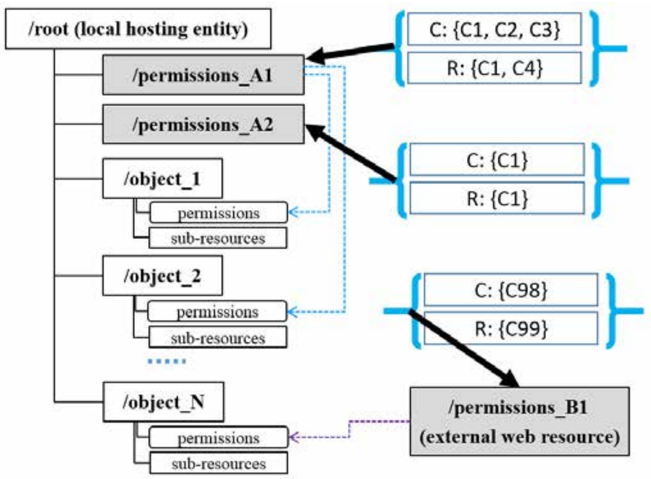


Fig. 12. Exemplary resource structure maintained by a web-enabled thing according to the case of Fig. 8.

IV. Conclusions

In this paper, we described the requirements for the access permission control to the resources of web-enabled devices in the web of things environment. Then, we presented an access permission control mechanism considering for the WoT characteristics. The proposed mechanism adopts resource-oriented architecture for Web-enabled things, utilizes the access conditions accommodating both the requester information and the context of the thing itself.

The generalized access permissions can be represented also as a web resource, easily reachable via Web architecture. This mechanism enables each Web-enabled thing to authorize access requests locally, even without dependency on a specific security domain. Moreover, it helps to apply an identical permission rule to the multiple resources just by referencing same access permission web resource. Thus, the proposed mechanism contributes to the flexible and decentralized access permission control for the Web of Things.

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