

Review of Subregion Selection and Analysis in Radio Astronomy

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ABSTRACT

There are currently a wide variety of astronomy tools available to users who want to visualise and analyse 3D data cubes. While the features of the tools have evolved, many of them still focus on the display and analysis of 2D slices and do not take advantage of the third dimension, forcing users to resort to manually analysing other shapes, a tedious process.

In this paper we review analysis and selection methods along with the features of current tools and how they align the needs of users.

CCS Concepts

•Applied computing → Astronomy; •Human-centered computing → *Human computer interaction (HCI)*; Visualization;

Keywords

Literature Review, 3D Selection, Astronomy Software

1. INTRODUCTION

HI Radio Astronomy data, while sometimes differing in specific implementation, is fundamentally encoded as a 3 dimensional array of floats, with each point being the flux (amount of energy transferred from a point) at a given right ascension, declination (which define a location on the celestial sphere) and frequency.[10]

While methods for automatically detecting galaxies in data cubes have improved over the years, they are still very susceptible to low signal-to-noise ratios[15], forcing astronomers to resort to direct human inspection. Once a potential galaxy is discovered much of the analysis that is done on the candidate could be automated, as it is for the most part simple algebra such as the computation of the mean, standard deviation and other statistics.[4]

As shown in our review of current tools in Section 4, most of the software displays the data in slices making analysis

non-trivial: selection is limited to a 2D square (sometimes rectangle) and analysis to average flux. None consider the wide variety of shapes celestial objects come in or leverage the third dimension in the data. All include a lot of noise in the analysis.

Useful information about the galaxy can be extracted fairly easily from a 3D subregion in the form of a user defined Elliptic Cylinder with a height equal to the range of frequencies the galaxy is emitting on. In Section 2 we list some methods for 3D selection and how we evaluate them. Section 3 reviews the type of information analysis can reveal. Section 4 has an enumeration of the current tools and what functionality they offer.

2. SELECTION OF SUBREGIONS

2.1 Methods

The issue of selecting 3D subregions is one that presents itself in many disciplines, for example selecting objects in virtual reality[8], specifying bones in medical imaging[2] or, as is our case, specifying volumes of interest for analysis of astronomical data[16]

. We present a few of the methods that are used, with a focus on user-guided selection.

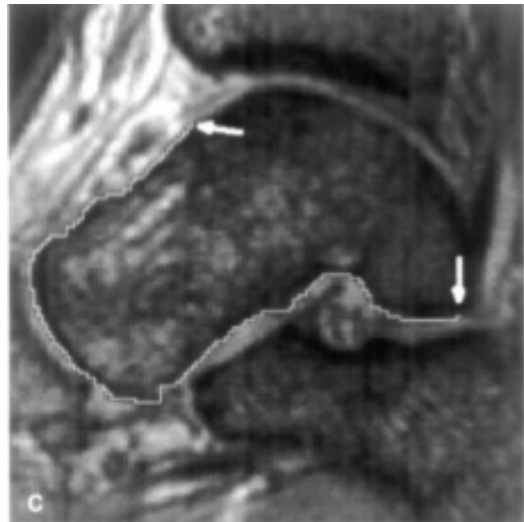


Figure 1: An example of the border detected by live-wire. The arrows show the two points the user selected, the white line the calculated path.[2]

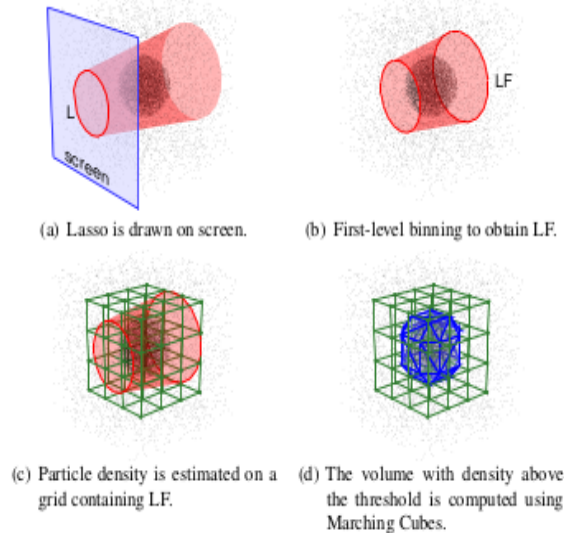


Figure 2: Visualization of CloudLasso algorithm.[16]

2.1.1 Live-wire

Developed for medical imaging, live-wire takes advantage of a user’s ability to recognise the boundaries of objects by combining it with computer algorithms adept at following the boundaries[2]. This allows for rapid and accurate delineation of object in relatively short times though it does require users to assist the computer slice by slice (Figure 1).

2.1.2 CylinderSelection

Lucas and Bowman[8] created CylinderSelection to select objects in virtual environments. The user draws a lasso around the desired objects and a conical shape is extended into the space as seen from the current point of view. While this is useful in virtual environments, a cylindrical shape may be more appropriate for astronomical data.

2.1.3 CloudLasso

Designed specifically for astronomy, CloudLasso is an extension of the CylinderSelection above, specifically for selecting subregions in cloud point visualization.[16] It takes the area defined by the CylinderSelection and a user defined density threshold and using the Marching Cubes algorithm[7], constructs a triangle mesh containing a volume with density above that threshold(Figure 2).

2.2 Evaluation

In our review of 3D selection techniques we found that user or expert testing was performed and further research did not reveal any heuristics that could be used. Due to the fact that we expect astronomy software to be used mainly by experts in the field, expert testing would be the most appropriate way to evaluate any new features.

3. DATA ANALYSIS

Hassan et al.[4] list three statistics/visualizations that astronomers are interested in when looking at data: mean and standard deviation, median and a histogram of the values.

Mean, median and standard deviation give users a high level overview of their data while the histogram of values can be useful in distinguishing signal and noise (through fitting the resulting curve to a gaussian).

Another visualization that would be of interest to users is a spectrum generated by taking the summation of the flux in the area on a frequency by frequency basis and displaying that. In the case of rotating galaxies this would result in very distinct double horned profiles that can be used to estimate the rotational velocity of the galaxy.

4. EXISTING TOOLS

4.1 Astronomy specific

Below we present a brief description of some tools that are either widely used or new with a focus on what they have to offer in terms of analysis of subregions. Table 1 has a summary that highlights the lack of 3D selection features in current tools.

4.1.1 CyberSKA Viewer

Kiddle et al.[6] developed CyberSKA as an online tool that provides the infrastructure and functionality to meet the needs of data-intensive endeavours such as the Square Kilometer Array.

Users interact with data through an online portal avoiding the need for the user’s computer to store and process the data. While it does allow for collaboration and sharing of specific views, it is limited to 2D interactions and even then only rectangles can be selected.

4.1.2 GIPSY

The Groningen Image Processing System (GIPSY) aims to offer the tools to analyse large amounts of 3D data while being able to connect with existing systems[14].

It is a well-established package, with a wide array of functionality but limits selection and analysis to 2D areas.

4.1.3 CASA

The Common Astronomy Software Applications (CASA) package allows users to process radio astronomy data. It is built as a collection of C++ tools wrapped by a Python interface. This allows users to write scripts to perform custom tasks[9].

It runs on consumer hardware and is still actively developed. Its graphical interface only allows for selection and analysis of 2D rectangular regions.

4.1.4 SAOImage DS9

SAOImage DS9 is a powerful and feature rich data visualization application. It is still in development with new features being added often[5].

It has features for automatically detecting iso-value contours in 2D but this does not extend into 3 dimensions.

4.1.5 Fits3D

Mohan et al.[11] recently released Fits3D, an interactive 3D data cube viewer with a focus on comparison of multiple Data cubes with visualization and the ability to annotate data being main focuses.

It is still a prototype and while it shows potential, it’s selection is still limited to boxes.

Table 1: Summary of Current Tools' Features

Tool	3D Selection And Analysis
CyberSKA Viewer	No
GIPSY	No
CASA	No
Fits3D	No
AstroVis	No
3D Slicer	No
CAVASS	Yes

4.1.6 AstroVis

AstroVis is a visualization tool that focuses on rapid response times, allowing users to get qualitative information rapidly[12].

It allows the user to save subregions, but these are limited to boxes.

4.2 In other fields

Medical imaging often produces data formats very similar to those used in astronomy[1], where the data represents density in 3D space rather than flux, so we will look at some of the more widely used tools.

4.2.1 3D Slicer

3D Slicer is an open source program for visualization of medical data. It has a focus on usability for non-programmers[13]. While it has many user submitted modules none of them add analysis capabilities, as they concentrate on the construction and viewing of isosurface (surfaces of equal value). Work has been done on adapting it for use with astronomical data but still focuses on visualization rather than analysis[13].

4.2.2 CAVASS

CAVASS is newer than 3D Slicer and specifically designed to offer better analysis tools[3].

It has some very interesting analysis tools not present in other packages. For example, CAVASS can generate an isosurface and then calculate the volume enclosed by it.

While these tools would need to be adapted to astronomical needs, they are a good starting point.

5. CONCLUSION

Our research has shown that current tools lack flexible 3D selection features that would allow galaxies, once identified, to be analysed faster.

The research suggests that an astronomy-specific implementation of CylinderSelection has the most potential, implemented first as a prototype and later integrated into an existing package.

We believe that expert testing would be the most appropriate and most time-effective solution.

6. REFERENCES

- [1] M. Borkin, A. Goodman, D. Alan, J. Kauffmann, and M. Halle. Application of medical imaging to the 3d visualization of astronomy data. In *Proceedings of IEEE Visualization Conference*, 2007.
- [2] A. X. Falcão, J. K. Udupa, S. Samarasekera, S. Sharma, B. E. Hirsch, and R. d. A. Lotufo. User-Steered Image Segmentation Paradigms: Live Wire and Live Lane. *Graphical Models and Image Processing*, 60(4):233–260, July 1998.
- [3] G. Grevera, J. Udupa, D. Odhner, Y. Zhuge, A. Souza, T. Iwanaga, and S. Mishra. CAVASS: A Computer-Assisted Visualization and Analysis Software System. *Journal of Digital Imaging*, 20(1):101–118, Sept. 2007.
- [4] A. H. Hassan, C. J. Fluke, D. G. Barnes, and V. A. Kilborn. Tera-scale astronomical data analysis and visualization. *Monthly Notices of the Royal Astronomical Society*, 429(3):2442–2455, Mar. 2013.
- [5] W. Joye. New features of saotime ds9. In *Astronomical Data Analysis Software and Systems XV*, volume 351, page 574, 2006.
- [6] C. Kiddle, A. R. Taylor, J. Cordes, O. Eymere, V. Kaspi, D. Pigat, E. Rosolowsky, I. Stairs, and A. G. Willis. CyberSKA: An On-line Collaborative Portal for Data-intensive Radio Astronomy. In *Proceedings of the 2011 ACM Workshop on Gateway Computing Environments*, GCE '11, pages 65–72, New York, NY, USA, 2011. ACM.
- [7] W. E. Lorensen and H. E. Cline. Marching Cubes: A High Resolution 3d Surface Construction Algorithm. In *Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '87, pages 163–169, New York, NY, USA, 1987. ACM.
- [8] J. F. Lucas. *Design and Evaluation of 3D Multiple Object Selection Techniques*. thesis, Virginia Tech, Jan. 2005.
- [9] J. McMullin, B. Waters, D. Schiebel, W. Young, and K. Golap. CASA architecture and applications. volume 376, page 127, 2007.
- [10] J. D. Mink. Astronomical data formats: What we have and how we got here. *Astronomy and Computing*, 12:128–132, Sept. 2015.
- [11] P. Mohan, C. Hawkins, R. Klapaukh, and M. Johnston-Hollitt. Three Tools to Aid Visualisation of FITS Files for Astronomy. *arXiv:1601.00264 [astro-ph]*, Jan. 2016. arXiv: 1601.00264.
- [12] S. Perkins, J. Questiaux, S. Finnis, R. Tyler, S. Blyth, and M. M. Kuttel. Scalable desktop visualisation of very large radio astronomy data cubes. *New Astronomy*, 30:1–7, July 2014.
- [13] S. Pieper, M. Halle, and R. Kikinis. 3d Slicer. In *IEEE International Symposium on Biomedical Imaging: Nano to Macro, 2004*, pages 632–635 Vol. 1, Apr. 2004.
- [14] J. Ruiz, J. Santander-Vela, V. Espigares, L. Verdes-Montenegro, and J. van der Hulst. GIPSY 3d: Analysis, Visualization and VO Tools for Datacubes. volume 411, page 406, 2009.
- [15] S. Westerlund, C. Harris, and T. Westmeier. Assessing the Accuracy of Radio Astronomy Source-Finding Algorithms. *Publications of the Astronomical Society of Australia*, 29(3):301–308, 2012.
- [16] L. Yu, K. Efstathiou, P. Isenberg, and T. Isenberg. Efficient Structure-Aware Selection Techniques for 3d Point Cloud Visualizations with 2dof Input. *IEEE Transactions on Visualization and Computer Graphics*, 18(12):2245–2254, Dec. 2012.