6.1 Direct warping

Direct warping is taking pixels from the original image and trying to throw them onto an output grid that represents the output, warped image. The main drawbacks of this method are the following:

• The output grid needs to keep track of how many pixels have landed in each section, to be able to correctly normalise the output value. This can be a nightmare to implement efficiently.

• There might be some deformations that will leave holes in the output grid. If for some reason the output grid is denser than the input one, the risk is to have so many holes that the output image does not make sense. To avoid that, one can oversample the input image to make it of similar density to the output image, but then the memory consumption is growing by the same amount. For large images, this is not a solution.

• If there is no possible assumption about the way input pixels are thrown onto the output grid, it is impossible to guarantee that the output pixels will be written sequentially. This makes it hard to optimise I/O accesses, and slow down to the extreme the processing of large images, even for simple transformations.

Direct warping is usually considered too dangerous to implement because of potential holes in the resulting image, and because of speed concerns. Image processing is a domain that needs optimisation no matter what the underlying hardware is. A pixel operation that needs a millisecond to run will have you wait more than 17 minutes in front of your screen if you have to process an ISAAC image, or 71 hours if you are processing a VST image.

The best optimisations in the image processing domain usually reach about a hundred clock ticks to achieve. On a modern PC running at 500 MHz, considering that the image processing software is alone running on the CPU, you will still have to wait 2 seconds per ISAAC image and 54 seconds per VST image. And that is for CPU time only, a bad I/O optimisation forcing the software to go to the disk regularly would multiply these figures by a factor thousand at least.

Direct warping is at the heart of the “drizzle” method implemented for HST image reconstruction. Drizzle makes use of a convolved linear interpolation scheme that brings more artefacts than simple linear interpolation. If big images are involved, or tricky (non-linear) deformations, or bad pixels, or large amounts of noise, this method is likely to create false information in the output image. The same is valid for almost all astronomical image processing packages: most of them use a linear reconstruction scheme for default interpolation method.

6.2 Reverse warping

Reverse warping is considering first the output grid as the image to obtain. The size of the grid can be determined by observing the transformation function between deformed and corrected image. For example: if the transformation is a scaling by a factor 2, the output grid will simply be 2 times bigger than the input image, containing 4 times more pixels.

The method is looping over all output pixels, computes by means of a reverse transformation which are the contributing pixels from the original image, applies an interpolation scheme as described above, and writes the result to the output image.

This has several advantages:

• The output grid cannot have holes, since all output pixels are reviewed.

• The output grid will be sequentially visited, allowing to cache the results to avoid going to disk too often.

• Because of the sequential nature of the operation (no matter what the transformation is), it is relatively easy to optimise the pixel accesses in a generic way, helping to achieve optimised but also portable code (i.e. a software that is fast no matter what the underlying hardware and OS are).

• The implementation is relatively easy to write and read, allowing a better maintenance.

If you implement a generic interpolation kernel scheme that allows the user to select the kernel to use, reverse warping becomes an easy task to implement and allows for large gains in speed in the resulting software.

This is the method implemented in the warping tool offered in the eclipse package (http://www.eso.org/eclipse/), and at the heart of the ISAAC imaging pipeline. The default kernel is the hyperbolic tangent mentioned above.

7. Conclusions

Astronomical image resampling is a complex operation that involves recent theorems in the field of signal and image processing, together with information theory knowledge to be carried out properly.

No information was given about the various methods that can be used to identify the transformation between two images. This is a complete research domain in itself, refer to the appropriate literature for more information. The emphasis in this article has been put on the various methods that can be used to interpolate pixels in an image, and efficient ways to implement them.

Usual interpolation schemes are shown to be insufficient in the usual noisy astronomical images, adding aliasing and other various artefacts into the images. There are more precise kernels such as the hyperbolic tangent, that are more suitable for astronomical image handling. It might also be a good idea to look into pre-processing filters to apply to the input images before trying to re-sample them.

If you care about the quality of your images whenever you have to apply resampling operations, you should query your favourite data reduction package to check out what kind of interpolation scheme is actually implemented behind the scenes. Choosing linear interpolation is rarely a good solution in the case of noisy images.

OTHER ASTRONOMICAL NEWS

Portugal to Accede to ESO *(from ESO Press Release 15/00, 27 June 2000)*

The Republic of Portugal will become the ninth member state of the European Southern Observatory.

On Tuesday, June 27, during a ceremony at the ESO Headquarters in Garching (Germany), a corresponding Agreement was signed by the Portuguese Minister of Science and Technology, José Mariano Gago, and the ESO Director General, Catherine Cesarsky, in the presence of other high officials from Portugal and the ESO member states .

Following subsequent ratification by the Portuguese Parliament of the ESO Convention and the associated protocols, it is foreseen that Portugal will formally join this organisation on January 1, 2001.

Signing of the Portugal-ESO Agreement on June 27, 2000, at the ESO Headquarters in Garching. At the table, the ESO Director General, Catherine Cesarsky, and the Portuguese Minister of Science and Technology, José Mariano Gago. Photographer: H.-H. Heyer

Uniting European Astronomy

In his speech, the Portuguese Minister of Science and Technology, José Mariano Gago, stated that "the accession of Portugal to ESO is the result of a joint effort by ESO and Portugal during the last ten years. It was made possible by the rapid Portuguese scientific development and by the growth and internationalisation of its scientific community."

He continued: "Portugal is fully committed to European scientific and technological de velopment. We will devote our best efforts to the success of ESO".

Catherine Cesarsky, ESO Director General since 1999, warmly welcomed the Portuguese intention to join ESO. "With the accession of their country to ESO, Portuguese astronomers will have great opportunities for working on research programmes at the frontiers of modern astrophysics."

"This is indeed a good time to join ESO", she added. "The four 8.2-m VLT Unit Telescopes with their many first-class instruments are nearly ready, and the VLT Interferometer will soon follow. With a decision about the intercontinental millimetre-band ALMA project expected next year and the first concept studies for gigantic optical/infrared telescopes like OWL now well under way at ESO, there is certainly no lack of perspectives, also for coming generations of European astronomers!"

Portuguese Astronomy: a Decade of Progress

The beginnings of the collaboration between Portugal and ESO, now culminating in the imminent accession of that country to the European research or ganisation, were almost exactly ten years ago.

On July 10, 1990, the Republic of Portugal and ESO signed a Co-operation Agreement, aimed at full Portuguese membership of the ESO organisation within the next decade. During the interim period, Portuguese astronomers were granted access to ESO facilities while the Portuguese government would provide support towards the development of astronomy and the associated infrastructure in this country.

A joint Portuguese/ESO Advisory Body was set up to monitor the development of Portuguese astronomy and its interaction with ESO. Over the years, an increasing number of measures to strengthen the Portuguese research infrastructure within astrophysics and related fields were proposed and funded. More and more, mostly young Portuguese astronomers began to make use of ESO's facilities at the La Silla observatory and recently, of the Very Large Telescope (VLT) at Paranal.

Now, ten years later, the Portuguese astronomical community is the youngest in Europe with more than 90% of its PhD's awarded during the last eight years. As expected, the provisional access to ESO telescopes – especially the Very Large Telescope (VLT) with its suite of state-of-the-art instruments for observations at wavelengths ranging from the UV to the mid-infrared – has proven to be a great incentive to the Portuguese scientists.

As a clear demonstration of these positive developments, a very successful Workshop entitled "Portugal – ESO – VLT" was held in Lisbon on April 17–18, 2000. It was primarily directed towards young Portuguese scientists and served to inform them about the ESO Very Large Telescope (VLT) and the steadily evolving, exciting research possibilities with this world-class facility.

Scientific Preprints

(March – June 2000)

1364. E. Pancino et al.: New Evidence for the Complex Structure of the Red Giant Branch in ω Centauri. *ApJ*.
1365. S. Bagnulo et al.: Modelling of Magnetic Fields of CP Stars. III. The combined interpretation of five different magnetic observables: theory, and application to β Coronae Borealis. *A&A*.
1366. M. Chadid: Irregularities in Atmospheric Pulsations of RR Lyrae Stars. *A&A*.
1367. T. Broadhurst et al.: Detecting the Gravitational Redshift of Cluster Gas. *ApJL*, and
A Spectroscopic Redshift for the CL0024+16 Multiple Arc System: Implications for the Central Mass Distribution. *ApJL*.
1368. R. Falomo and M.-H. Ulrich: Optical Imaging and Spectroscopy of BL Lac Objects. *A&A*.
1369. O.R. Hainaut et al.: Physical Properties of TNO 1996 TO_{66}. Lightcurves and Possible Cometary Activity. A&A.
1370. B. Leibundgut: Type Ia Supernovae. *The Astronomy and Astrophysics Review*.
1371. Contributions of the ESO Data Management and Operations Division to the SPIE Conference "Astronomical Telescopes and Instrumentation 2000". Conference 4010.
D.R. Silva et al.: VLT Science Operations: The First Year.
P. Quinn et al.: The ESO Data-Flow System in Operations: Closing the Data Loop.
A.M. Chavan et al.: A Front-end System for the VLT's Data-Flow System.
P. Amico and R. Hanuschik: Operations of the Quality Control Group: Experience from FORS1 and ISAAC at VLT Antu.
P. Ballester et al.: Quality Control System for the Very Large Telescope.
1372. S. Hubrig et al.: Magnetic Ap Stars in the H-R Diagram. *ApJ*.
1373. J.U. Fynbo et al.: The Sources of Extended Continuum Emission Towards Q0151+048A: the Host Galaxy and the Damped Lyα Absorber. *A&A*.
1374. S. Stefl et al.: The Circumstellar Structure of the Be Shell Star φ Per. *A&A*.
1375. M. Kissler-Patig: Extragalactic Globular Cluster Systems. A New Perspective on Galaxy Formation and Evolution. Reviews in Modern Astronomy, vol 13.
1376. E. Scannapieco et al.: The Influence of Galactic Outflows on the Formation of Nearby Galaxies. *ApJ*.
1377. J.D. Landstreet et al.: Magnetic Models of Slowly Rotating Magnetic Ap Stars: Aligned Magnetic and Rotation Axes. *A&A*.
1378. S. Cristiani et al.: The First VLT FORS1 Spectra of Lyman-Break Candidates in the HDF-S and AXAF Deep Field. *A&A*.
1379. D. Hutsemékers and H. Lamy: The Optical Polarization of Radio-Loud and Radio-Intermediate Broad Absorption Line Quasi-Stellar Objects. *A&A*.
1380. C. Stehlé et al.: Polarised Hydrogen Line Shapes in a Magnetised Plasma. The Lyman α Line.