# APPLES GRADING USING VIDEO SIGNAL PROCESSOR DM642

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*Classification is vital for the evaluation of agricultural produce. A machine vision system for the quality inspection and grading of apples has been developed. The color vision system grades apples on size, shape and defects. Color CCD cameras inspect the apples in flight as they pass under the cameras. The system for measuring the fruit quality based on the picture information fusion technology. Video signal processor DM642 performs the image processing and classification tasks.*

**Keywords:** Apples grading, Image processing, Defect inspection, Fruit quality

## 1. INTRODUCTION

Machine vision based quality grading of apple fruits is necessary for increasing the speed of sorting and eliminating the human error in the process. Research still continues to accurately segment and identify skin defects of apples.

The European Union defines three quality classes ("extra", "I", and "П") for the fresh apples with the tolerances of 5, 10, and 10 per cent by number or weight of apples, respectively [1]. The apples in the "extra" class must be of superior quality with no defects or irregularity in shape, whereas the classes "I" and "П" can contain defects up to 1 and 2.5 cm2, respectively. It is clear that the classification of different kinds of apples into predetermined categories as accurate and quickly as possible is a hard task. Please comply with these requirements:

### 1.1. Material and methods

Machine color vision system for apples grading based on a Texas Instruments video signal processor DM 642. Fig.1 shows hardware components and the Fig.2 the schematic diagram of the machine vision system.

The sensor module includes a back illuminated CCD cameras (6 and 10) with control units VariSpec liquid crystal tunable filters (11 and 12) and optics sensors for internal defects (4 and 5). Two independent light sources (7) for the reflectance and fluorescence images are incorporated into the system.

The quality of apples (1) on line (2) are controlled by video signal processor DM 642 (9).

The TMS320DM642 device is the highest-performance fixed-point DSP generation in the TMS320C6000™ DSP platform. The TMS320DM642 (DM642) device is based on the second-generation high-performance, advanced VelociTI™ very-long-instruction-word (VLIW) architecture (VelociTI.2™) developed by Texas Instruments (TI), making these DSPs an excellent choice for digital media applications. The C64x™ is a code-compatible member of the C6000™ DSP platform.

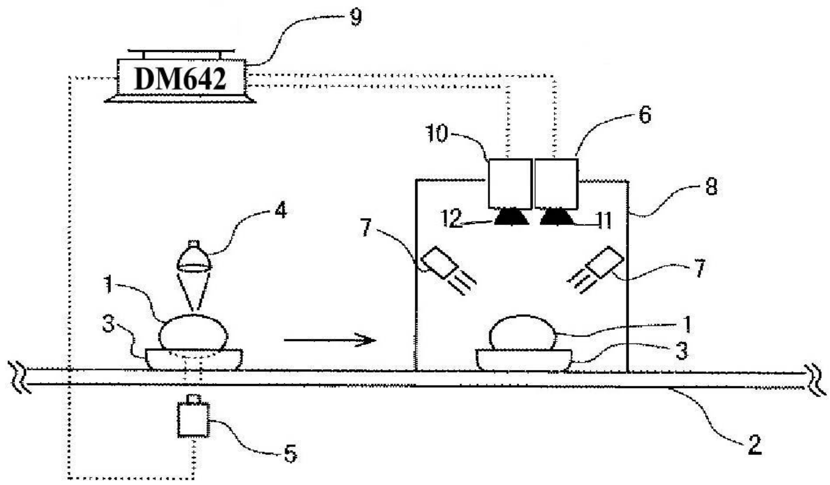


Fig.1

With performance of up to 5760 million instructions per second (MIPS) at a clock rate of 720 MHz, the DM642 device offers cost-effective solutions to high-performance DSP programming challenges. The DM642 DSP possesses the operational flexibility of high-speed controllers and the numerical capability of array processors. The C64x™ DSP core processor has 64 general-purpose registers of 32-bit word length and eight highly independent functional units—two multipliers for a 32-bit result and six arithmetic logic units (ALUs)— with VelociTI.2™ extensions. The VelociTI.2™ extensions in the eight functional units include new instructions to accelerate the performance in video and imaging applications and extend the parallelism of the VelociTI™ architecture. The DM642 can produce four 16-bit multiply-accumulates (MACs) per cycle for a total of 2880 million MACs per second (MMACS), or eight 8-bit MACs per cycle for a total of 5760 MMACS. The DM642 DSP also has application-specific hardware logic, on-chip memory, and additional on-chip peripherals similar to the other C6000™ DSP platform devices.

The DM642 uses a two-level cache-based architecture and has a powerful and diverse set of peripherals. The Level 1 program cache (L1P) is a 128-Kbit direct mapped cache and the Level 1 data cache (L1D) is a 128-Kbit 2-way set-associative cache. The Level 2 memory/cache (L2) consists of an 2-Mbit memory space that is shared between program and data space. L2 memory can be configured as mapped memory, cache, or combinations of the two. The peripheral set includes: three configurable video ports; a 10/100 Mb/s Ethernet MAC (EMAC); a management data input/output (MDIO) module; a VCXO interpolated control port (VIC); one multichannel buffered audio serial port (McASP0); an inter-integrated circuit (I2C) Bus module; two multichannel buffered serial ports (McBSPs); three 32-bit general-purpose timers; a user-configurable 16-bit or 32-bit host-port interface (HPI16/HPI32); a peripheral component interconnect (PCI); a 16-pin general-purpose input/output port (GP0) with programmable interrupt/event generation modes; and a

64-bit glueless external memory interface (EMIFA), which is capable of interfacing to synchronous and asynchronous memories and peripherals.

The DM642 device has three configurable video port peripherals (VP0, VP1, and VP2). These video port peripherals provide a glueless interface to common video decoder and encoder devices. The DM642 video port peripherals support multiple resolutions and video standards (e. g., CCIR601, ITU-BT.656, BT.1120, SMPTE 125M, 260M, 274M, and 296M).

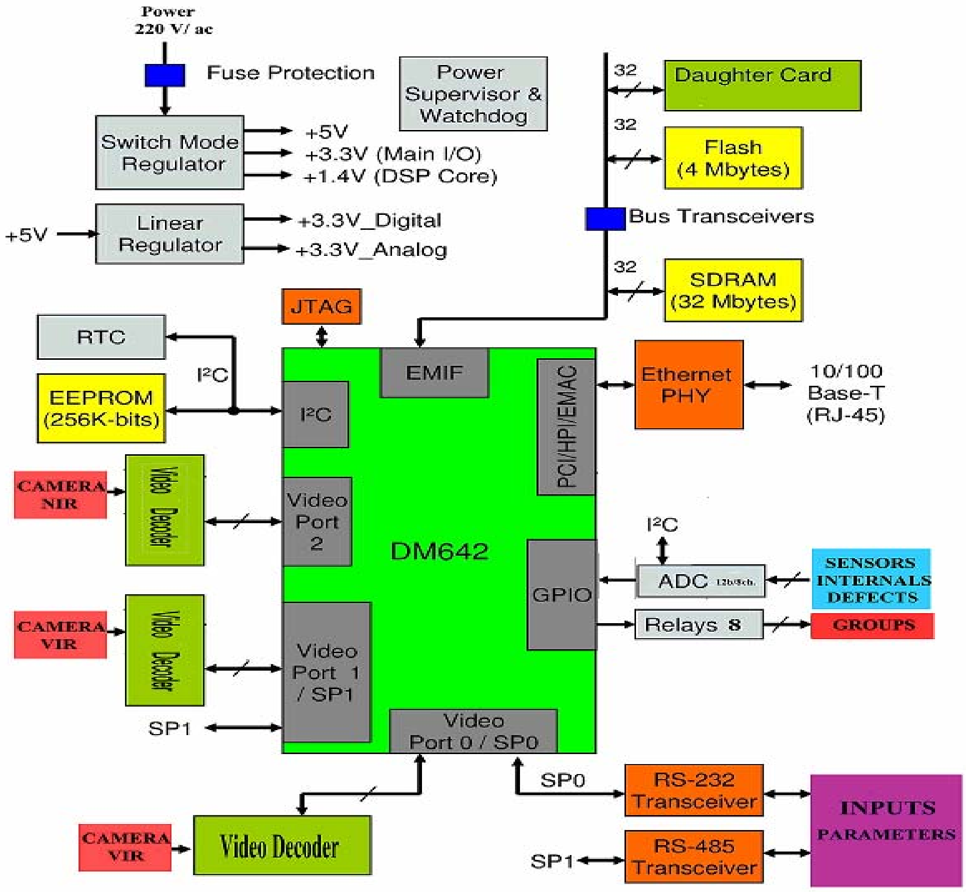


Fig.2

In general, uncontaminated apples surfaces showed higher reflectance in the VIS (>600nm) and NIR regions compared to the defective or contaminated surfaces, except for bruise spots, which had higher reflectance Fig.3. Areas with scabs exhibited the lowest reflectance. There was a very distinct absorption feature in the red region of the spectrum with maximum absorption centered at 680 nm.

This absorption was due to the presence of chlorophyll a molecules. The contaminated spots lacked the chlorophyll a absorption features, except for bruised areas. Low reflectance characteristics observed from approximately 450 to 550 nm region for uncontaminated apples were the manifestation of strong absorption by the constituent pigments such as chlorophyll b and carotenoids.

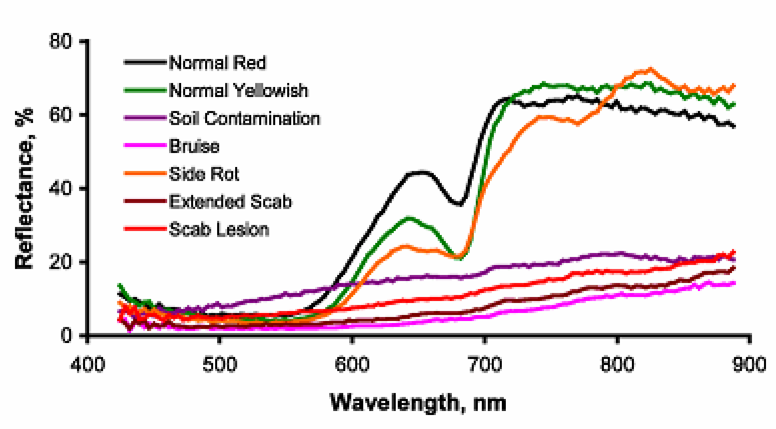


Fig.3

Differentiation between contaminated and defective apples from uncontaminated apples was achieved with multiple wavelength images. Due to the non-flat shape of apples, great differences in reflectance measurements vary across the apples from the centers to the edges. This variation masks the difference that might be seen for eithercondition. Second difference techniques would allow better differentiation of the contaminated and defective portions of apples. The algebraic expression for the second central difference is given by the following equation:

$$S''=(\lambda n,g)=S(\lambda n+g)-2S(\lambda n)+S(\lambda n-g), \quad (1)$$

where S(An) is the reflectance image at the center wavelength $\lambda_n$ and $S''(\lambda_n, g)$ is the second difference image at the wavelength $\lambda_n$ with a gap (g) in nm. The center wavelength and the gap were chosen to provide the best contrast between surface defects and uncontaminated portions of the apples. In general, when center spectral bands are associated with strong pigment absorption feature, e.g. carotenoids and chlorophyll a, the second difference images provide enhanced visual contrasts betweens the contaminated and uncontaminated parts of apples as compared to a single waveband image. The diagram of apples grading segmentation approach can be seen in Fig.4. Images of a fruit is introduced to the system. Apple area is extracted from the background by pre-processing.

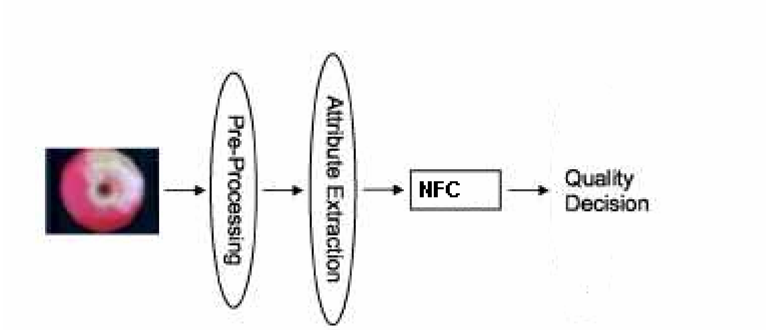


Fig.4

In order to get high performance of classification, the features should be in the same range, which can be achieved by normalization. The features are normalized so that the mean is 0 and the standard deviation is 1 by the formula:

$$f_i' = \frac{[f_i - \mu(f_i)]}{\sigma(f_i)} \quad (2)$$

where $f_i$ and $f_i^{'}$ are the initial and final values of a feature, respectively, $\mu(f_i)$ is the mean and $\sigma(f_i)$ is the standard deviation of all the values of the class that feature belongs to. "The designer usually believes that each feature is useful for at least some of the discriminations." [1] However, superfluous and class-conditionally dependent features may lead to terrible classification performance. So, principal components analysis was applied on the features to get an uncorrelated data set. First covariance matrix of the feature set was calculated and then the matrix of the eigenvectors of this covariance matrix was multiplied with the feature set, producing transformed feature set whose components are uncorrelated and ordered according to the magnitude of their variance. Then the components, which contribute only a small amount (1 per cent in this case) to the total variance in the transformed feature set, are eliminated.

In Tabl.1 are presented the results which were obtained with the classification of apples data.

| algorithm | accuracy %<br>(std. dev) |
|---|---|
| mountain clustering/ANFTS | 94.1<br>(3.8) |
| histogram based Fuzzy | 91.3<br>(3.4) |
| Bayes | 72.1<br>(17.8) |

Tabl.1

## 2. CONCLUSION

A machine vision based automatic grading system for apple fruits is introduced. Main goal of the project is to provide a fast algorithm for apples classification for real DSP platforms on DM642. Therefore, average, standard deviation, and median values are calculated over the segmented area of each fruit from all filter images. In addition to these features, defected ratio, which is the ratio of defected pixels of the fruit, is also computed. The fruit area is extracted from the background and it is eroded to reduce undesired effects of illumination. After this preprocessing, defected area of fruits are segmented by implemented Neuro-Fuzzy algorithms in DSP DM642.Visual results of this segmentation are found to be quite successful. After segmentation step, statistical features are extracted from defected regions and fed to several supervised classifiers for fruit sorting by binary classification (defected or healthy). Recognition rates of all classifiers vary between 72.1 % and 94.1 %.

## 3. REFERENCES

[1] Duda R. O., Hart P. E., Pattern Classification and Scene Analysis, Wiley & Sons, Canada, 2002

[2] UN/ECE Standard on apples and pears http://www.unece.org/tede/agr/welcome.htm then select Standards/Fresh fruit and vegetables

[3] http://www.ti.com ; datasheet TMS320DM642 Video/Imaging Fixed-Point Digital Signal Processor (Rev. K)