Classification of brain tumours by CT-image Walsh spectra

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Summary. Besides clinical and anamnestic data, image information from CT-image data in the tumour border was used for classification of brain tumours. If the image regions are properly selected a classification rate of 85% is obtained with a hierarchic classifier, although our study is based on only 139 patients.

Key words: Brain tumours – Pattern recognition – Computed tomography

Direct decision from digital image information (computer vision) is a complex task. Therefore the evaluation of images is often based on visually assessed features and on data measured with operator interaction by standard measuring software.

We devised a system for the differentiation of the 7 most common supratentorial brain tumors. It uses pixel data from windows located in the tumour border, where tumour specific structures are expected. An alternative set of features, consisting of patient data and image features such as distances and densities measured with standard CT image evaluation software was also tested. First both feature sets were evaluated separately, then they were combined, because both obviously contained complementary information (Fig. 1). For classification and data analysis linear discriminant analysis was used.

The major problem in using pixel data for classification is an effective algorithm, that reduces the large amount of image data, but maintains useful information. For this the two-dimensional Walsh-transform was used. Walsh- and Fourier-transforms are able to derive stable statistical features of large-area patterns of "noisy" appearance, while there is evidence that human vision (in analogy to the detection of large-area bar patterns) analyses only small areas and is less efficient [4]. We also had CT's of 14 histologically proven astrocytomas evaluated by 7 experienced neurologists. Less than 60% of them were classified correctly and only 26% with the correct grade.
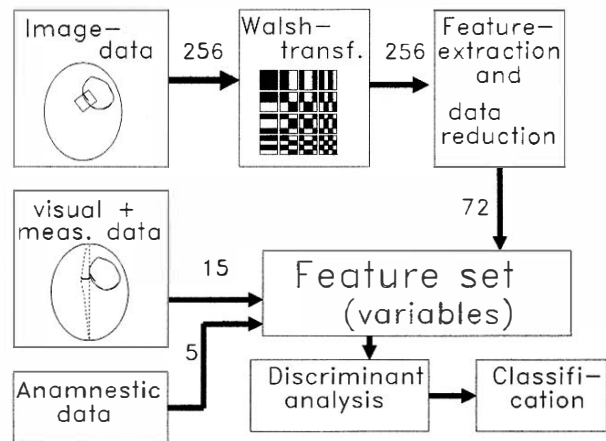

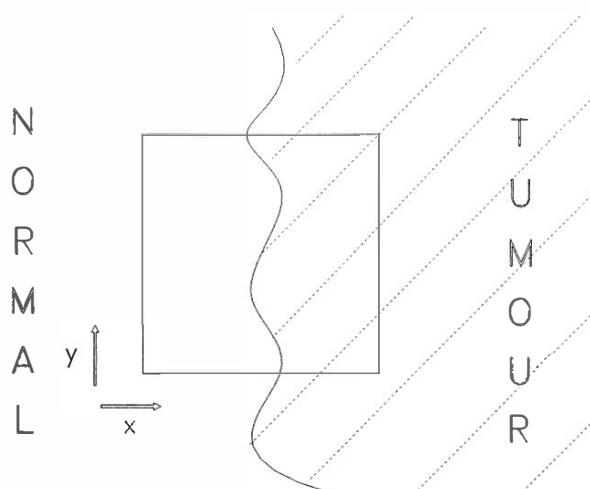**Fig. 1.** Information used for classification

Fig. 2. Standard position of the window for Walsh-transform centered at the tumour border, where the Walsh-coefficient $C(0,1)$ is a maximum. The tumour is at the right-hand side
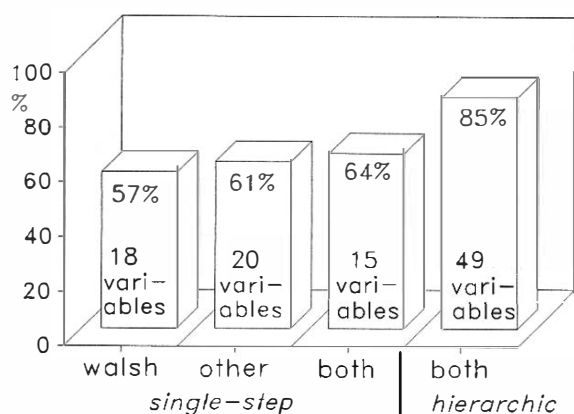
Fig. 3. Rates of true classifications and the optimum number of features selected for decision by discriminant analysis for the two sets of features, their combination and for hierarchic classification
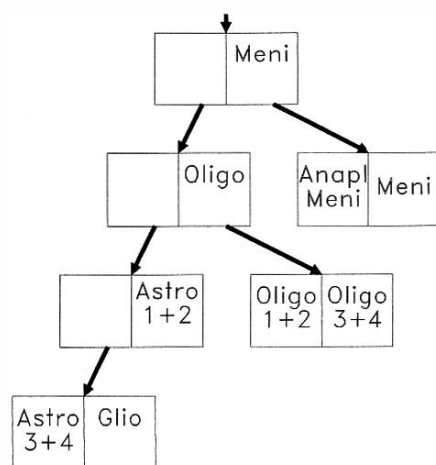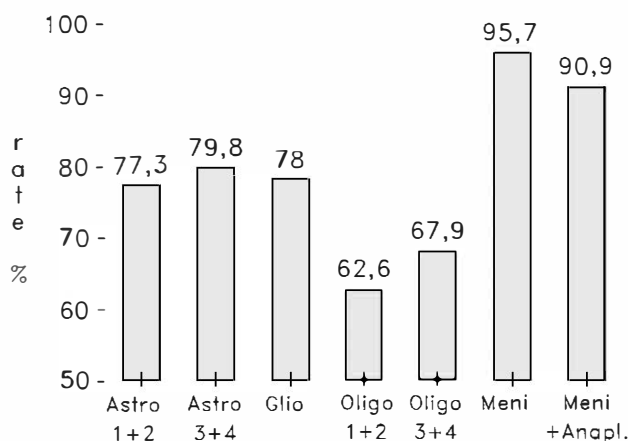

Fig. 4. Structure of hierarchic classifier

Fig. 5. Rates of correct classifications for the hierarchic system

Method and technical parameters

Our study is based on a relatively small sample of 248 scans from 139 patients with histologically proven diagnosis (Table 1). Main limiting factor for the number of patients is the availability of images in digital form.

Table 1. Composition of the test sample

Class		Patients	Scans
1 Astrocytoma	grade 1 + 2	31	51
2 Astrocytoma	grade 3 + 4	23	39
3 Glioblastoma		36	68
4 Oligodendroglioma	grade 1 + 2	10	14
5 Oligodendroglioma	grade 3 + 4	6	11
8 Meningeoma	non-anaplastic	28	54
9 Meningeoma	anaplastic	5	11
Total		139	248

Table 2. The alternative set of features

Measured image features	Visually assessed image features
1. Average tumour density	12. Tumour density (hypo-/ iso-/hyperdens)
2. Average tumour density with contrast medium	13. Calcifications
3. Standard dev. of density in the tumour	14. Localisation
	15. Ventricle compression
4. Standard dev. of density with contrast medium	16. Hydrocephalus
	17. Spread across center line
5. Displacement of center line	18. Size of oedema
6. Ratio of displacement of center line to diameter of tumour	19. Pattern of contrast medium (qualitative description)
	20. Delineation of tumour with contrast medium.
Anamnestic features	
7. Age	
8. Sex	
9. Duration of anamnesis	
10. first significant symptom	
11. Progression	

CT-images were taken with a Siemens Somatom, at 125 kV, 230 mAs, 8 mm slice thickness, and a measuring time of 10 s per slice. Generally, scans were made with and without contrast medium for each patient (Visotrast 290; 1 ml per kilogram body weight).

From each scan we selected up to 4 windows of 16 × 16 pixels, centered at the tumour border.

From their Walsh-spectrum a shift-invariant set of features with 72 coefficients is derived and averaged from 4 windows per scan. The alternative set of data is formed by 20 features (Table 2).

Results and conclusions

Both feature sets were investigated with discriminant analysis. The prospective rate of true classifications is estimated with the so-called Pi-method. 1/10 of the available cases is evaluated by a classifier derived from the rest of the cases, and this process is repeated 10 times [1].

The discriminant analysis program selects a subset of variables, for which the classification rate becomes a maximum (Fig. 3). For the combined set of features the number of selected parameters was less than for both sets alone. This indicates, that both feature sets either contain redundant information, or that linear single-step discrimination does not use the information efficiently.

Therefore we calculated an hierarchic classifier for the combined set of data (Fig. 4). The calculation of 6 binary classifiers is laborious, but yields a much better rate of estimated true classifications – 85%. Different features are selected at each stage, and the total number of used features is much higher (49 of 92) than in the single-step procedure (15 of 92).

Figure 5 shows, that Meningeomas are well detected, while the separation of oligodendrogliomas is more difficult. The rate of correct classifications therefore varies with the composition of the investigated sample of patients. For a distribution of the tumour types derived from the literature it is 85%, for our sample 82% were calculated. Despite the small number of patients this result is comparable to that of other authors [2, 3], although a practically applicable system would have to cope with more than only 7 alternative diagnoses [3].

While the statistical calculations are time consuming, the Walsh-transforms and the final decision are accomplished within less than 10 s on the PDP-11 computer of the Evaluskop. The results justify the development of an improved program with pull-down menus, operated with the pen of the systems console.

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