MORPHOLOGICAL CLASSIFICATION OF GALAXIES WITH ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

There is an obvious need for automated classification of galaxies, as the number of observed galaxies increases very fast. We examine one approach to this problem, utilising Artificial Neural Networks (ANNs). We quote results from a recent study which show that ANNs can classsify galaxies morphologically as well as humans can. The work is presented as an example of what can be accomplished, classification-wise, in an automated manner: such tasks may have wide application in the large amounts of data that are generated by the GAIA astrometry satellite, or its associated auxiliary observations.

Keywords: galaxies: morphology, automated processing

1. INTRODUCTION

Morphological classification of galaxies is traditionally done by visual inspection of photographic plates. This is a task requiring skill and experience. It took years to compile catalogues of galaxies containing of the order of 10^4 entries. However, the number of galaxy images available today or in the near future is at least two orders of magnitude larger.

Clearly, such quantities of images cannot be classified by humans. There is an obvious need for automated methods that will put the knowledge and experience of the human experts to use and produce very large samples of automatically classified galaxies.

Here we consider an automated classifier whose task is to replicate the work of expert human observers. Our chosen classification tool is Artificial Neural Netrworks (ANN), which proved to be well suited to this task in a pilot study (Storrie-Lombardi et al. 1992). This is by no means the only possible choice, but there are certain attractive statistical features to the ANN approach, which are discussed elsewhere (e.g. Lahav et al. 1995).

2. CHOICES OF PARAMETERS FOR TRAINING THE ANN

For a full description of the galaxy sample see Naim et al. (1995). We used a diameter-limited ($D > 1.2$ arcmin) sample of 835 galaxies taken from the APM Equatorial Catalogue of Galaxies (Raychaudhury et el., in preparation). The plates were obtained with the 48-inch UK Schmidt telescope at Siding Spring, Australia, and digitised by the Automated Plate Measuring (APM) machine in Cambridge.

The images were then classified by six independent experts (R. Buta, H. Corwin, G. de Vaucouleurs, A. Dressler, J. Huchra and S. van den Bergh), as described in Naim et al. (1995). Classifications were performed on or converted to the Revised Hubble System (de Vaucouleurs 1959).

The digitised images contain of order 10^4 picture elements. Our first task was to compress the information in a full picture to relatively few morphological parameters. Using software we wrote for this purpose we first reduced the images, then sampled each of them on 30 ellipses, all with the same ellipticity and position angle as the entire image.

This sampling method provided us with a standard set of measurements for all galaxies, regardless of angular size, tilt and position angle, containing roughly 6400 points for each galaxy. We then looked at ways of extracting few significant features from this standard set.

In Fig. 1 we show the images of four galaxies from our sample. These represent four distinct cases we had to deal with: the two on the left are early-type galaxies, and the two on the right are spirals. The top two are seen face on, allowing many details to be seen, while the bottom two are seen edge-on. Fig. 2 shows the plots of the sampled ellipses of these galaxies (innermost ellipse is bottom, outermost is top), and Fig. 3 shows their light profiles (average ellipse intensity versus ellipse number).

Normally the central bulges of such bright galaxies are over-exposed on survey plates, and this accounts for flat regions in the light profiles. Even so, one can see that the flat region is much larger for the early type galaxies than for the spirals. The outer half of the light profiles is much flatter in the spirals. The ellipses themselves are of no use for the edge-on images, showing more noise than actual structure. For the face-on galaxies, however, they show a clear trend with type: there is little long–range structure in the early–type galaxy, whereas the arms of the spiral clearly stand out.

Using our software to extract such features, we ended up with 24 parameters, which included ellipticity, surface brightness, light profile parameters, light concentration indices, arms to disk ratios and arms parameters.

3. RESULTS

We trained the ANN on these features and then tested it on fresh data. We found that the ANN's rms dispersion relative to the mean types of the experts was 1.8 types (on the 16 type scale of the Revised Hubble System). For comparison, rms dispersions between pairs of experts range between 1.3 and 2.3 types, and the overall rms dispersion between all pairs of experts was also 1.8 types. This suggests that our choice of input parameters for the ANN gave a good description of morphological features that are important for classification. In Fig. 4 the ANN classification is plotted against the mean expert type for each galaxy. Error bars denote the internal dispersion in the ANN classifications over 10 runs.

4. FUTURE WORK

ANNs represent a general flexible tool which is readily applicable to other astronomical problems. Large quantities of data are a blessing for this method, not a limitation. It was demonstrated here that ANNs can be trained to replicate the work of human experts. The application of this particular ANN to the full APM Equatorial Catalogue of Galaxies is under way and an automatically classified catalogue is expected soon. Application to the large quantities of data to be generated by the GAIA astrometry satellite, or during the course of acquiring the proposed auxiliary observations—spectral types, radial velocities, etc, should be considered.

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Figure 1. Four galaxies from the sample, demonstrating face-on (top) versus edge-on (bottom), and early types (left) versus late types (right).

Figure 2. Full plots of the sampled elliptical annuli for the four galaxies. Innermost annulus is bottom.

Figure 3. The light profiles of the same four galaxies as above.

Figure 4. ANN classifications versus corrected expert mean types.