Forensic vs. Computing writing features as seen by Rex, the intuitive document retriever

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Abstract—The paper reveals the superficial matching between script features as understood by forensic experts and computer scientists and advocates the development of computational instruments tailored to fit the features traditionally used by the forensic community. In particular, and including other areas of graphonomics and the general public, there exists a demand for software for the analysis of intuitive features, think "slant" or "roundness," as opposed to analytical features, like "Fourier transform" or "entropy." Rex, a software with such a capability, is introduced and used to explore the potentialities of this approach for script forensics. An investigation of properties of the script contour orientation, the feature used by Rex, is also presented.

***Index Terms*—script features, contour orientation, computational graphonomics, handwriting forensics,**

I. Introduction

In this paper I wish to discuss the distinction between the typical forensic and computer science writing features (section II), introduce a software that takes into account their specifics (section III) and investigate the behavior of the feature used by the said software (section IV). The overall goal of the paper, beside the immediate benefits derived from the individual topics, is to provide thinking material about the challenges building software adapted to forensic applications.

II. Forensic vs. Computing writing features

Semiotics — That much forensic handwriting expertise is subjective and would profit from mathematics and computing in its quest for objectivity and replicability is publicly admitted [1], but the less advertised side of reality is that of software insisting to treat the users on feasts of mathematics and technology without actually meeting their needs [2]. At the root of this dialogue of the deaf lies, among other interesting factors of the sociology of science, the very words "writing feature." For forensic experts the "feature" is usually intuitively comprehensible, such as "slant" [3], while for computer scientists the most powerful "features" are mathematical concepts, like "Fourier components" or "fractal dimension," which need specialized knowledge for their properties to be understood. Developing measurement software for intuitive features not only gives forensic professionals tools which they know how to handle, but also allows them to communicate about their work — an essential aspect in respect to testimony in court. Intuitive features additionally benefit the design of computer systems, improving the ergonomy of user interfaces as exemplified in section III.

Table I
Divergence in use of writing features across graphonomics areas

intuitive ◄	**Writing features**	► analytical
pen pressure, stroke width, character slant, allographs, line justification, baseline shape, regularity, aesthetic quality...		Fourier components, wavelet coefficients, entropy, fractal dimension, hidden Markov model...
▼ primary use	**Graphonomics areas**	▼ primary use
✘	forensics, paleography, typography, art, education, medicine	·
·	writing recognition, digital libraries, biometrics, neurocognitive sciences	✘

Cognition — An interesting viewpoint on the debate over intuitive and analytic features is to consider mathematics as an evolutionary outcrop of the neural computing capacities of the brain. Intuition is evolutionary unconscious learning by interaction with the environment to which conscious analysis supplements when novelties arise. Thus the two can be envisioned as a continuum, mathematics progressively becoming intuitive.

Sociology — To think that the divergence of the two feature types is a function of mathematical educational level is overlooking a fundamental distinction. Writer identification and verification are main mobiles of computational handwriting forensics, and because here only results count, it can use any method without even the need of thorough understanding insofar as it is better. This evolutionary mindset of a goal-focused black box approach is faced by the knowledge-oriented crystal ball attitude seen in the traditional graphonomical research, which adds to the control tasks mentioned above a considerable interest in the handwriting ecosystem, i.e. the structures and dynamics of handwriting features across populations and the underlying factors: material, cognitive, biomechanical, sociocultural.

Linguistics — The issues with the term "feature" extend to a further worldview cloaking inconspicuously its users. The proposition "This font is Roman" is considered in philosophy either as an expression on a property owned by the font (objectivism) or attributed to the font by an observer (subjectivism) [4], [5]. The difference is one of lifestyle: the world is there for

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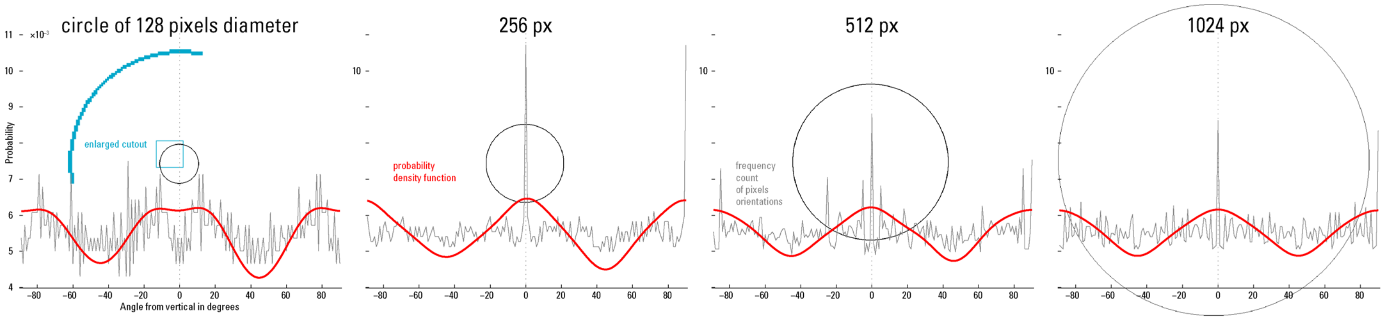

Fig. 1. Contour orientation profiles — Look carefully at the enlargement of the 128 pixels diameter circle and you'll see four horizontal and vertical pixels in a row: a bitmap shape representation has more pixels in these directions than warranted by the ideatic shape. The distortion decreases with object size. The ordinate values reveal that bias is small: its amplitude is ~0.002, while for a typical written document the mean is ~0.025 and the maximum ~0.04 (see Fig. 3 and [16]–[18]).

truth to be discovered or for models to be invented. Translated at lexical level this is what defines the terms "feature" and "descriptor," among their numerous handwriting related synonyms [3]. To this author "descriptor" seems more appropriate since it doesn't presuppose anything about the object (it just is) and it's easier and more fun to be critical about a model than a truth. Incidentally, while "feature" prevails in graphonomics, "descriptor" has a foothold in the wider pattern recognition community, as witnessed in a wording like "shape descriptor."

Implications — Computer scientists have to consider in common intelligence with forensic experts three issues worth mentioning because they bear an influence on how the software presented later in the paper is to be used. The issues are the desired precision of the analysis, the definition of the features and the affordability to analyze them in the current state of the art. I will illustrate this through two visual examples.

Precision — Fig. 1 presents three bitmap circles of various sizes for which the orientation along their contour is measured (details in section III). Being circles, we would expect that all orientations be equally well represented, but due to the discrete nature of the underlying raster in which the shapes live the distribution is biased towards the orthogonal direction — the distribution will peak at 0 and 90 degrees ([6], [7], for hexagonal grids see [8]). Making a model of the distortion and applying it to arbitrary orientation profiles should solve the issue, but it turns out that the distortion is shape specific. For example, a vertical line has no distortion at all, so there is no need for correction. A somewhat better choice is to increase the image resolution at capture time or after, with the drawback of generating voluminous files and knowing that often only low resolution images are available. This digital geometry problem is compounded upstream by the design of discrete Gaussian filters for orientation measurement [9], and downstream by digitization, the same physical document producing at pixel level different shapes depending on its alignment with the digital grid of the imaging system, hence affecting the replicability of results [10], [11]. A number of techniques address these issues [12]–[15] but the implications for handwriting analysis have yet to be fully explored, starting with the question of how much precision is needed for which application. High accuracy graphonomics is therefore an area open to investigation.

Definition — I discuss now the slant of three Roman script characters as perceived by a human and raise the question of how this simple feature should be defined. In the case of **I** the slant is vertical and corresponds to the shape's axis of equilibrium through its center of gravity — here the slant is a physical property of the object. For an **O** there is no way to tell how the character is oriented would the baseline be unknown — slant is here a property of the object relative to the surrounding. The slant of **y** can be considered as upright only if we are able to identify the shape as character "y" and be aware of the convention that this lower case letter has to be considered vertical despite its physical right-leaning — this is a case of semantic slant. A deeper examination might reveal even more criteria. In conclusion, a slant analysis algorithm implementing human expert behavior appears to be more challenging than suspected, given first the very difficulty to define the feature, and secondly due to the mix of perceptual and cultural considerations to model.

Afordability — The last sentence leads to the issue of affordability: do we have the technological means to perform comprehensive slant analysis since we need to recognize unconstrained handwritten characters? This task not being presently solved, a positive answer can be given only if we are happy with a certain degree of imprecision, its exact amount having to be determined. Some of the fine computational forensic expertise that we would wish to attain is thus yet out of reach.

III. Rex, the intuitive document retriever

Rationale — Written documents in databases can be retrieved by appearance by one of the following methods: visual (using a reference document), semantic (describing script features), haptic (by drawing) and exogenous (from document ecosystem metadata). Semantic retrieval is convenient because it is intuitive (it takes place via a graphical and natural-language interface), free of any preexisting model (not always available) and can describe aspects of a script (contrary to the holistic approach of visual retrieval). The software that grew out of these considerations, called Rex, suits the demand for tools supporting forensic specific features as described above (Fig. 2) [16]–[18].

Technicalities — The software measures the local orientation along the writing contour, a popular computational graphonomics feature [19]. This is done by applying on the binary image

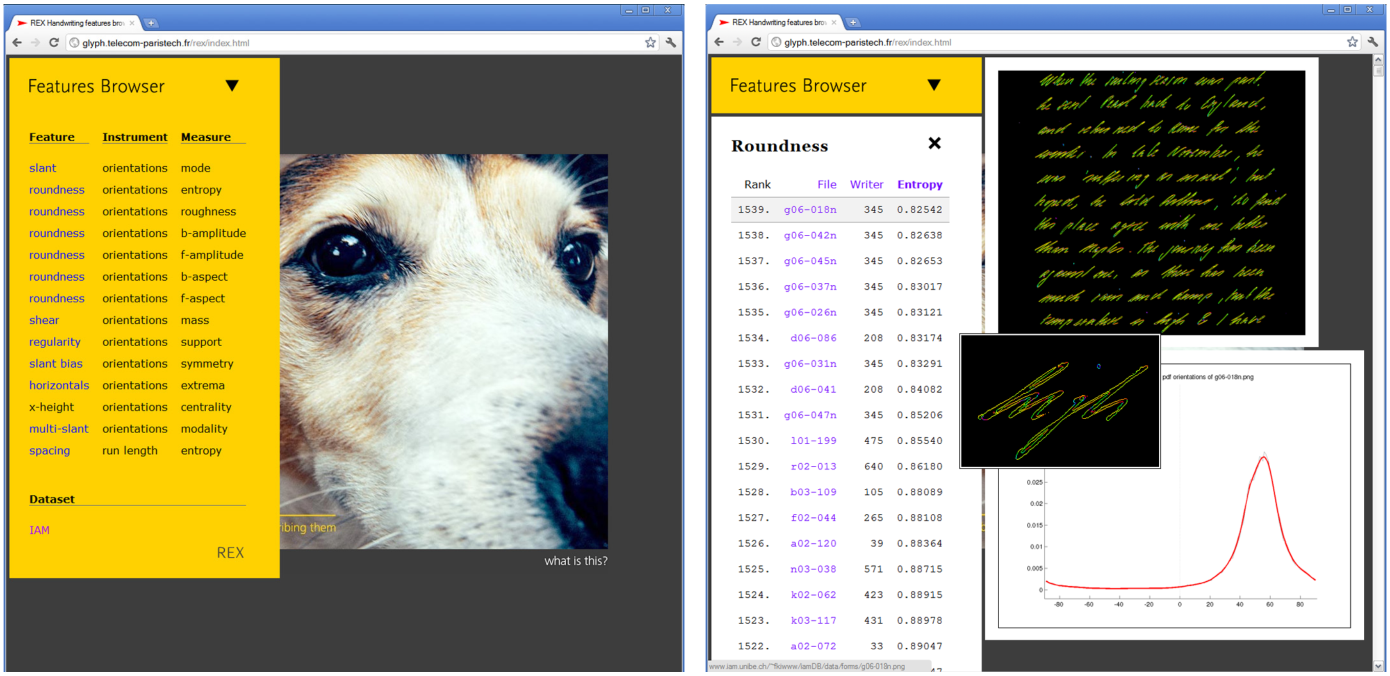

Fig. 2. Rex screenshot — After selecting an intuitive script feature (left picture, showing also the underlying mathematical measurements and instruments), users obtain a list of documents ranked according to the quantitative value of the feature, in this case "roundness" (right picture, giving the file and writer id too). The document and a mouse-over zoom with pixels colorcoded by orientation is presented, as well as the orientation profile and a hyperlink to the original document.

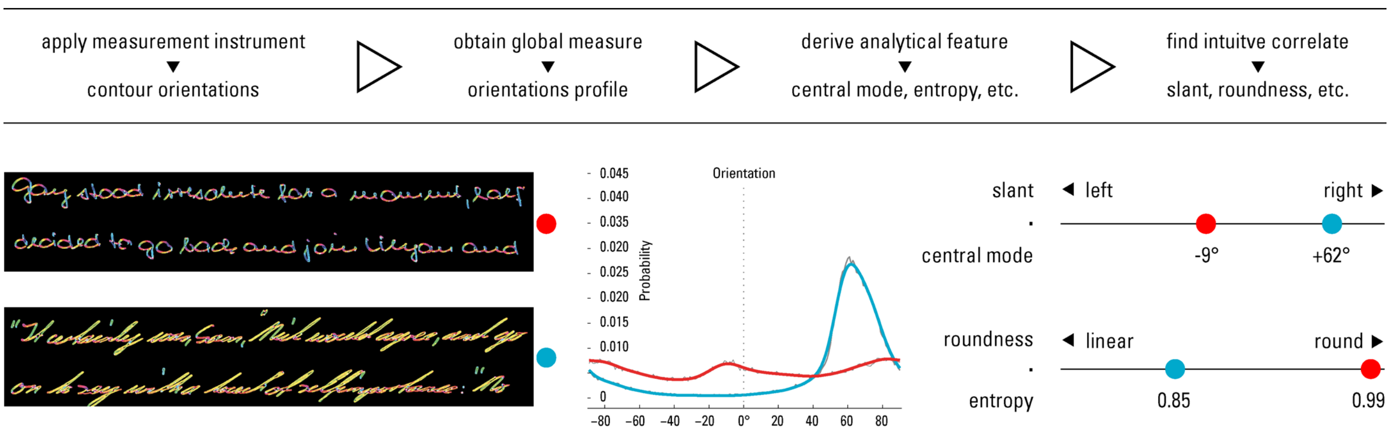

Fig. 3. Pixels to vectors to scalars to concepts — Prospecting for intuitive writing descriptors by extracting various statistical parameters of a global measurement. The colormap of the script samples (P02-081 and L01-199 of [8]) encodes the contour orientation at each pixel location — red for example being horizontal.

of the contour an anisotropic Gaussian filter bank with one degree of radial displacement. At this stage of this well-known approach two innovations are introduced, in addition to the fine grained resolution. First, after deriving the probability density function from the orientations' frequency count, statistical properties of the distribution are obtained. Second, it was discovered that these statistics correlate with various script features of the intuitive type, perceived as distinct one from another, such as "slant," "roundness" or "density" (Fig. 3). To sum up, Rex behaves like a handy, multipurpose Swiss army knife.

Applications — The Swiss reference is not fortuitous, since the handwriting documents presently used by Rex originate in that country (IAM Handwriting Database 3.0 [20]). This shows again the surprising versatility of the tool in that it is not only a document browser, but also a teaching tool about handwriting. In addition to learning about individual documents, Rex provides an insight in the make-up of a population of writers — that of the canton of Bern from where most of the dataset writers hail (Fig. 4). The question that immediately springs to mind — "Do writers from other parts of the world have similar characteristics?" — is typical of the richness of research and pedagogical possibilities opened by such an instrument (indeed, the few Greek, Chinese and other foreigners among the contributors show scriptural characteristics apart form the Swiss majority). If the present usage of Rex is rather limited to a browser of a specific dataset and much development can be imagined, it is nevertheless also an intriguing tool to experiment with as a testbed for other computational forensic applications.

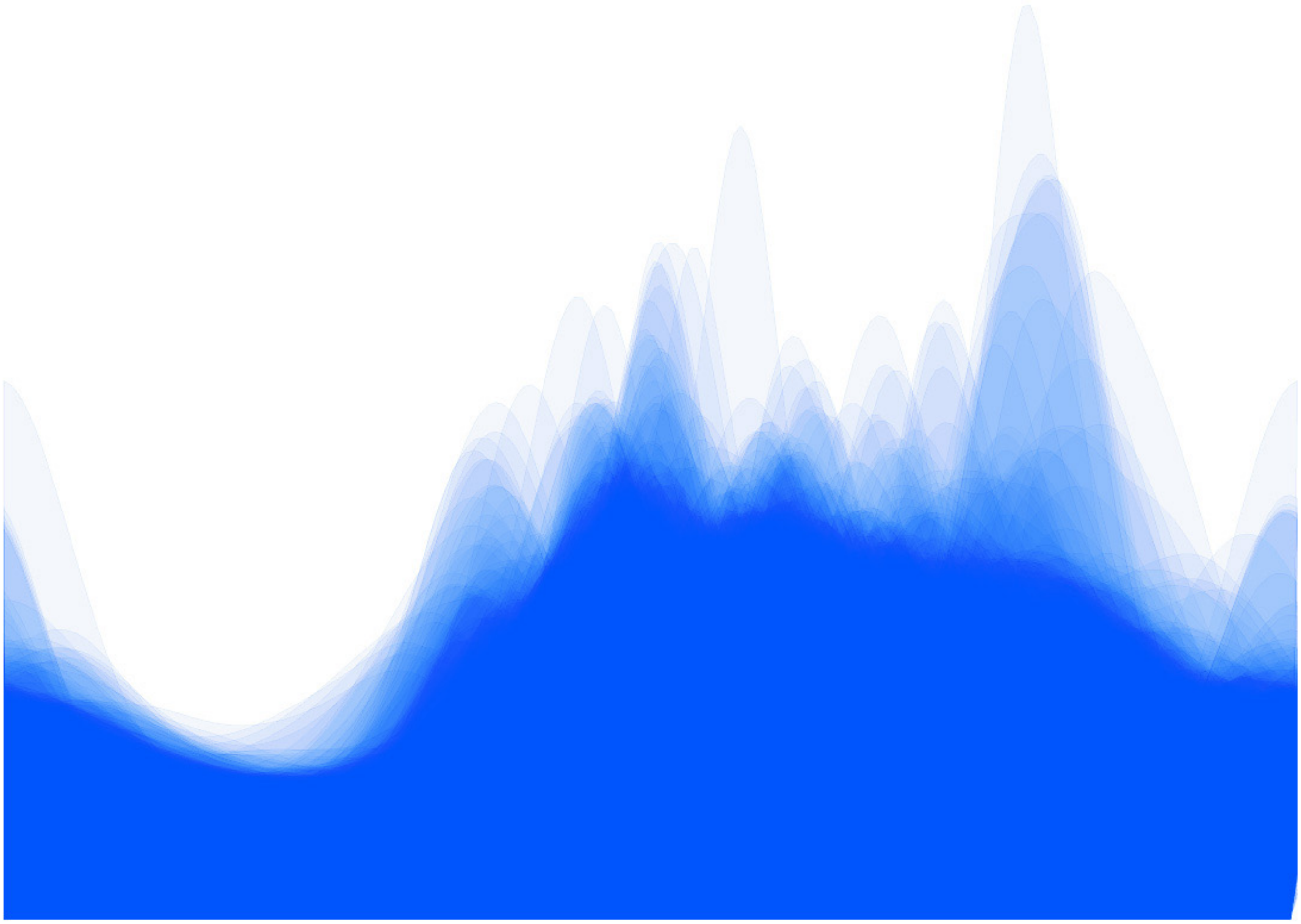

Fig. 4. “1539 Swiss Mountains” — Superpositon of all orientation profiles of the Swiss IAM Offline Database 3.0. We might be aware that few people have a left-slanted handwriting, but this visualization makes the phenomenon visible and measurable: there are few and only small peaks on the left-hand side of the image. It is also apparent that peaks on the right are narrower, hence slanting a handwriting reduces its roundness, making it more linear: a shear transform takes place.

IV. Properties of the orientation feature

While contour orientation is a concept easy enough to grasp, it has a number of less apparent properties with implications for the expertise work. They reveal why studies find orientation not the best performing biometric instrument [19].

Rotation — The feature is evidently not rotation invariant, meaning that the same document will have different measurement profiles depending on, for example, the skew of the paper in a scanner (Fig. 5.1–2). However the difference is only a translation of the profile, thus the bias can be corrected.

Organization — Contour orientation exhibits some unusual cases of shape invariance, all deriving from its low sensitivity to the spatial organization of pixels, due to the fact that, by definition, the measure is done locally. It is thus possible to have perceptually different shapes with the same orientation profile. Fig. 5.5 demonstrates scrambling invariance.

Localization — The various informations that can be read in the global orientation profile can’t be traced to specific locations in the written document. If there is, say slant variation in a particular line, we see it in the profile, but can’t localize the given line and even not know if the variation is concentrated in one line or spread over the entire document.

Convexity — For 180° shape rotations the profiles are identical, leading to shape confusion (Fig. 5.3–4).

Neighborhood — Fig. 5.6 shows that lines and circles in certain configurations can look the same to the orientation instrument: it is unaware about the neighborhood.

Additivity — Shapes contribute linearly to profiles, facilitating combinatorial pattern simulations from primitives.

V. Conclusions

I conclude by reminding that forensic and computational script features are usually not identical, that they need to be thoroughly explored to be safely used, and that public software, like Rex, introduced here, are excellent learning opportunities.

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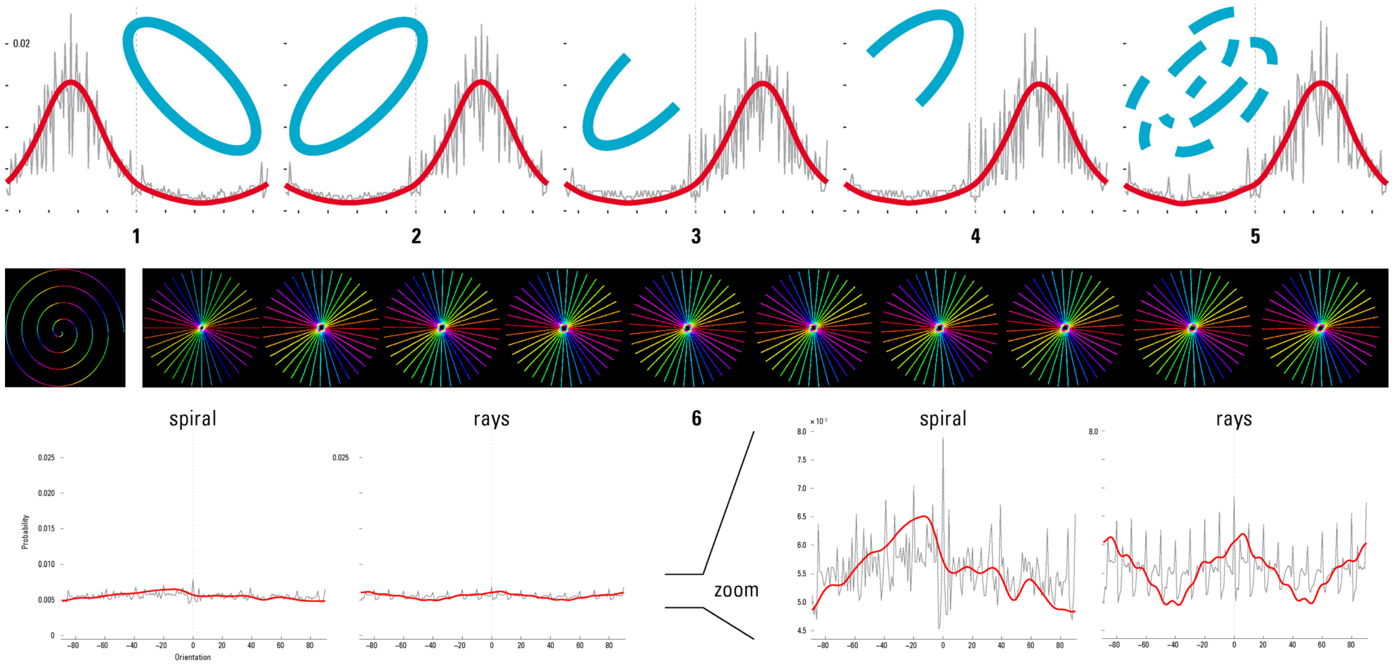

Fig. 5. Cases of confusion — (1, 2) A rotation of shapes (in blue) is equivalent of a translation of the orientation profile (in red). (3, 4) Rotation by 180° or (5) breaking up a shape doesn't affect the orientation profile beyond quantization errors. (6) The bitmaps row shows a spiral and 10 ray bundles, each bundle being rotated by 1° in respect to its neighbor, covering the entire angular sensitivity spectrum of the measurement instrument. Despite the perceptual pattern difference — one linear, the other curly — the orientation profiles are similar, especially when seen at the scale of the writing of Fig. 3 (the differences become visible when zooming in).

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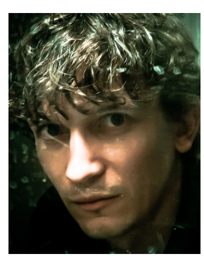

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