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Challenges with textured hair analysis: single fibre and hair assembly assessments and statistical explorations

Introduction

The first reported measurable characteristics of curly hair used for assessing its geometric variability were the average curvature (average radius of the curves formed by the fibre), the ratio of minimum/maximum curvature, the crimp (number of times the direction of fibre changes), the ratio of natural to straight hair length [1]. In recent years, automation of single fibre geometry assessment via computer graphics, image analysis and modelling programmes has been reported [2]. Such approaches are aimed at more accurate and precise curvature characterisation. Consumer-relevant instrumental testing such as combing ease and friction were historically developed and interpreted in the context of straight and wavy hair's characteristics. For high curl types hair curvature was considered dominant in all dimensions of hair manageability [3]. The increased popularity of hair styles based on maintaining the textured hair's natural curvature has spurred research into better tailored products and hair testing methods. **The aim of this study was to explore the applicability of hair tress testing techniques such as combing ease and friction on textured hair in conjunction with a machine-learning based approach to single fibre curl assessment.**

Hair assembly testing

Materials and methods

- Hair: eight tresses (curl type 4) per each condition, weight =1±0.2g
- Experimental conditions: untreated hair (**Unt**); control formulation (**Con**); control + Ceramide (**Cer**); control + Triolein **(Tri),** control + Hydrolysed keratin (**Ker**).
- Each formulation was applied as a leave-on product as a part of controlled wash and heat styling cycle, five cycles were applied to each tress.
- Coefficient of Friction **COF** and Total Combing Work **TCW** were performed on each tress before the wash and heat styling cycles (**t0**), and after the final cycle (**t1**).
- Statistical analyses: *t*-tests for each condition comparing means at t0 and t1; one-way Independent Samples ANOVA with covariate applied to the mean t0-t1 differences of all conditions and adjusted to the respective covariate t0; Principal Component Analysis (PCA) of the mean t0-t1 (non-adjusted) difference per condition

Results and discussion

Table 1. TCW and COF results for all conditions, including the adjusted and unadjusted means of the t0-t1 differences.

Condition	TCW t0	TCW t1	ΔTCW unadj	ΔTCW adj	COF t0	COF t1	ΔCOF unadj	ΔCOF adj
Cer	0.16	0.09	0.07	0.03	0.44	0.35	0.09	0.11
Tri	0.11	0.06	0.05	0.05	0.51	0.32	0.19	0.18
Ker	0.10	0.06	0.03	0.05	0.50	0.27	0.23	0.22
Con	0.10	0.05	0.05	0.07	0.46	0.24	0.22	0.23
Untreated	0.11	0.01	0.10	0.10	0.49	0.09	0.40	0.39

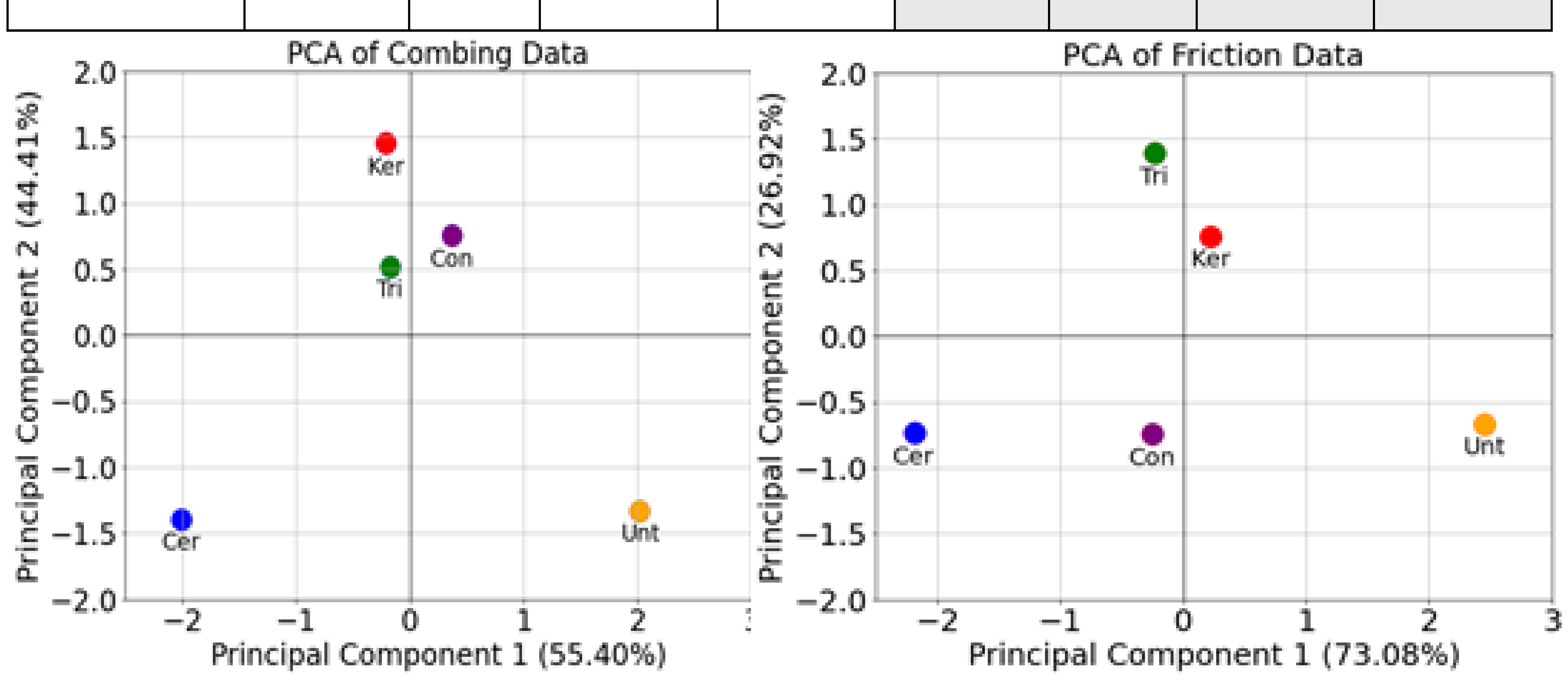

Figure 1. Principal Component Analysis of unadjusted t0-t1 means for the TCW and COF. Two principal components accounting for all variance were identified.

- Repetitive heat styling caused irreversible cortex damage and hair straightening to textured hair, thus reducing TCW and COF.
- Some treatments demonstrated capacity to protect hair, preserving the capacity of hair to return to its natural texture after washing, and maintaining TCW and COF closer to t0 values.
- The covariate adjustment accounted for the tress variability inherent to textured hair tresses.
- The PCA of TCW shows that curvature and lubrication made notable contribution to this test accounting for 55.4% and 44.4% of the variability
- The PCA of COF shows that curvature accounted for a larger 73% of the variability, whilst lubrication was less impactful 27%.

Single fibre hair testing

Materials and methods

- Hair: eighty fibres randomly selected and removed from eight tresses (curl type 4).
- Each fibre was labelled individually and vertically suspended and attached to a white card labelled correspondingly.
- Each fibre was treated with 5ml **Dimethicone** 350cpi (Azelis, UK) for 15min, and dried on absorbent paper.
- Each fibre was photographed, as suspended on its card, using DSLR Canon 250 camera (macro lens 100mm, automatic setting) at **t0** (before) and **t1** (after soaking) and the following image features were extracted: **number of intersects, the estimated number of curves, whole fibre mean curvature, quartile curvatures (four quartiles) and the normalised fibre area.**
- Statistical analyses: unpaired *t*-test for the t0 and t1 values of each feature, Pearson correlations between all features, PCA analysis of all features

Results and discussion

Table 2. Extracted feature mean values for mean t0, mean t1 and mean t0-t1, *p≤0.05

	Number of intersects	Estimated number of curves	Average curvature	Curvature 1st quartile	Curvature 2nd quartile	Curvature 3rd quartile	Curvature 4th quartile	Normalised area
t0 mean value	41.76	56.56	56.73	8.05	26.00	11.96	64.03	0.31
t1 mean value	40.81	51.91	80.12	5.32	14.15	15.04	92.22	0.32
Difference	0.95	-4.65*	-23.39*	2.72*	11.86*	-3.08*	-28.20*	-0.01

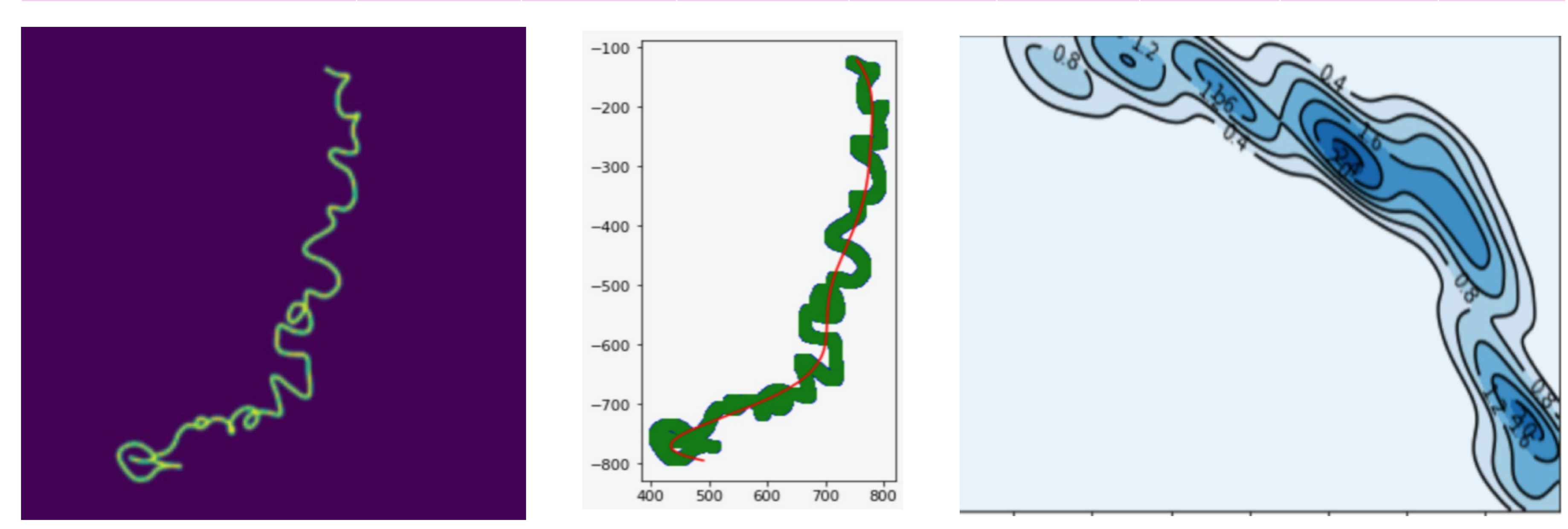

Figure 2. Illustration of the extracted fibre line and the consequent image processing for feature extraction.

- Significant changes from t0 to t1 were identified for the following features: estimated number of curves, the average curvature and the curvature of each quintile
- Corelations between the average curvature and the first and fourth quartile were recorded
- Lubricating hair coating might reduce curvature, especially at the distal end of the fibre
- Six principal components explaining the variance in all features were identified

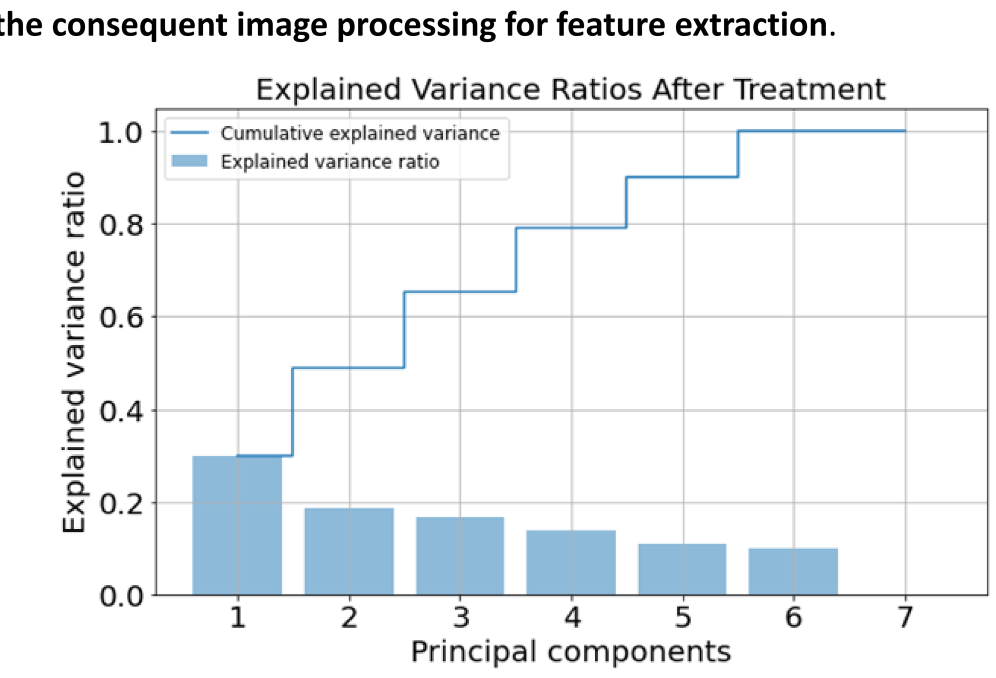

Figure 3. Explained variance ratio (%) and cumulative explained variance for the principal components identified

Conclusions

- Textured hair testing requires different experimental settings, statistical analysis and data interpretation from those used for straighter hair types.
- Curvature dominates all measurements at assembly level; however, lubricating product effects on the hair surface could be assessed too by combining appropriate methods
- Single fibre assessment methods could provide additional information of relevance to hair assembly assessment, for example, predictions of the curvature effect and fibre alignment; machine learning techniques can support the data processing and provide new tools for textured hair assessment

References
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