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조명 변화 감지에 의한 영상 콘트라스트 개선

Image Contrast Enhancement by Illumination Change Detection

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요 약

영상처리를 통한 이동 물체 인식과 화질 개선 등의 연구에서 조명 변화가 성능에 큰 영향을 미치기 때문에 조명 변환에 대한 대응은 컴퓨터 비전 응용 분야에서의 중요한 관심사 중 하나이다. 조명 변화를 감지할 수 있게 되면 변화가 있는 시점에서부터 적절한 개선 알고리즘을 적용함으로써 인식률 향상 및 화질 개선 효과를 증대시킬 수 있다. 이에 본 연구에서는 급격한 조명 변화를 감지함에 있어 실시간성을 얻기 위하여 지역 정보를 이요하고 퍼지 논리를 도입하여 이를 효과적으로 감지하는 방법을 제안한다. 급격한 조명 변화를 감지하는 효과적인 방법으로 모서리 영역과 가운데 영역에 대한 각각의 히스토그램의 평균과 편차, 그리고 변화 추이를 반영하기 위하여 이전 프레임의 각 영역에 대한 히스토그램의 평균과 편차와의 변화량을 입력으로 급격한 조명 변화가 있을 때 입력 값의 변화 패턴을 퍼지 규칙으로 만들어 조명 변화를 감지하도록 하였다. 또한 움직이는 물체에 가려 발생하는 변화와 구별하기 위하여 전체 영역에 대한 평균과 편차 변화량을 도입하여 논리적으로 추론하여 차이를 구별할 수 있도록 하였고 점진적으로 조명이 변화하는 것을 감지할 수 있도록 하였다. 다양한 테스트 데이터에 대해 객관적인 정확도 측정 기법을 이용하여 민감도와 특이도를 계산하여 제안한 방법의 효용성을 보였다. 적응형 뉴로-퍼지 추론시스템을 도입하여 대비제한 적응 히스토그램 평활화 (CLAHE)의 매개 변수를 자동으로 선택할 수 있는 방법을 제안하여 급격한 조명의 변화를 감지한 결과를 바탕으로 화질을 개선할 수 있음을 보였다.

키워드 : 퍼지 , 퍼지 규칙 , 지역 정보 , 이미지 히스토그램 , 적응 신경 퍼지 추론 시스템 , 제한 적응 히스토그램 균등화를 대조 .

Abstract

There are many image processing based algorithms and applications that fail when illumination change occurs. Therefore, the illumination change has to be detected then the illumination change occurred images need to be enhanced in order to keep the appropriate algorithm processing in a reality. In this paper, a new method for detecting illumination changes efficiently in a real time by using local region information and fuzzy logic is introduced. The effective way for detecting illumination changes in lighting area and the edge of the area was selected to analyze the mean and variance of the histogram of each area and to reflect the changing trends on previous frame's mean and variance for each area of the histogram. The ways are used as an input. The changes of mean and variance make different patterns w
hen illumination change occurs. Fuzzy rules were defined based on the patterns of the input for detecting illumination changes. Proposed method was tested with different dataset through the evaluation metrics; in particular, the specificity, recall and precision showed high rates. An automatic parameter selection method was proposed for contrast limited adaptive histogram equalization method by using entropy of image through adaptive neural fuzzy inference system. The results showed that the contrast of images could be enhanced. The proposed algorithm is robust to detect global illumination change ,and it is also computationally efficient in real applications.

Keyword : Fuzzy Logic, Fuzzy Rule, Region Information, Image Histogram, Adaptive Neural Fuzzy Inference System, Contrast Limited Adaptive Histogram Equalization.

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1. Introduction

According to many computer and robot vision applications including background modeling, foreground extraction, object tracking, surveillance system, and many other algorithms fail when sudden and gradual illumination changes occur in real time. Therefore, there is a need to detect such illumination changes on certain frames and that images need to be enhanced in order to get the information that is in interest. Illumination changes can occur frequently in images due to many light sources such as sun rise and set or turn on and off, in our everyday life. Illumination change affects the entire or particular pixels in the same way and scene which changes its contrast globally (or partially) from one frame to another. This study was concentrated only on global illumination changes.

When illumination changes occur in image most computer and robot vision algorithms lose their information suddenly and fail to working. B.Xie et al [1] utilized order consistency for sudden illumination change detection. This method only considers reference and current frame's neighboring pixels and used threshold. The sudden illumination changes lead to misunderstanding of background and foreground regions [2]. Our previous work [3] only used the changes of mean and variance of histogram of whole frame.

2. The proposed method

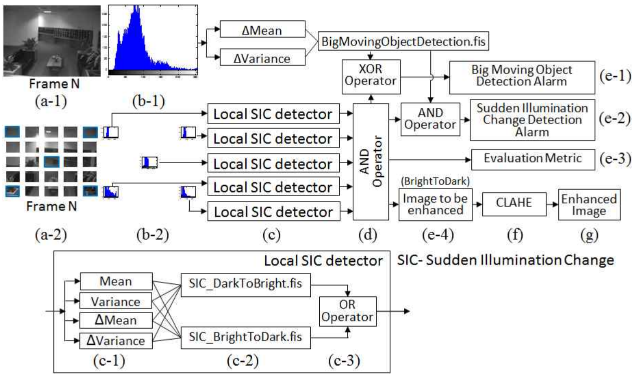


그림 1. 급격한 조명 변화와 큰 이동물체 감지 시스템

Fig. 1. Proposed sudden illumination change detection method work flow

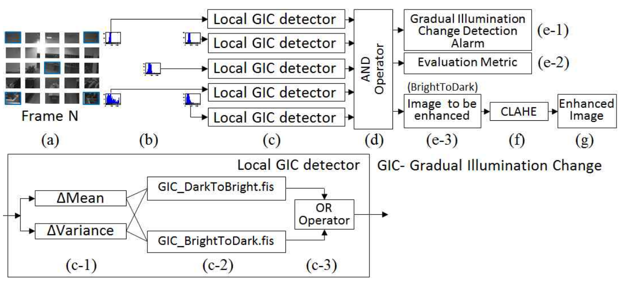


그림 2. 점진적인 조명 변화 감지 시스템

Fig. 2. Proposed gradual illumination change detection system

2.1 Fuzzy Logic

Fuzzy sets and logic were introduced by L.Zadeh in 1965. Fuzzy logic has been used to improve decision-making, to reduce resource consumption, and to increase performance [4]. Heart of the fuzzy logic is fuzzy inference system (FIS). In this work, fuzzy inference system for illumination change detection was designed. Adaptive Neural Fuzzy Inference System (ANFIS-first introduced by Jyh Shing et al [5]) integrates the best features of fuzzy systems and neural network [6]. It has an advantage of learning from data. Fuzzy rule consists of a set of linguistic statements, called rules. These rules are of the form IF premise, THEN consequent where the premise is composed of fuzzy input variables connected by logical operators (e.g. AND, OR, NOT) and the consequent is a fuzzy output variable. Similarly to how membership functions are defined, the fuzzy rule is derived either based on domain knowledge, or through using machine learning techniques [4].

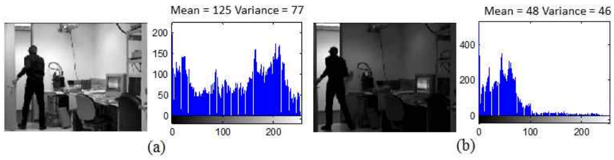
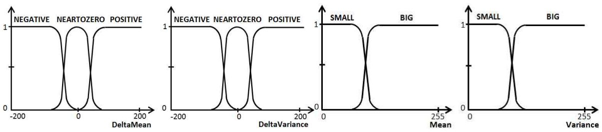


그림 3. 불 끈 상태의 두 프레임 히스토그램

Fig. 3. Turning off light case of consecutive frame and its histogram



(a) (b)

그림 4. 퍼지 멤버십 함수 및 퍼지 집합

Fig. 4. Fuzzy membership function and fuzzy sets

2.3 Image Contrast Enhancement method

Uniform histograms says a scene with significant contrast (as shown in Fig.3.a) and value of that histogram's mean and variance is big, whereas narrow histograms reflect less contrast (as shown in Fig.3.b) and corresponding mean and variance is small. In image processing, enhancing the contrast of image is important part. Contrast limited adaptive histogram equalization (CLAHE) is a technique for avoiding the excess amplification, while maintaining the high dynamic range of the sub-block [7] by clipping histogram of image whereas clipping parameter should be defined by user manually.

2.2 Fuzzy rule expression for illumination change detection

This paper has main two contributions: The first contribution is set of fuzzy rules for changes of the mean, variance, delta mean and delta variance(local region information) of histogram of edges and lighting areas was defined. Global region information is utilized to detect big moving object.

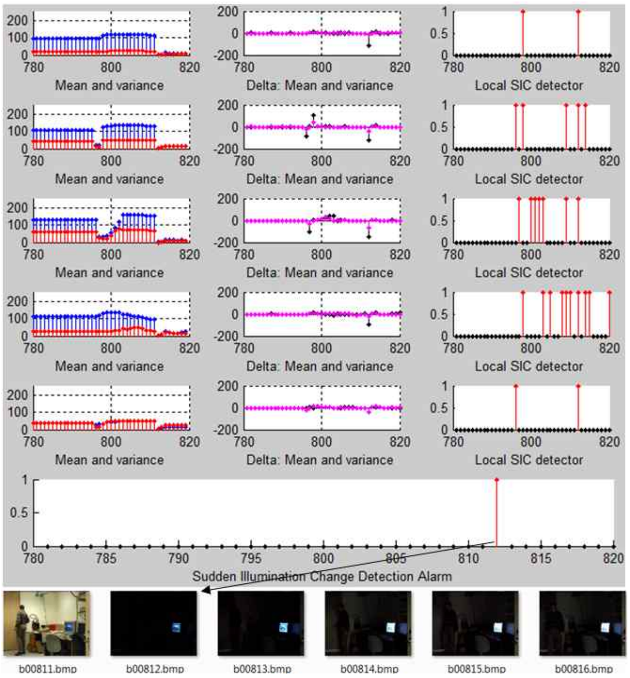


그림 5. 지역 정보 이용한 급격한 조명 변화 감지 결과
Fig. 5. Detection of sudden illumination change using global region information

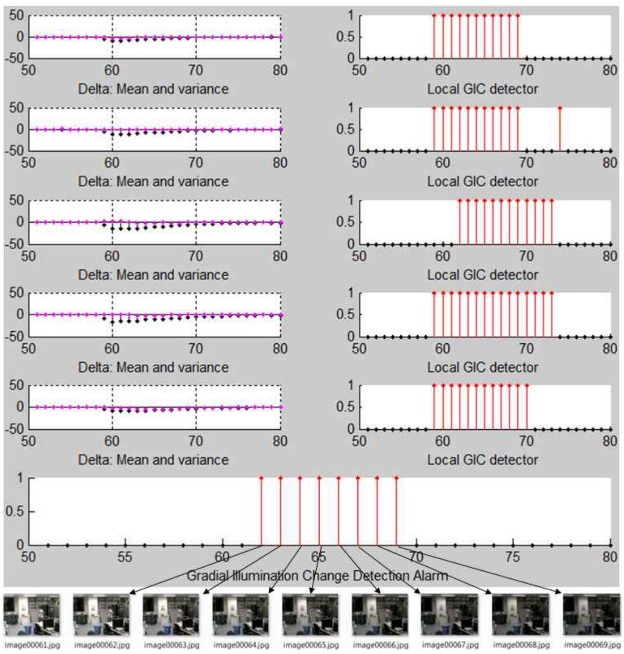


그림 6.지역 정보 이용한 점진적인 조명 변화 감지 결과
Fig. 6. Detection of gradual illumination change using local region information

Work flow for proposed sudden, gradual illumination change and big moving object detection method was depicted in Fig.1 and Fig.2, respectively.

The second contribution is an automatic parameter selection method for CLAHE and which was applied to the frames on which illumination change has occurred. By enhancing image contrast which is illuminated by light source, track information that is in interest, can be kept. Illumination changes are divided in two cases. One can occur from bright to dark, and the other can occur from dark to bright.

Input image in Fig.1 (a) and Fig.2 (a) is divided into sub-regions. The five regions are chosen, including tiles of edges and middle one. Height and width of frame are divided into equal five tiles, respectively. In Fig.1 (b) and Fig.2 (b) histograms of each selected tiles are depicted.

By differentiating mean and variance of histogram of frame N-1 and N, the delta mean and delta variance can be identified respectively. The mean, variance, delta mean and delta variance of histogram are used as crisp inputs into fuzzy inference system called "SIC_DarkToBright.fis", "GIC_DarkToBright.fis", "SIC_BrightToDark.fis"and "GIC_BrightToDark.fis" are as shown in Fig.1 (c-2) and Fig.2 (c-2), respectively. Detection result of two FIS are combined with logical OR operator. Changes of mean, variance, and delta mean and variance make different patterns when sudden illumination change occurs. Detection results of selected tiles are combined with logical AND operator (Fig.1.f) in order to check the illumination change on the whole region (frame). Once illumination change (only for bright to dark case) has been detected, CLAHE method was applied on the frame where illumination change occurred from bright to dark case. Mean and variance could be the element of fuzzy set “Small” or “Big as shown in Fig.4 (a). If histogram's mean and variance are small then those values belong to fuzzy sets “Small”, otherwise those values belong to fuzzy set “Big”, delta mean and delta variance could be the element of fuzzy set “Negative”, ”NearToZero” or “Positive” as shown in Fig.4 (b), respectively.

In general, histogram is broad (uniform or equal) while if image contrast is normal as shown in Fig.3 (a) and histogram is narrow (or not equal) while image contrast is too dark or too bright as shown in Fig.3 (b). Thus, mean and variance of histogram make specific patterns depending on the image contrast. The mean, variance, delta mean and variance could be the element of fuzzy sets (and fuzzy membership function) which are illustrated in Fig.4. Changes of local region information generate a specific form when sudden and gradual illumination changes occur. Fuzzy rules are defined based on forms of the input. Simulation work for the detection result of sudden and gradual illumination changes are depicted in Fig.5 and Fig.6, respectively. First five row shows mean, variance (first column), delta mean, variance (second column) and detection result (third column) of local region.

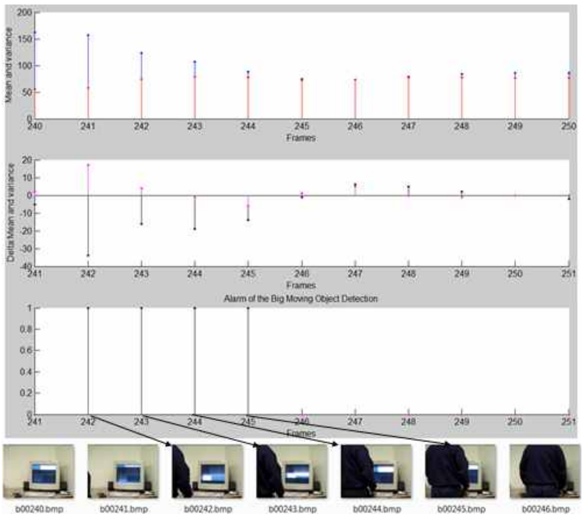


그림 7. 글로벌 영역 정보를 이용한 큰 이동물체 감지 결과
Fig. 7. Detection of big moving object using global region information

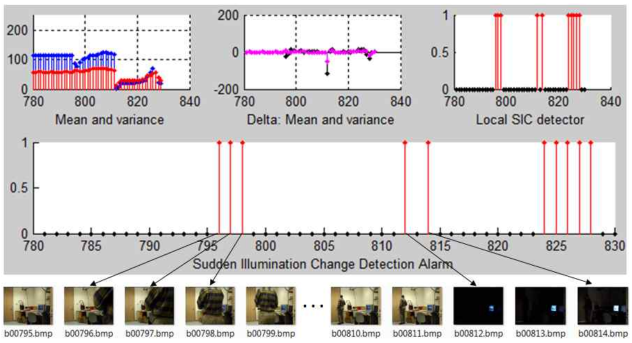


그림 8. 글로벌 영역 정보를 이용한 결과
Fig. 8. Experiment result of the global region information

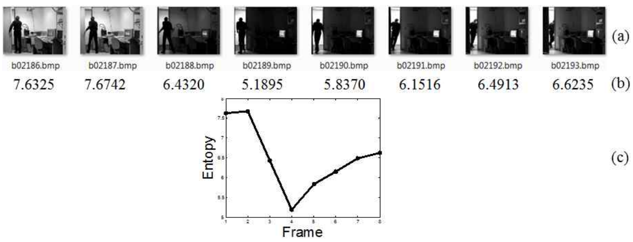


그림 9. 영상 및 그의 엔트로피
Fig. 9. Image and its entropy

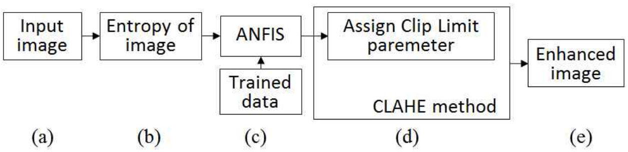


그림 10. ANFIS 기반 CLAHE 방법 흐름도
Fig. 10. ANFIS based CLAHE method

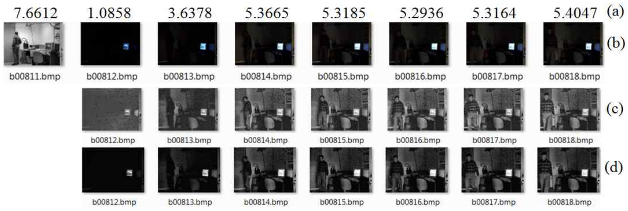


그림 11. 기존의 AHE와 우리의 제안 된 방법의 비교 결과
Fig. 11. Comparison result of conventional AHE and our proposed method

Sixth row indicates the final detection of sudden and gradual illumination change. Variations of delta mean and variance make specific patters when moving object (especially big) covers the frame. Fuzzy rules are defined based on changing patterns of input. In the left side of bottom of figure Fig.8, global region information (mean, variance, delta mean and variance) is illustrated and detection result of big moving object and video sequences are shown in the bottom of the figure. From frame 796 object starts covering the frames and our method detect the object that is moving.

2.4 Global versus Local Region Information

In our proposed method local region; including area of edges and middle one are selected as highlighted in black squares in Fig.1 (a-2) and Fig.2 (a-2). Calculating histogram of small region spends less time than whole region's calculation and it enables efficiency of our proposed method. Selected tiles are enough to represent the illumination change of whole frames. Reason is when global illumination change occurs on a certain frame then scene contrast changes its color globally. Another reason is to get rid of camouflage effects. Our previous work [3] used the variations of mean and variance of global region's histogram was utilized for detecting sudden illumination change occurred frames. Changes of mean and variance for big object covering case and sudden illumination change case were similar to each other. By using global region information it is hard to distinguish whether sudden illumination change or big moving object as shown in Fig.8. Hence this causes the false positive of detection system in our case. So we selected five tiles in order to walk through this problem as shown in Fig.5 and Fig.8. By using local region information we can distinguish big moving object and sudden illumination change. Detection result of sudden illumination change using local region information and big moving object using global region information are inferred using logical operators in order to distinguish them. It is unable to detect big moving object as shown in Fig.8 by using local region information.

표 1. 급격한 조명 변화의 평가 지표 결과.
Table 1. Sudden Illumination Change Detection result with different evaluation metrics

Evaluation Metrics/ Dataset	Lightswitch1	LightSwitch2	Camera Parameter	Motinas_toni Change_ill
Total frame	2713	2798	4999	339
Ground Truth of SIC	3	15	3	3
True positive	3	4	3	2
False positive	0	0	0	0
False negative	0	11	0	1
True negative	2710	2783	4996	336
Recall	1	0.2667	1	0.6667
Specificity	1	1.0000	1	1.0000
FPR	0	0	0	0
FNR	0	0.0040	0	0.0030
PWC	0	0.3931	0	0.2950
Precision	1	1.0000	1	1.0000
FMeasure	1	0.4211	1	0.8000

2.5 Image Contrast Enhancement

CLAHE method was applied to enhance the image contrast which is caused by illumination change. The second contribution of our work is automatic clip limit parameter method for CLAHE by utilizing entropy of image through ANFIS. Zujun Hou et al [8] investigated the connection between entropy and image visibility. The entropy was used to measure the visibility of image in our work. It gradually decreases when sudden illumination change occurs on frames as shown in Fig.9. Entropy of image and several manually selected parameters (for example entropy = 7.1571, clip limit = 0.0034 etc.) are selected to train the data into ANFIS. Work flow is drawn in Fig.10. In Fig.10 (a) input image (on which sudden or gradual illumination change occurred from bright to dark case) and entropy of that image is calculated (b), several stipulated input-output data is used in to ANFIS and CLAHE assigns its clip limit parameter from ANFIS (d). In Fig.11 result of conventional Adaptive Histogram Equalization (AHE) and our proposed method for CLAHE are compared. Fig.11 (a) indicates entropies of input images, (b) input images to be enhanced, (c) is result of our proposed automatic parameter selection for CLAHE and (d) is result of conventional AHE method.

표 2. 점진적인 조명 변화의 평가 지표 결과.
Table 2. Gradual Illumination Change Detection result with different evaluation metrics

Evaluation Metrics/ Dataset	LightSwitch2	Camera Parameter	Motinas_toni_ change	Lobby
Total frame	2796	4996	337	1543
Ground Truth of GIC	6	34	4	2
True positive	6	32	4	2
False positive	0	0	0	0
False negative	0	2	0	0
True negative	2790	4962	333	1541
Recall	1	0.9412	1	1
Specificity	1	1.0000	1	1
FPR	0	0	0	0
FNR	0	0.0004	0	0
PWC	0	0.0400	0	0
Precision	1	1.0000	1	1
FMeasure	1	0.9697	1	1

3. Simulation and Result

In this study, some experimental results dealing with the proposed method was provided by using delta mean and variance in order to detect sudden illumination change and big moving object on a certain frames. Our method performed with different kind of benchmark dataset (*.avi video sequences) such as LightSwitch, Camouflage and simulation work was done in Matlab. Detection result of sudden and gradual illumination changes are shown in Fig.5 and Fig.6, respectively. From the detection point CLAHE method was applied in order to enhance. Result of enhanced image shown in below of Fig.12. Detection result of illumination changes were tested with different evaluation metrics as defined in [9]. Specifically precision, recall and specificity showed high rates as shown in Table 1 and Table 2, respectively.

3.1 Evaluation Metrics

In order to analyze the performance of our proposed method we tested with different evaluation metrics. Performance is good if specificity, precision and recall are high or equal to one. Table.1 shows example of false positive ratio method and IC abbreviates illumination change, SIC (Sudden Illumination Change), GIC (Gradual Illumination

Change), respectively. If and only if the prediction of illumination change and detection output is equal to one then that is true positive rate. If prediction and detection output are different then that is false positive. Evaluation metrics are compared with ground truth of illumination changes and result of illumination change detection of our proposed method. Then it calculates the specific measurements separately and identify the our method performance.

4. Conclusion

In our previous work [4] we used only variations of mean and variance of global region's histogram for detecting sudden illumination change. As a result, whole sudden illumination change occurred frames were detected. In this paper a new method for detection of illumination change was introduced by using local region information and fuzzy logic approaches. After detecting illumination changes (sudden and gradual), (CLAHE) method was applied in order to enhance the contrast of image in prior to the application of other methods. Thus, CLAHE method assigns clip limit parameter automatically using entropy of image through (ANFIS). In addition, our proposed method also detects big moving objects. Working with local region is more reliable and precise than global region. Fuzzy logic improves the efficiency for detecting the illumination changes, and it enables our method can process online. The result of detection through evaluation metrics has demonstrated high rates. Our method is robust to global illumination changes. The result shows that the identified method is computationally efficient and applicable in real time applications. Our future work will concentrate on local illumination change case.

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