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.

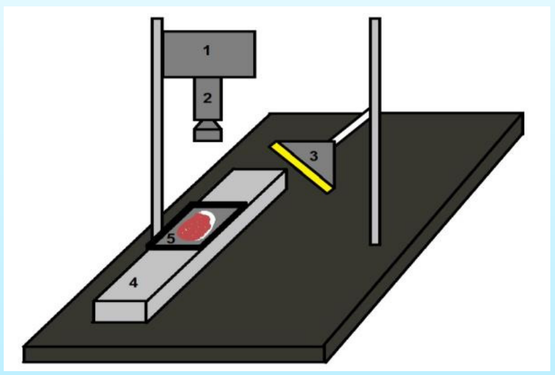


Fig.1. Schematic diagram of the HSI system.
[1] CCD camera [2] Spectrograph and lens [3] Halogen lamp [4] Sliding track [5] Scanning tray

(a) **(b)**

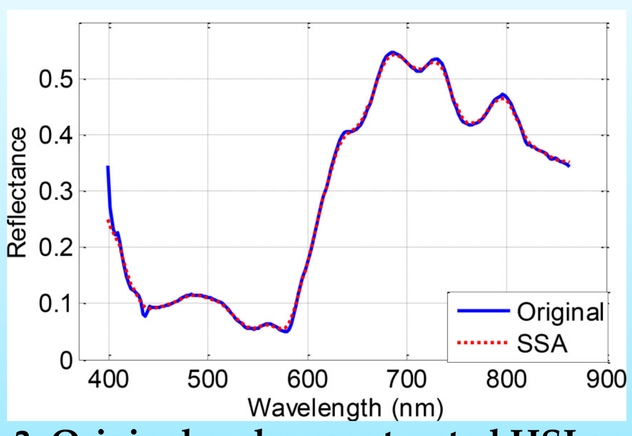
Fig.2. Instruments for measuring beef eating quality.
(a) Meat tester (b) pH meter

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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