Computer-aided facial recognition of Cornelia de Lange syndrome: a comparison to the recognition by human experts

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With the advent of novel automatic face analysis techniques, our ability to analyze facial morphology from photographs has improved significantly.

Dysmorphic features of individuals with Cornelia de Lange syndrome (CdLS) can be relatively easily recognized in its classic form caused by NIPBL mutations; recognition in variants caused by SMC1A and SMC3 mutations is much more challenging. A survey conducted by Rohatgi et al. (Am J Med Genet A. 2010 152A:1641-53) measured the accuracy of facial recognition of CdLS by human experts. We tested a computer-based system for facial recognition of the CdLS patients using photographs from the study by Rohatgi et al.

To "train" the system, we used CdLS images from the Gorlin collection as positive samples, and images of other syndromes as negative samples. 130 anatomical points were automatically located on the face and multiple lengths, angles and ratios were computed for each face. These measurements were used, in combination with statistical methods, to evaluate existing dysmorphic features and to estimate the probability of CdLS. In addition, local image information was integrated in order to provide the appearance or "gestalt" description of the face. Automatically identified cranio-facial anatomical landmarks enabled this system to evaluate directly for every part of the face, or for the entire face, the probability of CdLS without relying on specific dysmorphic attributes.

Our system was able to distinguish between patients and controls 84.4% of the time. Individuals with NIPBL mutations were identified 100% of the time, mild or variant cases 67% of the time, and non-CdLS cases 89% of the time, while the average human experts' success rates were 87%, 54%, and 90%, respectively. The accuracy of the computer system places it at the 85th percentile of that of the surveyed experts. The computer-based system missed four cases: three cases with SMC1A mutations and one mild familial case with no mutation. In addition, one false positive case was a patient with a subtelomeric 9q deletion.

Overall, we have demonstrated that computer-based analysis can be successfully used in supporting experts for the correct recognition of patients with CdLS. The facial analysis system was able to overcome variation in pose, illumination, expression and age, and to produce results comparable with those of the human experts.

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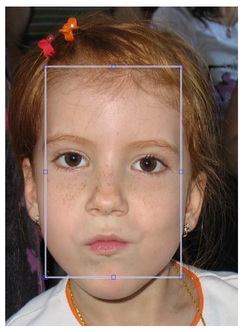
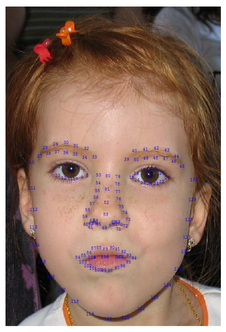
[1] Sarika Rohatgi, Dinah Clark, Antonie D. Kline, Laird G. Jackson, Juan Pie, Victoria Siu, Feliciano J. Ramos, Ian D. Krantz, Matthew A. Deardorff. 2010. Facial diagnosis of mild and variant CdLS: Insights from a dysmorphologist survey. American Journal of Medical Genetics Part A Volume 152A, Issue 7, pages 1641–1653.

Image Analysis Pipeline

1. Detect → **2. Localize facial feature points** → **3. Represent** → **4. Build models** → **5. Evaluate**



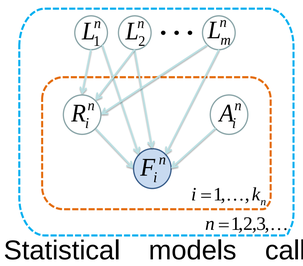
Using a probabilistic model the frame of the face is located



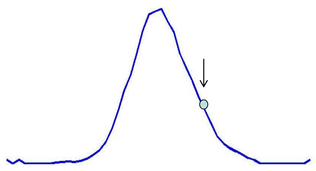
Within this frame 130 fiducial points are located using local image detections

Various local properties such as ratios of distances and local image descriptors are estimated

F - are the observed image data
R - are the output correlation variables
L - are the decision variables
A - models the noise



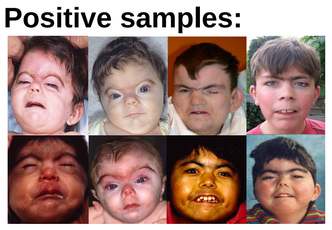
Statistical models called Bayesian networks are constructed to measure CdLS and dysmorphic feature probabilities



Every specific image is placed on the curves measuring its CdLS feature probability (“empirical p-value”)

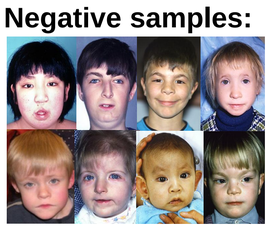
Training the System

Positive samples:



34 CdLS images from the Gorlin collection

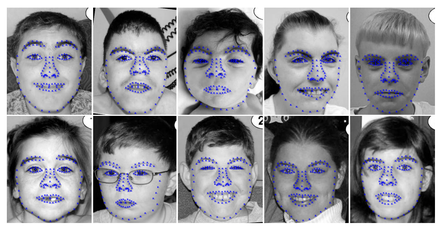
Negative samples:



97 images of other syndromes from the Gorlin collection

Testing the System

Automatic facial contours analysis is used to extract relative measurements



Features Analysis

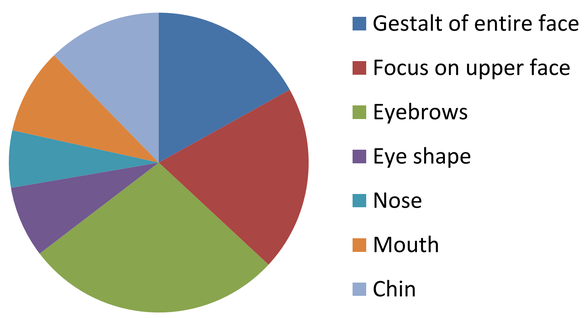
Statistical models are used to detect various dysmorphic features

	Dysmorphic Feature	N	corr	p-val
1	Palpebral Fissure, upslanted	4	0.35	0.09
2	Synophrys	21	0.41	0.02
3	Paranasal Tissue, fullness	1	0.35	0.05
4	Nasal tip, broad or nasal tip, wide	3	0.26	0.14
5	Nose, short	15	0.14	0.43
6	Nares, anteverted or nasal tip, upturned	14	0.40	0.03
7	Philtrum, short	6	0.44	0.01
8	Philtrum, long	16	0.46	0.01
9	Vermilion, upper lip, thin	22	0.54	0.00
10	Micrognathia or chin, short	11	0.35	0.05
11	Face, round	8	0.38	0.05

Gestalt Analysis

“Gestalt" description of the face is used to evaluate the entire images at once, without relying on dysmorphic features

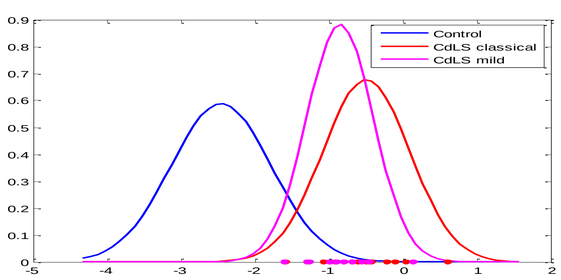
A heat map displaying distinguishable regions of CdLS patients



Relative contribution of each facial region

Results

	System Detection %	Human experts Detection %
NIPBL	100	87
Mild or variant cases	67	54
Non - CdLS	89	90
Average	85.3	77



Curves that were fitted to the detection scores obtained for three populations: classical CdLS, mild CdLS, and non-CdLS control

False negative images

- The obtained accuracy of the computer system places it at the 85th percentile of that of the surveyed experts.
- The computer-based system had only four false negatives, in cases which were challenging for human experts as well: three cases with SMC1A mutations and one mild familial case with no mutation. In addition, one false positive case was a patient with a subtelomeric 9q deletion.

Practical implications for clinical and research use: Computer-based analysis can be successfully used in supporting experts for the correct recognition of patients with CdLS