Singular spectrum analysis for hyperspectral imaging based beef eating quality evaluation: a new pre-processing technique

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Abstract

- Hyperspectral imaging (HSI) is an emerging platform technology that integrates conventional imaging and spectroscopy to attain both spatial and spectral information from an object.
- In recent years, HSI has rapidly matured into one of the most powerful tools for food quality analysis and control.
- In the project, HSI has been applied for beef eating quality evaluation.
- Pre-processing of HSI spectral profiles is needed, in order to eliminate undesired noises.
- Singular spectrum analysis (SSA) will be demonstrated to be an effective pre-processing step in de-noising HSI spectra.

Data collection

- 211 beef samples (2.5 cm thick) of the *M. longissimus thoracis* (11th rib) were imaged at 2 days post-mortem using Gilden photonics HSI system (Fig.1).
- HSI system wavelength range: 400 – 863 nm.
- Beef eating quality is related to tenderness, juiciness and flavour.
- Slice shear force (SSF) was measured at 7 days and 14 days post-mortem using Tenderscot meat tester (Fig.2a) as the tenderness reference.
- Ultimate pH was measured at 7 days and 14 days post-mortem using Hanna meat pH meter (Fig.2b) as the flavour reference.
- Data was split into calibration set (75%) and validation set (25%) for each quality trait.

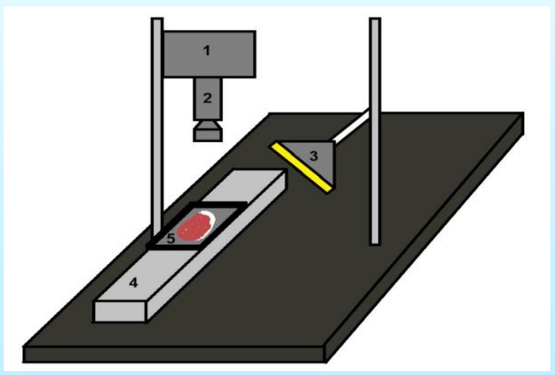


Fig.1. Schematic diagram of the HSI system.
[1] CCD camera [2] Spectrograph and lens [3] Halogen lamp [4] Sliding track [5] Scanning tray

(a) (b)

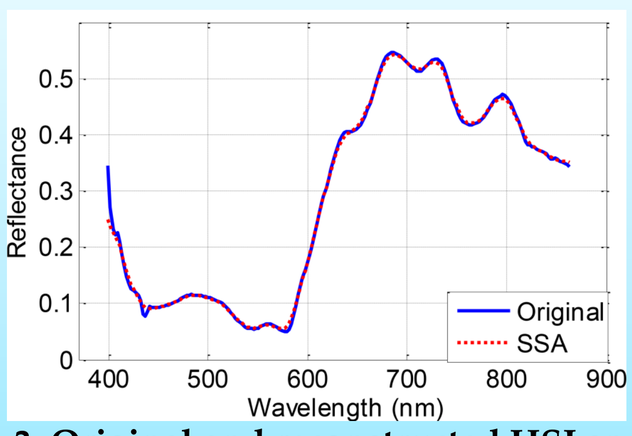
Fig.2. Instruments for measuring beef eating quality.
(a) Meat tester (b) pH meter

Table 1. Summary statistics of studied beef quality traits.

Trait		SSF7	SSF14	pH7	pH14
Calibration set	n	159	159	154	154
	Min	46.97	63.35	5.44	5.46
	Max	299.54	291.56	6.37	6.46
	Mean	131.46	132.23	5.63	5.69
	SD	48.18	42.91	0.13	0.14
Validation set	n	52	52	51	51
	Min	69.41	73.61	5.46	5.48
	Max	285.62	239.82	6.34	6.41
	Mean	130.73	131.32	5.63	5.69
	SD	45.69	39.91	0.14	0.14

Data pre-processing

- SSA is a new technique commonly used for time series analysis and forecasting.
- SSA is based on the singular value decomposition (SVD), which is able to decompose the original vector into a few independent components, including the 'clean' vector, oscillations and noise.
- Usually the 'clean' vector is located in the biggest eigenvalue (corresponding to the 1st component), so reconstruction can be done using the 1st component.
- Parameter to tune: window size L.



Window size
L = 5

Fig.3. Original and reconstructed HSI spectral profile.

Experiments and results

- Principal component analysis (PCA) was applied on the SSA treated spectra to reduce the dimensionality to 30.
- Support vector machine (SVM) was used to construct the regression model on the calibration set.
- The model performance was assessed on the validation set using coefficient of determination (R^2) and ratio of performance deviation (*RPD*).

Table 2. Performance comparison of original HSI spectra and SSA treated spectra for predicting beef eating quality attributes on the validation set.

Trait	Original spectra		SSA treated spectra		
	R^2	RPD	L	R^2	RPD
SSF7	0.1938	1.1019	2	0.3288	1.2082
SSF14	0.1001	1.0264	2	0.1104	1.0249
pH7	0.4227	1.2490	3	0.4511	1.2822
pH14	0.2785	1.1234	7	0.3419	1.2090

- In conclusion, SSA demonstrates its ability in removing noise and improving the prediction accuracy for HSI based beef eating quality evaluation.

QMS
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