A Brief History Of Oribotics

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Abstract

This paper covers the brief 4 year history of Oribotics as a tangible field of study; as a hybrid field of study, with art exhibits as the end goals. I will cover my definition of Oribotics, the origin and evolution of oribotics, design problems and solutions.

While thinking generally about origami and technology I realised the two fields are very similar. Origami often borrows from nature, and often highly regarded origami works are the most 'natural. The same aspirations exist in robotic behaviour and movement. Robots are programmed machines, and origami is programmed paper, that is paper coded with creases.

1 Definition of Oribotics

Oribotics is a hybrid field of research, joining two complex fields of study; origami and technology, specifically 'bot' technology, such as robots, or intelligent computer agents known as bots. The name is broken into two parts, ORI which comes from the Japanese verb Oru literally means 'to fold', and BOT is the shortened form of the word robot. Oribotics is origami that is controlled by robot technology; it is paper or foldable material that will fold and unfold on command.

An Oribot by definition is a folding robot, therefore any robot that folds, or any device that uses technology and folded actuators together is an oribot. The definition blurs at the boundaries where origami models, by themselves, exhibit mechanical characteristics. While there may be no robotic component, paper can possesses a programmed memory for movement. Oribotics research seeks for rigid and non-rigid crease patterns that have a natural folding motion. Natural folding is found in crease patterns that posses the ability to undergo repetitive shape transformation by mechanical means

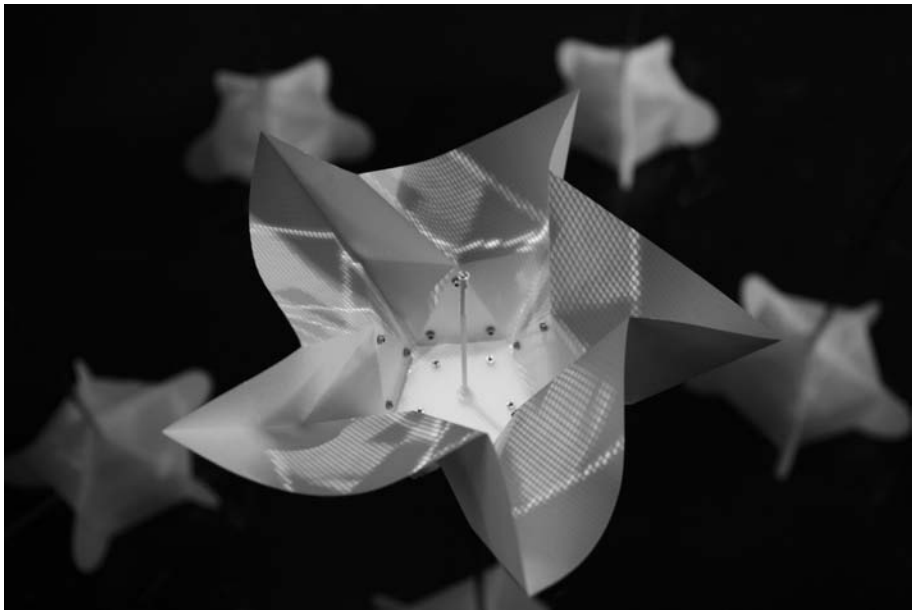

Figure 1: Image from *Oribotics [Laboratory]*

without compromising their folded form. Forms like the Miura Ori, flapping bird, and the oribot Atom Flower possess this natural folding motion. The idea of natural folding is inspired from the unfolding found in nature, especially that found in leaves and flowers.

2 The Origin of Oribotics

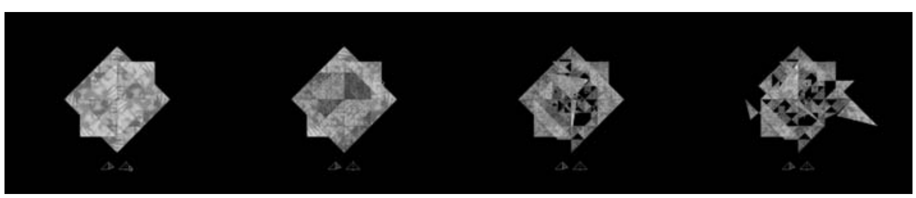

Figure 2: *Root 2* Interactive Macromedia Flash animation

The origins of Oribotics, are not found in fragments of paper, but rather fragments of code. Small snippets of ideas emerged in 2002 when I began making origami animations using Macromedia Flash. I was using Actionscript to make them interactive. Root 2 was my first interactive work using this theme (see figure 2). It has two

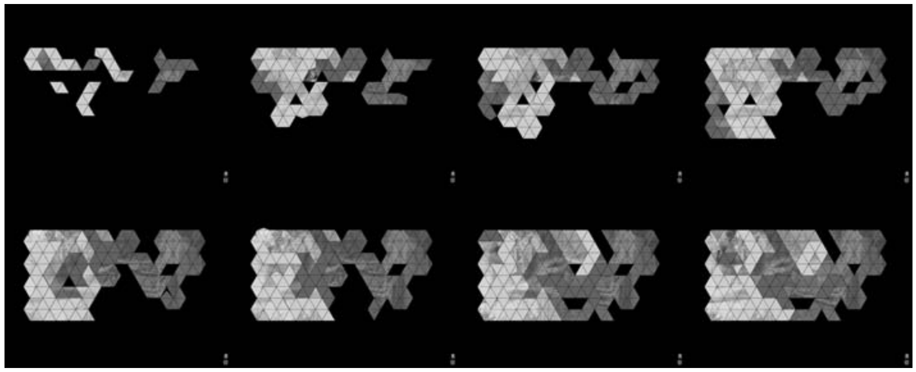

Figure 3: *Orimattic* Generative Macromedia Flash animation

modes, divide and fold. It begins with a set of isosceles triangles (half squares). When divide is active, the mouse recursively makes root 2 divisions of the existing triangles. When fold is active, the mouse makes the triangle animate a fold hinging on one of the shorter edges.

Orimattic takes a step along the same path, adding a tiny bit of AI to the mix (see figure 3). Orimattic was a work commissioned in 2002 for the Bed Supper Club in Bangkok, designed to be projected alongside an origami installation which took over the entire club. As such the work needed to change autonomously, creating an ever changing origami wallpaper. The core of the programming was the 'bot' that controlled the animation. The bot is an origami snake of equilateral triangles, that can only walk on a triangular grid. The work used 6 base images, and 6 colours, that combine randomly at startup. As each 'bot' takes a step, it leaves a foot print, and each subsequent step rubs the footprint down in opacity, gradually revealing the image below.

2.1 Tetrabot

Later in 2002, I was granted a residency at the Latrobe Regional Gallery, and during the weeks prior to starting, I was having visions in the morning of Orimattic being made as a 3 dimensional robot, or as walking tetrahedrons moving on the floor with projected animation. Once my residency began, and I started work I found that it was actually quite tricky to make a folding, walking tetrabot with lego. In 2005 I read in a New Scientist magazine that NASA actually built a successful Tetrabot [1] that walked beautifully. This original idea sparked several others ideas including a mechanised flapping bird.

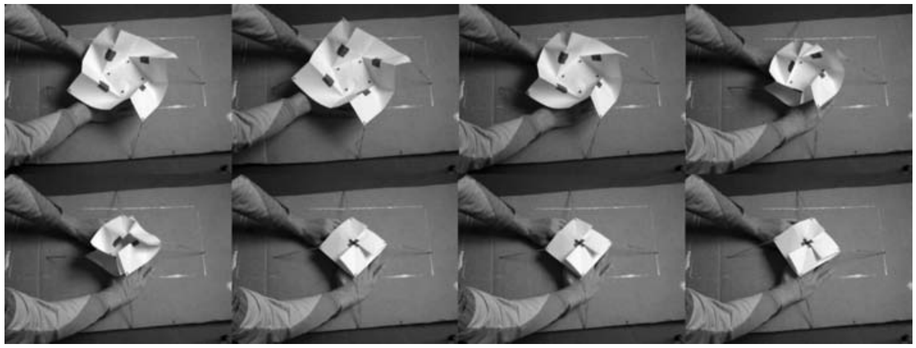

Figure 4: Tato rubber band theory

2.2 Robotic Tato

One of the most promising was a robotic Tato, an idea inspired by Chris Palmer's extensions to the Japanese Tato. My first attempts at pure mechanical construction were conceptually solid, but the practical results were not especially interesting. My mechanical design intended to move in the same path as the folding paper, however, when I attached the paper, the lego proved too inaccurate, and just crushed the paper. So instead of using mechanics to push the paper in and out of shape, I began experimenting with pulling the paper. Figure 4 illustrates the low tech, rubber band and cardboard box approach I chose to successfully prove this theory.

3 Oribotics 2004

The rubber band proof was enough to inspire me to write an application for a youth arts festival, and led me to dub the work Oribotics. And what followed was a period of prototyping pentagonal designs. Which, with the robotic programming by my father Ray Gardiner, resulted in the global premiere of Oribotics (figure 5). Many design changes occured, the most significant was the design of the pentagonal crease pattern, used because of the pentagons mathematical perfection, its beauty, and its regular occurrence in nature as signified by the Fibonacci sequence.

3.1 Design problems with oribotics 2004

There were several fascinating design problems with Oribotics 2004. It was beautiful, but in terms of design, it was a flawed project. The audience found these problems endearing, as they summed up the fragility and fallibilty of technology. The sense of natural entropy

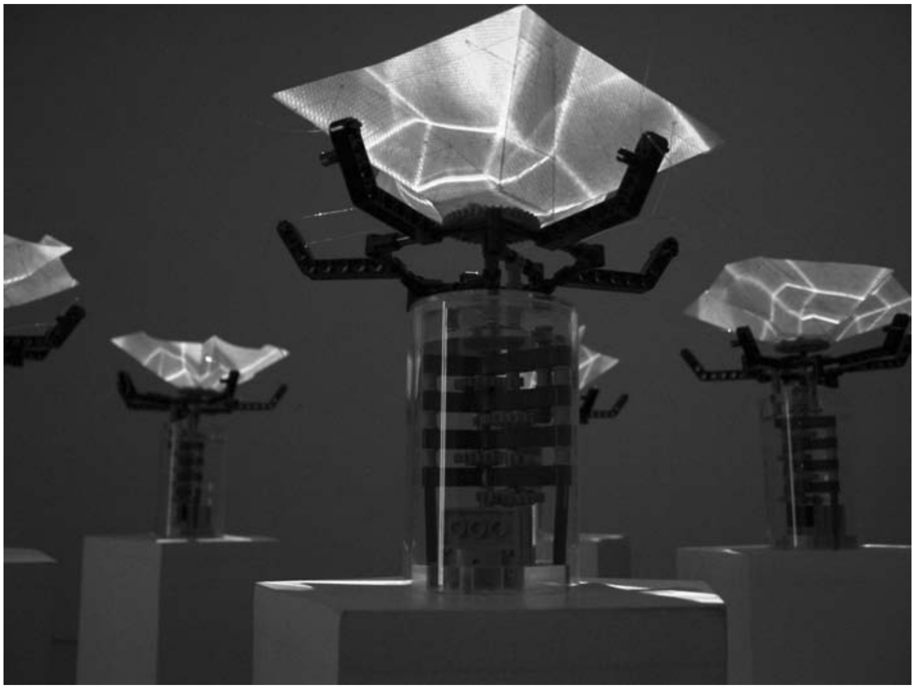

Figure 5: *Oribotics*, 2004, Next Wave Festival, Melbourne

was maintained, the flowers bloomed, required some 'Gardening', and some eventually died. The problems were plentiful, both in the choice of materials, and crease pattern design, and most of all the mechanical design produced alot of stress and therefore required alot of energy.

3.2 The corruption and breakdown of the crease pattern

The life of the flowers was initially counted in days. So I worked through a number of paper stocks, and plastic sheet re-inforcement designs, and improved the counter to weeks, if all was perfect. But any corruption in the crease pattern would cause eventual breakdown of the origami mechanism. My final solution was to use a plastic/fabric lamination, wherein I would cut up plastic sheets, with gaps for folds and then, using heat, laminate the plastic between the fabric (see figure 6).

4 Oribotics 2005 [atom generation]

In late 2004, I was awarded an Artists Residency in Tokyo 2005 by the Australia Council for the Arts. When I arrived in Tokyo in May 2005,

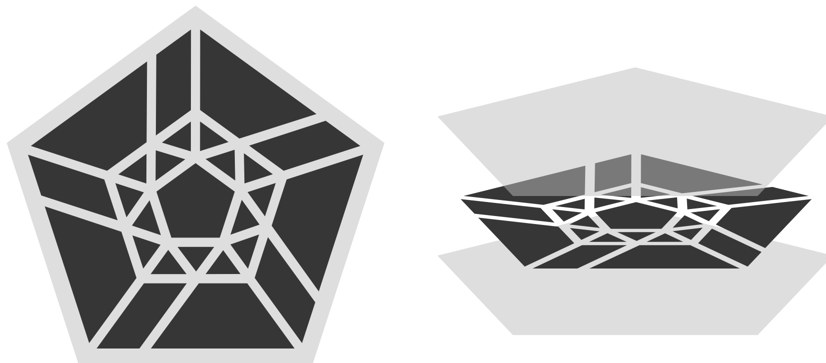

Figure 6: Lamination, the dark grey shows the shape of the plastic parts cut out, and the light grey shows the fabric area. The right hand image shows the sandwich of materials.

it was my aim to solve these problems and make a better, stronger Oribot. I was full of optimism, high from the energy of a series of talks and exhibitions in Belgium. Mr Jun Maekawa was a guest of ours at Folding Australia earlier in the year, and he suggested that he could introduce me to a number of people with whom I could speak to about oribotics research. Kindly, Mr Maekawa took me to meet them, and on our travels we met with Mr Shunsuke Ito, the chief robotics engineer at Denso, and Mr Ohara, an engineer at Kuramae Industries.

At Denso in Nagoya, Aichi, I was introduced to Mr Ito's masterwork titled 'Karakuri Maiginu' featuring two mechanically folding origami cranes. To my surprise he was not using computers, but elegant mechanical design, with superbly crafted brass hinges, and fabric. A feature of his design for the cranes was the areas of rigidity and flexibility in the crease pattern. I was very inspired to see a work of this calibre.

Mr Ohara was the head engineer of the origami paper cup project as introduced in 3OSME by Tomoko Fuse et al. I had many questions for Mr Ohara regarding his research into industrial folding techniques. I was made aware that the project was still in development, and that the research was still 'top secret'. So I am unable to share any details, except that even by hand it is quite difficult to fold a paper cup, but the result is very strong, and I use a folded cup on my desk as a pen

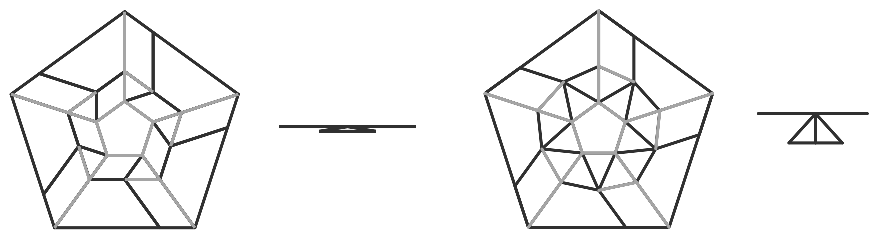

Figure 7: 2004 crease pattern and profile (left), 2005 crease pattern and profile (right).

holder.

4.1 Crease Patterns

While looking at the crease pattern for the Karakuri, a few ideas began to suggest them to me. I realised that the original crease pattern demanded far too much stress on the paper as the folds moved through 180. So I re-designed the model, and introduced a pyramid shape in the middle of the closed flower. The re-design provided faces with more leverage, and less of an angle of movement, thus reducing the stress in the model. After many trips to the Japanses craft store Tokyu Hands, and many experiments with paper stocks and mechanical designs, I found the most elegant way to actuate this new crease pattern.

The new crease pattern, and mechanical design was taken back from Japan and prototyped in Australia before evolving into the atom generation of oribots.

5 Prototyping

The prototyping process was rather direct, and not as well documented. It focused almost solely on the mechanical and electrical design. The process was to design 3D models, and translate them into 2D planes which could be cut from flat sheets of 3mm plastic, and assembled back into physical 3D models. The key elements of design were as follows.

5.1 Base

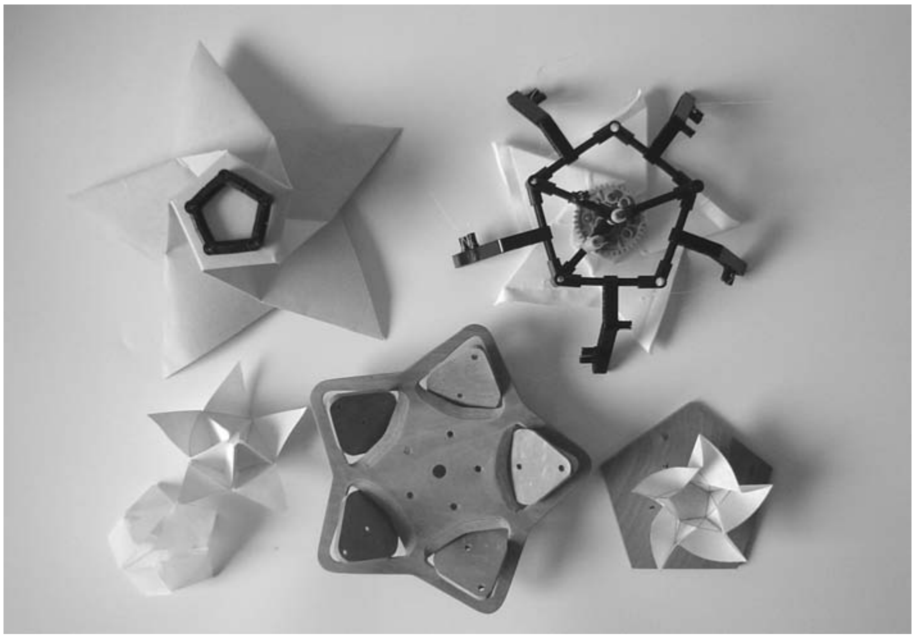

Figure 8: A range of prototype models for Oribotics [laboratory]

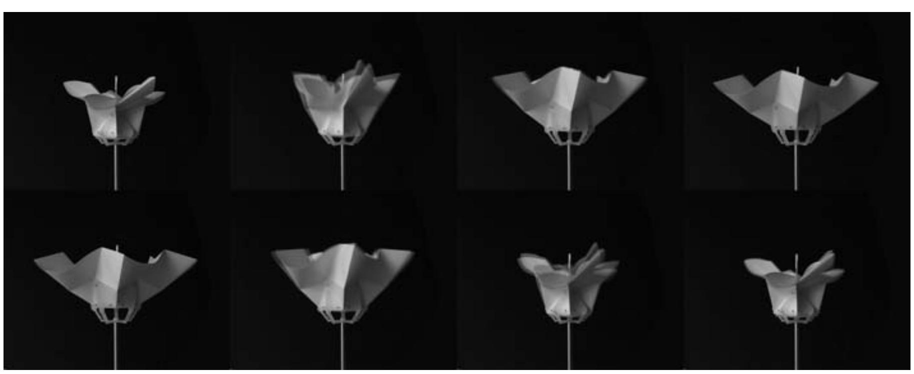

Figure 9: A profile of the hand actuator in motion from closed, to open, and back to closed.

Inside the base are the following main components: The custom designed printed circuit board; with a PIC microprocessor; an LED or two; and a high quality Servo motor, like the kind used in Radio Control Models. The electronic system was designed and programmed to specification by Ray Gardiner.

5.2 Hand/Actuator

The hand actuator constitutes the parts that touch, and are fastened to, the paper. All of the parts are laser cut from 3mm acrylic. When choosing the material, I wanted something that would seem light, and not bulky. With one single degree of motion, this relatively complex set of folds are actuated, capable of 1000's of repetitions. These particular works are almost a year old, some of them have been operating for over 3 months day in day out (see figure 9).

5.3 Flower

The exhibition flowers use a pearlescent paper to reflect as much light as possible. The paper was carefully scored, folded, holes punched, and bolted to the hand. Over a period of a year, the only degradation I have seen is a little wear at the corners, as all of us find when we fold on the same fold over and over again. Though the commercial versions use a plastic paper, which shows no sign of wear at all.

5.4 Light Sensor

The only eye of the Oribot is a Light Dependent Resistor. The PIC brain in the base, receives light levels as changes in voltage from the sensor. It has a calibration range, so that in exhibition, it opens with a particular level of light, and closes at a another. Brightness opens the flower and a darkness closes it, and so the audience liken it to a real flower.

6 Oribotics [laboratory]

The final work was premiered at the Asialink Centre at the University of Melbourne, over 2 nights with 4 performances. Figure 10 shows a view of the final installation. The installation used digital animation from data projectors to animate light on each of the oribots. During the exhibition there were percusive performances. In the exhibition space there were 15 oribots, 8 speakers, 4 computers, 2 projectors. For the performance there was 1 projection screen for the score composed by David Young, and instruments by Rosemary Joy, played by percussionist Eugene Ughetti.

Figure 10: Oribotics [laboratory] Asialink Centre, Melbourne

The oribots, sensitive to light, were networked via animation beaming from the data projectors above them. For the audience the literal connection was that the weather was being projected onto the oribots, and that was making them move. Acutally, the arrangement was a little more complex, the animation changed according to the city that the robot was linked to, showing the cities current weather condition as read a from live XML data source. Each weather condition had a corresponding pattern as influenced by origami paper designs.

7 Conclusion

As a field of study Oribotics is a hybrid of science and art that has grown in complexity over the past four years. To date the project has been supported with funding from the New Media Board of the Australia Council for the Arts, Arts Victoria, the City of Melbourne, Aphids, and Ray Gardiner. The next generation of Oribots, with the working title 'Oribotics [network]' is supported by Arts Victoria's Arts Innovation Board, and will premiere in 2007 at Federation Square in Melbourne.

For more information, and video see www.oribotics.net

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References

[1] Will Knight, *Shape-shifting tetrabots tumble into action*. New Scientist, Issue 2494, 09 April 2005.