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PATTERN RECOGNITION: INVARIANTS IN 3D

Application to tag the number of jets in e^+e^- events with a neural network

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Application to tag the number of jets in e^+e^- events with a neural network

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*Abstract.*We define invariants for 3D objects with a spherical symmetry.These new invariants are used to tag the number of jets in e^+e^- events.

1-INTRODUCTION

In pattern recognition,some 2D invariants were used to solve some rotation invariant problems[1].

But in e^+e^- events,the jets have a spherical 3D symmetry.The usual method to tag the number of jets is the clusterization using classical algorithms .An attempt to use a neural network was done by Jousset[3] using an Hopfield network.

In this paper we propose a set of 3D invariants which can be used to tag the number of jets in e^+e^- events.

2-INVARIANTS IN 3D ROTATION

The angles used in 3D rotation are ϑ and ϕ;we know the spherical orthogonal functions $Y_{lm}(\vartheta,\phi)$[3].

A function $f(\vartheta,\phi)$ can be developped using $Y_{lm}(\vartheta,\phi)$ functions.

$$f(\vartheta,\phi)=\sum_l\sum_m \alpha_{lm}\ Y^*_{lm}(\vartheta,\phi)\ .$$

If the axis are rotated with α,β,γ Euler angles the rotation angles become ϑ' and ϕ'. The new development is

$$f(\vartheta,\phi)=\sum_l\sum_m \alpha'_{lm}\ Y^*_{lm}(\vartheta',\phi').$$

But we know a relation between ϑ,ϕ and ϑ',ϕ' angles[3].

$$Y_{lm}(\vartheta',\phi')=\sum_{m'} \mathcal{D}^l_{m'm}(\alpha,\beta,\gamma)\ Y_{lm'}(\vartheta,\phi),$$

where the $\mathcal{D}$ functions are the usual orthogonal functions with Euler angles.

The relation between α' and α is then:

$$\alpha'_{lm}=\sum_{m''} \mathcal{D}^l_{m''m}(\alpha,\beta,\gamma)\ \alpha_{lm''}.$$

Using the orthogonal relation[3]

$$\sum_m \mathcal{D}^{l*}_{m''m}(\alpha,\beta,\gamma)\ \mathcal{D}^l_{m'm}(\alpha,\beta,\gamma)=\delta_{m'm''},$$

we see that the combination of the α values

$$\beta(l)=\sum_m \alpha_{lm}\ \alpha^*_{lm}$$

is invariant for a 3D rotation.

The α parameters are computed with the relation

$$\alpha_{lm}=\int f(\vartheta,\phi)\ Y_{lm}(\vartheta,\phi)\ d\Omega,$$

using the associated Legendre functions $P^l_m(\cos\vartheta)$ we write for α

$$\alpha_{lm}=(-)^m\left[\frac{(2l+1)(l-m)!}{4\pi\ (l+m)!}\right]\int P^l_m(\cos\vartheta)e^{im\phi}\ f(\vartheta,\phi)\ d\Omega\ .$$

The contributions to $\beta(l)$ of opposite m values are identical.

3-SIMULATION OF 3 CLASSES

We have simulated 3 classes of different simple objects with dots on a sphere.

Classe 1:2 dots at $\vartheta_1=0,\phi_1=0$ and $\vartheta_2=\pi,\phi_2=0$.

Classe 2:3 dots at $\vartheta_1=0,\phi_1=0$; $\vartheta_2=2\pi/3,\phi_2=0$ and $\vartheta_3=2\pi/3,\phi_3=\pi$.

Classe 3:4 dots at $\vartheta_1=0,\phi_1=0$; $\vartheta_2=\pi,\phi_2=0$;

$$\vartheta_3=\pi/2,\phi_3=0;\vartheta_4=\pi/2,\phi_4=\pi.$$

We have verified the invariance of $\beta(l)$ values with random Euler angles.When we introduice a noise in the positions of the dots,the $\beta(0)$ value is discriminating for the classes,because

$$\beta(0)=\frac{1}{4\pi}(\sum_{dots} P_0^0)^2,$$

this value is independant of the noise.

4-TAGGING THE NUMBER OF JETS IN e^+e^- EVENTS

We give preliminary results on a method to tag the number of jets in e^+e^- events without external parameter.

In LEP detectors,the tracks of an hadronic event are given by the momentum p_i,the ϑ_i and ϕ_i angular positions.

We choose as f function the relation:

$$f(\vartheta,\phi)=\sum_{i\ tracks} p_i\ \delta(\cos\vartheta-\cos\vartheta_i)\delta(\phi-\phi_i)$$

then

$$\alpha_{lm}=(-)^m\left[\frac{(2l+1)(l-m)!}{4\pi\ (l+m)!}\right]\sum_{i\ tracks} p_i P_m^l(\cos\vartheta_i)e^{im\phi_i}.$$

We have generated 2,3 and n jets events with the ALEPH Monte-Carlo simulation.The jets were clustered with the JADE algorithm using ycut=(6/E)**2.

We have trained a (15,30,3)MLP network with 15 β parameters and 5000 events in each class.

The test was done with a sample with 26654 2 jets events,24122 3 jets events and 5154 n jets events.

We consider as true jets the jets generated by the JADE algorithm.The classification given by the MLP network gives:

The purity of a 2 jets sample is 87.4%,
The purity of a 3 jets sample is 81.7%,
The purity of a n jets sample is 50.9%.

The percentage of true 2 jets tagged as 2 jets is 88.7%,
The percentage of true 3 jets tagged as 3 jets is 70.9%,
The percentage of true n jets tagged as n jets is 78.8%.

5-CONCLUSION

We have computed a new family of 3D invariants.We have given some preliminary results to tag the number of jets in e^+e^- events.

The tagging of jets can be improved,because we have supposed that the JADE algorithm is perfect;it is also possible to use with the invariants some shape variables as the aplanarity which describes the 3 jets events.

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