

ASRix : A Simple Digital Image Rectifier

S. Nickerson, A. Chapiro

C A R T : Computer Aided Recording Tools 501-99 Holland Avenue, Ottawa, Ontario, Canada K1Y 0Y1
steve@icomos.org, asrix@sympatico.ca

KEYWORDS: Rectification, 3D, Accuracy, Calibration, Single-Image Technique

ABSTRACT

It is now more than ten years since the first image rectification programs appeared on the market and by now you would expect that every Heritage Recorder or Conservation Architect would be using one as a standard tool. This does not seem to be the case. It is our contention that this is because for the most part they are a trickle-down tool, a spin off from more complex systems and that the complexity, or at least the perception of complexity, has remained with this class of tools, slowing their adoption.

ASRix was no different in that its underlying algorithm came from the photogrammetric package DIPAD but that was more than a decade ago. Since then it has been developed by and for Heritage Recorders until, today, it is a package that is very easy to use and addresses most of the problems experienced by those tasked with bringing the Heritage Record from the field to the computer.

We identified the main issues as being:

- Ease of data input
- Reducing the possibility of input errors
- The ability to use 3D coordinates when available
- Correction for camera lense distortion
- An interface with the CAD program modeling the data
- A quantitative evaluation of the accuracy of the final product

The features that we feel have resolved these issues are as follows:

- Direct input from the flat files produced by survey data, eliminating typos
- The processing of 3D coordinates by having users identify three points on the plain then converting all points to that plain
- A built in camera calibration routine
- An Interface with AutoCAD which can collect coordinates from and insert the rectified image into the AutoCAD 3D environment.
- The ability to measure the distance from each point identified to its equivalent on the rectified image to provide a value for accuracy

A brief introduction to the recently released ASRix V2.0 and examples of its use and output will be accompanied by the results of a recent course in Heritage Recording where students from around the world used this and other tools to produce a 3D model of Santa Cecilia in Trastevere, an 18th century rebuilding of a 9th century church in Rome, then compare their results with those of an earlier course which recorded the same monument.

Why doesn't every architect use rectification software? Prices are going down and are now trivial compared to the CAD programs they are using and even more trivial compared to the other ways available for them to document flat surfaces.

There is the perception that simple image processors can do the same thing, which, to some extent they can, though not if you are looking for accuracy. There is also the question of marketing. Most architects are not aware that these tools exist.

But I think the main reason is because for the most part they are a trickle-down tool, a spin off from more complex systems or a "free" component of them and the complexity, or at least the perception of complexity, of these tools has kept potential users away.

ASRix too was a spin off, its underlying algorithm coming from the photogrammetric package DIPAD (Streilein, A, 1991; Streilein, A 1995) but that was more than a decade ago when we took Dr. Streilein's algorithm and wrapped it in a simple Windows interface that did nothing except rectify images.

We called it ASRix and used it extensively for a number of years. It was very easy to use, but for working Heritage Recorders it still left something to be desired. The main issues that made Image Rectification a less than ideal tool were the following:

Data Entry

World Coordinates had to be entered manually, introducing the possibility of human input errors, but more importantly it was often difficult to get the measurements in the coordinate system required for rectification.

Accuracy

Any individual image looked pretty good and the few points we could actually test were usually within a few centimetres of where they should have been, but collages of several images did not match perfectly. More importantly, there was no quantitative evaluation of the accuracy of the final product

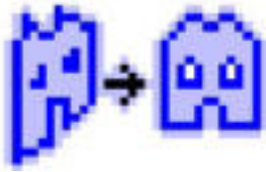
Interface with CAD

A problem which was often reported were the difficult transitions between CAD programs and the rectifier. We needed more efficient ways to get coordinates from AutoCAD drawings and simplified ways to insert rectified images into the CAD environment.

Troubleshooting

A last limitation had to do with errors. As long as there were good coordinates and, more importantly good field notes, the rectification worked well but a bad point or the failure to correctly note which point number was associated with which feature resulted in the what we came to call butterflies and correcting such errors was always very frustrating and time consuming.

ASRix v2



Improved Data Entry Possibilities

3D Coordinates

Perhaps the biggest improvement was adding the possibility of using 3D values as world coordinates. At first glance it doesn't seem like this should be important at all because a rectified image, by its very nature, is a 2D object but the problem was the same as that which had delayed the widespread use of CAD for Heritage Recording. It is predicated on assumptions that are not appropriate for recording.

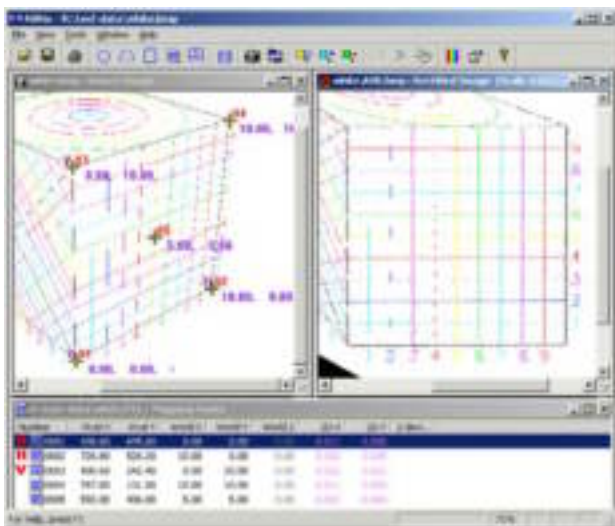
Real things are not flat any more than they are vertical, horizontal or at right angles so it is very difficult for the Heritage Recorder on the ground with only a tape measure to get good 2 dimensional measurements. As a result many now rely on surveying instruments to obtain their measurements and these devices provide their data in 3 dimensions.

Of course it is necessary to transform the 3D values to the 2D coordinates needed for rectification so ASRix has added some tools to help users determine the plain that best fits their data and make the transformation from the surveyed coordinates to the selected plain.

This is accomplished by having users identify three of the measured points as defining the coordinate system for that image. Points are tagged as being:

- The Origin (X=0, Y=0 in the 2D system)
- The Horizontal Axis (X>0, Y=0)
- The Vertical Direction (Y>0)

ASRix then calculates the plain defined by these three points and the deviation of all the other points from it. Using the feedback from these calculations users can decide which points best describe the plain they want to rectify.



The definition of the coordinate system is mandatory, and critical. Without this information the software cannot determine which face of the object is represented by the image being rectified (inside or outside of a wall for example). By default the first 3 points selected are used but careful manipulation of these values can significantly improve the results.

Because operation is more complex when using 3D coordinates the 2D implementation was retained and is the default as long as

the world coordinates have no values in the 3rd dimension.

Direct input from Survey instruments

The problem with 3D coordinates obtained from Survey instruments is that they tend to be long strings of numbers the transcribing of which is often accompanied by user input errors. To eliminate this problem we decided to go straight to the source by adding the ability to read the coordinates directly from the flat files downloaded from survey instruments.

Version 2 provides an interface where users can define the parameters of their instruments output file which ASRix will then parse to extract the point number, and the X, Y & Z coordinates. When this connection is activated users need only pick a point on the image and type in the appropriate point number. The file from the survey instrument provides the world coordinates.

Having the software look up the World Coordinates makes the 3D interface much faster to use and than any manual input system imaginable and almost completely eliminates user input errors (you still have to get the point number right).

With adequate survey data (four or more points for each image) it becomes a simple matter to build a 3D (perhaps closer to 2.75D) photo collage of rectified images. What is needed is an environment for 3D visualization. While this is on our list for future development it is not going to happen any time soon so, in the interim we have adopted AutoCAD as the vehicle for our 3D modeling.

Interface with AutoCAD

If you have only partial data a source of coordinates for rectification can be the partially completed CAD models.

Perhaps the data available includes a foundation, some architectural scraps and a few historic photographs. You start with an accurate drawing of the foundation and for the third dimension measure the bricks you found on site and count the courses in the photograph to make some assumptions about height. From this information an approximation of the objects dimensions and volumes can be drawn in CAD in 3D.

In the past transferring this information to the rectification program has been another manual exercise and, as such, was prone to errors but now ASRix v2 facilitates this process by allowing users to select 3D points from AutoCAD entities and transfer them to the rectifier as World Coordinates. Once rectified using these values the image can be automatically inserted into AutoCAD 3D space at the appropriate scale with the only manual component being the trimming away of the parts of the image not on the rectification plain.



If you have all the coordinate information you need for rectification from a survey ASRix will insert the rectified image into AutoCAD 3D space automatically.

Using the rectified image with the CAD program to fill in the details revealed by the rectification was another obstacle. Having obtained a rectified image it had to be inserted into AutoCAD and scaled appropriately before it could be used as a background for tracing details. Then, if a 3D model was required, the various 2D components would have to be manually assembled. For this situation ASRix v2 has automated everything but the tracing and annotation.

As each image is inserted a coordinate system, view and associated layers are created (all have the image name in common). This allows the tracing and annotation of details on the image plain and a suite of customized AutoCAD commands allows quick movement among the images and their working environments (UCS, view and layer).

In the final analysis, when these tools are combined even an inexperienced user can build a very useful 3D model from single images and minimal measurements, usually within a few hours.

Accuracy:

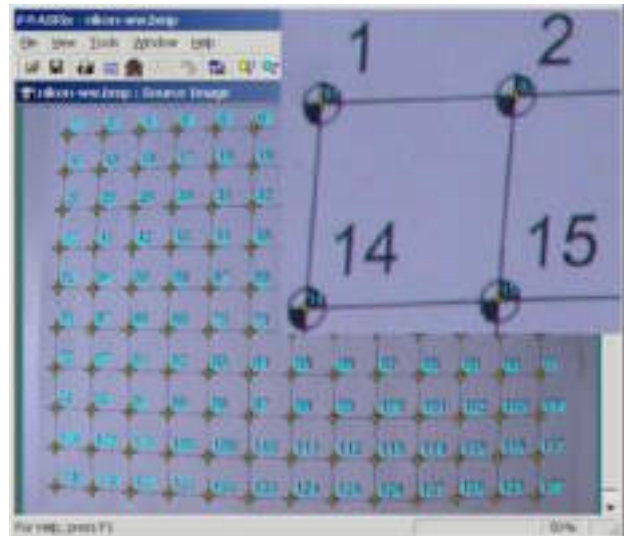
For most 3D modelling by architects, even conservation architects, accuracy seems to be well down the list of priorities. Many are ready to accept the tools provided by image processors or even rubber sheeting because they can make an image “look” ok

One example (from a prestigious institution that will remain nameless). A two image collage had been prepared of a wall that made a turn of about 6 degrees (in plan). The discrepancy was less than 2 cm but they asked that the whole wall be treated as a single plain to be handled by a single rectified image. This would have resulted in a maximum error of more than 20 cm (+/- 10cm) but distributed over the whole wall (+10 cm at the edges -10 cm at the angle). They felt it would “look” better without the visible discrepancies at the junction of the two images.

So why worry about accuracy?

I guess it's habit or perhaps professional ethics. I assume that, as a Heritage Recorder, it is incumbent on me to state what I feel the accuracy is of any work I do. Also, I'm sure that if I claimed an accuracy of +/- 10 cm that same client would reject it as inadequate (and I doubt they would be swayed if I said “+/- 10 cm but it looks good”).

To be truthful visual mismatches bothered me as well. We knew it was mostly due to camera distortion and could be much reduced by using a calibrated camera and correcting the image for distortion before doing the rectification. The problem was that most of those we expected to be using ASRix were not going to be buying semi-metric cameras or paying several hundred euros to have their cameras calibrated.



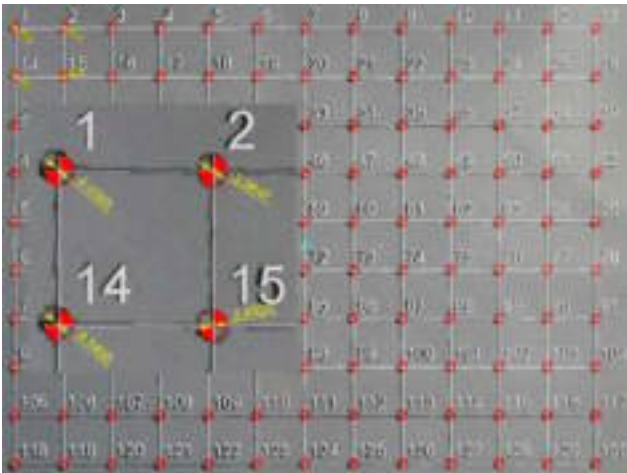
So with the help of CIPA (actually Dr. Antonio Almagro of Spain and Dr. George Karras of Greece) we undertook to add a calibration routine to ASRix v2. Dr. Karras had published an algorithm that seemed a perfect fit (Karras, G. 2001) and our implementation of it uses all of the new features of v2 and most of the old ones.

1. The procedure starts with the printing of a grid distributed with the software then photographing it with the camera set as it would be (or was) when taking the photographs for rectification.
2. The photograph is brought into the rectifier and each target is registered. If linked to a database of the grid coordinates there is no need to manually enter the World Coordinates.
3. The Camera Calibration routine is then invoked where you give the parameters you are about to calculate a name and click “Calibrate”. You can also decide if you want these parameters to be used by default whenever you rectify.

Future development in this area will add a utility to convert the calibration parameters from other, more sophisticated, calibration procedures so that they can be utilized to the fullest in ASRix.

The other part of the accuracy conundrum is knowing just how large your errors really are. Here it was the AutoCAD interface that provided a method of quantifying these values.

The grid used to calibrate the lenses is a plot of an AutoCAD drawing so it follows that if you take a picture of the grid, correct all the errors you can (both distortion and parallax) then insert it back into the AutoCAD drawing that created it you have tested all your systems and the discrepancy between the two should be a reliable measure of your overall accuracy.



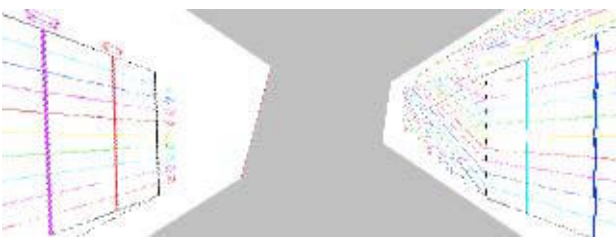
The grid measures 1500 units from the centre to the outer corners and, in the example above, taken by a Nikon 4500 camera, set at its widest angle, there is a maximum error of about 7 units (0.5%) near the corners of the image. The same camera with an add-on wide angle adapter shows a maximum error of 10 units (0.7%). Such errors are not negligible, 5 cm at the edges of a 10 meter wall, but not bad for the small amount of work involved and they can be reduced by using more photographs of smaller areas.

Troubleshooting

User input errors having been pretty well resolved with the data connection feature and systemic errors, if not eliminated, at least well understood, the problems left are actual mistakes. There are two sorts of errors and they can be separated into **Butterflies** and **Edge Errors**.

The most common of the butterfly errors has been mistakes made in identifying the measured points on the photographs. On a long stone wall it is easy to mark the wrong points on the prints of the photographs and very difficult to figure out which point it is that you actually measured. The solution of course, is to keep really good field notes but no matter how meticulous you are you will encounter this situation.

The solution is to have **redundant points**.



A Butterfly

Our rule of thumb is that here should be a minimum of 6 points measured for each photo. With these extra points at your disposal, you can usually figure out which one is incorrectly identified by examining the residuals.

Number	Real X	Real Y	World X	World Y	World Z	X-res	Y-res	Z-res
0001	408.60	695.60	0.00	0.00	0.00	0.384	0.874	
0002	706.80	526.20	10.00	0.00	0.00	0.151	-0.440	
0003	400.60	242.40	0.00	10.00	0.00	0.151	-0.440	
0004	717.80	131.00	10.00	10.00	0.00	0.268	1.022	
0005	698.00	242.00	5.00	-5.00	0.00	-1.526	-1.247	
0006	481.00	580.00	2.00	2.00	0.00	-0.027	0.246	

Point 005 is a probable source of the problem

When you have a suspect point it can be disabled and the rectification performed without it. If it works you can either try to figure out where it should have been or delete it (which you can do because you have the extra points). More than one bad point is more of a problem.

Another source of butterflies has to do with getting the point numbers out of sync with the field notes. This too is easy to do, especially with the new total stations that have a hair trigger button right beside the rotation knob. Our attempt to simplify the search for this type of error relies on a control in the database connection dialogue that allows you to roll the point numbers forward and backward. This works if all the numbers are offset from your notes, if the errant point was added between two good points you will have to adjust the point numbers one at a time.

Small errors are generally a matter of technique. Careful measurements and careful placement of the points in the photograph will minimize most of them but one that isn't quite so obvious happens where two photos overlap.



Mismatched Plains

The error in the example above is due to the two photographs not really being of the same plain. Because you have to select three points in each image to define its coordinate system only a perfectly flat surface or blind luck would produce a plain common to both. To minimize this error try to have two points in common along the line of the overlap and use these as part of the coordinate systems of both images.

ARIS and ASRix

ARIS is a series of courses addressing "Architectural Conservation, Heritage Recording, and Information Management" which were presented in 2003 and 2005 by ICCROM in Rome. Our part of this course has been to introduce students from around the world to some simple tools and complex concepts on the subjects of Heritage Recording and Information Management. ASRix has been one of the tools since the beginning.

The first ARIS course **ARIS03** was held in October 2003 with the courtyard and square of the church of Santa Cecilia in Trastevere as the recording project for the 12 students taking part. For the rectification exercise we were using an early beta version of ASRix v2. At that time the AutoCAD interface was in its infancy and there was a primitive data access tool that would read only DBF files.

To overcome the camera distortion we used a calibrated camera provided by Antonio Almagro and a correction routine he had developed called CorDis. As well as the technical complications this created it was a less than satisfactory solution because most of the students, when they returned to their own countries and work would not have access to such a camera. As a result it was decided that the camera calibration feature should be added as an internal component of ASRix.

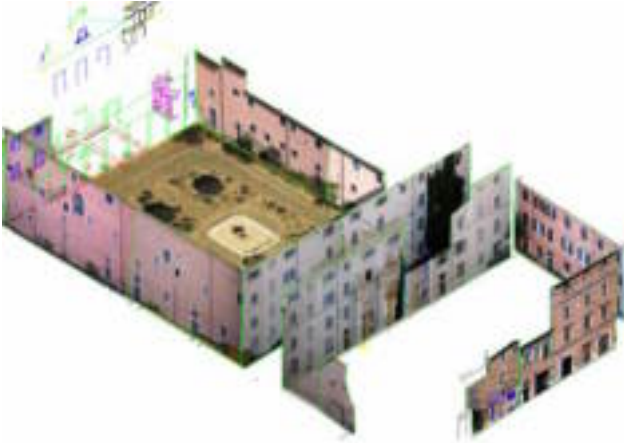


Photo collage from ARIS03

The conversion of the survey data to the DBF format was also found to be a problematic and unnecessary step and we decided to write our own tool to parse the text files downloaded from the survey instruments. In this it was one of the students, Karim Peltonen, that helped in the development by providing several formats and interpretations of the data they described.

By the time of **ARIS05**, in the spring of 2005, ASRix v2 was stable and pretty much complete so all the components could be



ARIS05 photo collage well tested by the 16 students. The test case was an urban survey of the Piazza Mercanti which is adjacent to the work on Santa Cecilia done by ARIS03. The only real difficulty we encountered had to do with an 8 megapixel camera and Windows '98 which couldn't handle the memory requirements.



The collages of ARIS03 & ARIS05 combined

It is hoped that future ARIS courses will continue to develop the model the streets in Trastevere around ICCROM and that other simple tools in support of Heritage Recording will grow out of the unique combination of needs and expertise this program brings together.

REFERENCES:

Nickerson, S. 2005, ASRix Digital Image Rectifier

<http://nickerson.icomos.org/asrix/>

ARIS05

<http://nickerson.icomos.org/aris05>

ARIS03

<http://nickerson.icomos.org/aris03>

Karras, G. 2001, Simple Calibration Techniques for Non-Metric Cameras *Proceedings of CIPA International Symposium 2001, Potsdam, Germany* ISSN 0256-1840

<http://nickerson.icomos.org/asrix/papers/2001-03-gk01.pdf>

Streilein, A. 1995, CAAD Meets Digital Photogrammetry

Proceedings of ACADIA '95, University of Washington, Seattle, USA. ISBN 1-880250-04-7

Streilein, A. 1991, Development of a Digital System for Architectural Photogrammetry

Proceedings of CIPA XIV Symposium 1991, Delphi, Greece.

ISBN 960-7018-28-1