A Shift HSV Algorithm for a Low-Power Monitoring System using an FPGA toward Internet of Things Agriculture

[1]Takahisa Kurose [2]Hiroki Nakahara [2]Shimpei Sato [1]Tetsuo Morimoto
[1]Ehime University, Japan [2]Tokyo Institute of Technology, Japan

Abstract— An agriculture monitoring system observes growth of agricultural crops. It requires high-performance with a battery drivable system. To satisfy them, we use an FPGA, and realize a shift operation based HSV converter. Although the proposed shift-based HSV converter causes 8.4% error compared with the original HSV one, its power consumption is 26.51 times smaller than the original one.

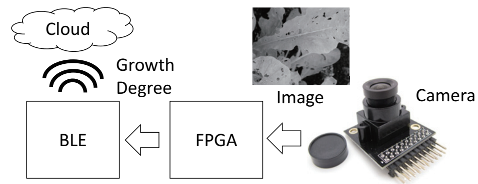

Fig. 1. A monitoring system for an IoT agriculture.

I. Introduction

With a rapid increase of the Internet devices and the sensor devices, the Internet of Things (IoT) has been proposed as a keyword for the next generation industry. In 2020, due to a growth of the Internet, the number of sensor devices will reach to five billion [3], and they will be connected to the Internet. However, since a large scale spread of such devices increases the amount of communication between sensor devices and the cloud, its power consumption is a dominant in the IoT era. Many of sensor devices are required to operate in a standalone. Therefore, when driving by a battery, it cannot be operated for a long time unless reducing power consumption.

II. A Monitoring System for an IoT Agriculture

In this paper, we propose a low power agriculture monitoring system toward to the IoT. In the case of monitoring for outdoor cultivation, it requires a battery driving system. To reduce the power consumption, we propose a shift HSV color conversion. Fig. 1 shows a monitoring system for a growth of a green leaf. First, a green leaf image is captured by a camera, and it is send to an FPGA. Then, it performs an image processing to calculate *the growth degree* which is defined by the number of pixels for a green leaf area. Finally, a wireless communication module transfers growth degree to a server on a cloud. In this paper, we used the Bluetooth low-energy (BLE) [1] that is a low power and satisfies a practical transfer speed.

III. HSV Converter to Compute a Growth Degree

To recognize the color of a green leaf, we convert the input RGB images into the HSV ones [2]. We set thresholds for hue (H), saturation (S) and brightness (V), and count the number of pixels which exceeds the thresholds as greed leaf area. In this paper, we realize it by a hardware friendly circuit. Let max denotes the maximum pixel value for the RGB, and min denotes the minimum one. Then, the HSV conversion is shown as follows:

$$H = \begin{cases} 60 \times (\frac{B-G}{max-min}) & (R = max) \\ 60 \times (2 + \frac{B-G}{max-min}) & (G = max) \\ 60 \times (4 + \frac{B-G}{max-min}) & (B = max) \end{cases}$$

$$S = 255 \times \frac{max - min}{max}$$

$$V = max$$

Next, we show an algorithm for the growth degree.

Algorithm 3.1 *1. Obtain the RGB image from the camera.*
2. Convert into the HSV image.
3. $g \leftarrow 0$.
4. For each a pixel, if an HSV pixel value exceeds the threshold, then $g \leftarrow g + 1$.
5. Output g*, then Terminate.*

Since algorithm 3.1 requires the threshold, we empirically set it. Fig. 2 shows an original HSV converter. Since it requires multipliers and dividers, the amount of hardware tends to be large, and dissipates much power.

IV. Power Reduction by Shift HSV

As shown in Fig. 2, since the original HSV converter uses the multiplier and divider, the conversion is slow and power consumption is large. Especially, since the divider realized by a sequential circuit requires many cycles, it is

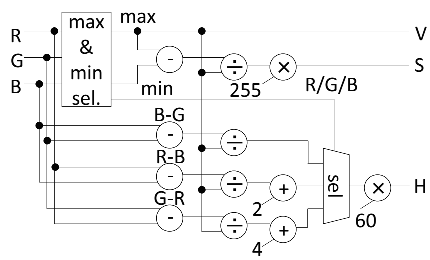

Fig. 2. Original HSV color converter.

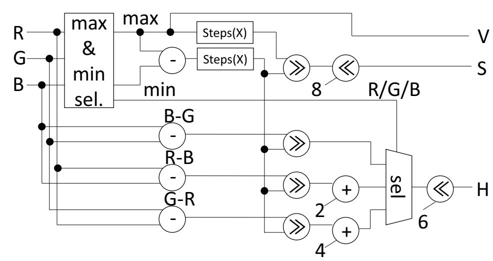

Fig. 3. Shift HSV color converter.

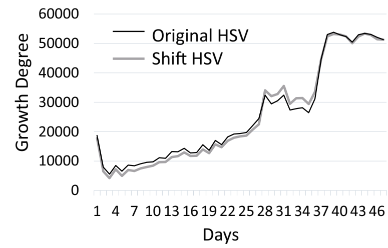

Fig. 4. Comparison the original HSV with the shift one.

TABLE I
Comparison of HSV Methods.

HSV Method	Area #LE	Area #REG	Time [sec]	Power [Wsec]
Original	589	329	153.6×10^{-3}	33.94×10^{-3}
Shift	329	0	6.1×10^{-3}	1.28×10^{-3}

TABLE II
Comparison with Embedded Processor.

	Time [sec]	Power [Wsec]
FPGA@50MHz	6.1×10^{-3}	1.3×10^{-3}
Arduino Zero Pro@48MHz	36.2	1.3×10^{-3}

not suitable for the hardware realization. In this paper, we propose *a shift HSV* which approximates the HSV conversion by a shift operation. Following expressions show the proposed conversion.

$$H = \begin{cases} 64 \times (\frac{B-G}{Steps(max-min)}) & (R = max) \\ 64 \times (2 + \frac{B-G}{Steps(max-min)}) & (G = max) \\ 64 \times (4 + \frac{B-G}{Steps(max-min)}) & (B = max) \end{cases}$$

$$S = 256 \times \frac{max - min}{Steps(max)}$$

$$V = max,$$

where $Steps(X)$ denotes a step function which approximates the given X:

$$Steps(X) = 2^n, \text{where } 3 \cdot 2^{n-2} \leq X \leq 3 \cdot 2^{n-1}$$

Fig. 3 shows a shift HSV converter. Since the proposed HSV converter treats the values for the power of two, the multiplier and divider are replaced into the shift circuits. Although it causes the error compared with the original HSV, it does not affect the identification of the green leaf area by using an appropriate threshold.

V. Experimental Results

A. Comparison of HSV Algorithms

As for the growth degree, we compared the original HSV with the proposed shift-based one. We used VGA images of leaf vegetables for 60 days until the harvest from germination. Fig. 4 compares the HSVs. Although the average error rate is 8.4%, its trend is almost the same.

B. Implementation Results

We implement the proposed monitoring system using an Odyssey Corp. MAX10 FPGA evaluation kit, an OV7670 camera, an Atmel Corp. atmega320p microprocessor, and a BLESerial2 wireless translation module, respectively. Table I compares the HSV converters. In the table, *Time* denotes the conversion time from a VGA image. Since the proposed shift HSV can realized by a shifter, it was 25 times faster than the original one. As for the area, it reduced the number of LEs by 44.2%. As a result, power consumption for the shift HSV is 26.51 times smaller than the original one.

Table II compared with the embedded microprocessor (Arduino Zero Pro: ARM Corp. Cortex-M0@48MHz). Since the FPGA based one is 5934 times faster, its power consumption is 4065 times smaller than the Arduino-based monitoring system.

VI. Conclusion

In this paper, we proposed a shift operation based HSV converter in order to reduce the power consumption for the IoT agriculture monitoring system. Although the proposed shift-based HSV converter caused 8.4% error compared with the original HSV one, its power consumption was 26.51 times smaller than the original one.

VII. Acknowledgements

This research is supported in part by the Grants in Aid for Scientistic Research of JSPS.

References

[1] DigiKey Corp., "Comparing low-power wireless technologies," http://www.digikey.com/en/articles/

[2] G. H. Joblove and D. Greenberg, "Color spaces for computer graphics," *Computer Graphics*, No. 12, Vol. 3, pp. 20-25, 1978.

[3] "Growth in the Internet of Things," https://www.ncta.com/platform/broadband-internet/behind-the-numbers-growth-in-the-internet-of-things-2/