The Wadham Journal

Issue 3, Hilary 2013

Sharing the fascinating work of Wadham graduates with the MCR alumni and the wider College community

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Contents

Editors' Comments

Welcome to the third issue of The Wadham Journal! This issue features the fascinating research of four of our MCR members, both past and present:

Michael Bridgman is reading for an MPhil in Modern Economic History. Examining the economic repercussions of a Western Union telegraph operator strike in late nineteenth century America, his research analyses the volatility of financial markets in responding to events of the wider world.

Russell Tucker, DPhil in Biomedical Engineering and beloved outgoing MCR President, then takes us through his promising research into tendons. His work could potentially contribute to the creation of a cure for the debilitating injuries that have plagued many sportsmen and sportswomen, David Beckham included.

Liyu Wang, a Wadham graduate in Biomedical Engineering now working as a Research Assistant at ETH Zurich, sets out the latest developments in cutting edge robotic technologies in his piece for the journal. Liyu asks how we can improve upon the adaptability of robots, in order to allow them to react to unpredictable and irregular physical environments

Adam Harper, studying for a DPhil in Music, rounds off the issue by inviting us to consider what constitutes great folk music. His work argues that, for many listeners past and present, an aesthetic of 'authenticity' trumps questions of conventional musical skill or high quality sound recordings. Adam's article also presents a great opportunity to get to know some eccentric yet fascinating musicians, so why not listen along as you read?

The Wadham Journal offers a platform for MCR students to share their research with the college community. As demonstrated by this eclectic issue, Wadham students study an enormous variety of subjects, and we hope to offer you a taste of this diversity each term.

If you would like to get involved, submit an article or share any of your academic achievements with your peers, then we could love to hear from you. Have you recently won an award? Published your own book? Started your own company? If the answer is yes, then please send us an email.

We hope you enjoy the issue!

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Broken Telephone: Information and volatility on the 19th century New York Mining Exchange

Michael Bridgman MPhil Modern Economic History

In his seminal 1965 work, Eugene Fama introduced the 'efficient market' to modern financial parlance and catalyzed a tremendous debate on the markets' ability to fully synthesize information into market prices. The efficient market is formally conceptualized as "a market where there are large numbers of rational profit maximizers actively competing, with each trying to predict the future market values of individual securities, and where important current information is almost freely available to all participants".

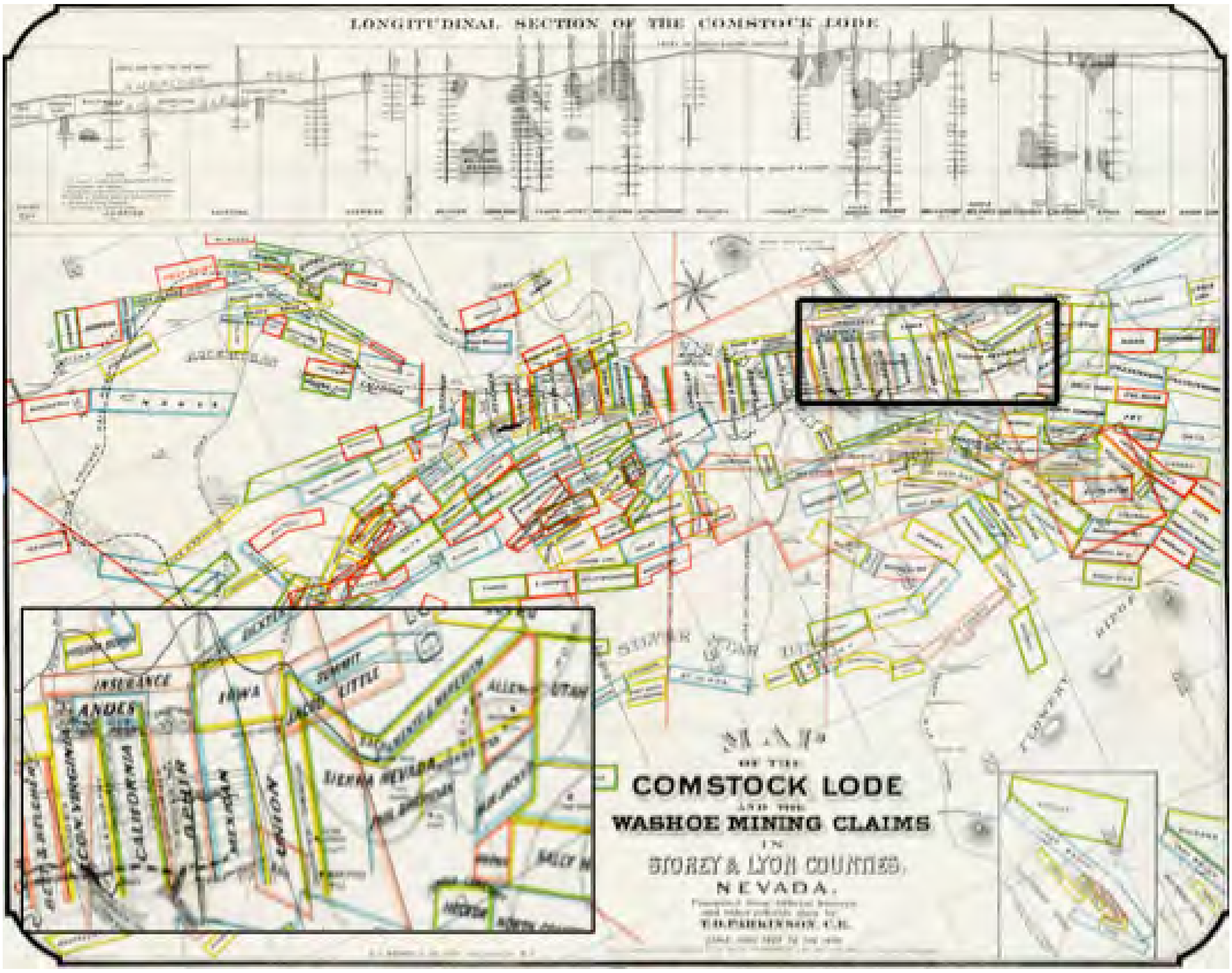
According to the efficiency hypothesis, such a market has as least two defining features; viz., all information contained in past prices is absorbed into the current price and "new information is instantaneously reflected in prices," thus preventing abnormal returns. Initially, this assertion regarding market behaviour found sustained support from Samuelson (1965), Mandelbrot (1966) and Fama, Fisher, Jenson and Roll's (1969) renowned study.

A decade later, however, and consensus around the EMH had weakened considerably. Numerous studies were published that found substantial anomalies in the market. Rozeff and Kinney (1976) show conclusively that markets exhibit seasonality in returns. Particularly, January returns are significantly lower than returns in any other month. Gibbons and Hess (1981), finding that even markets do not like Mondays, show that prices on Mondays are consistently lower than prices for any other day. Finally, Rendleman, Jones and Latone (1982) show that after an initial reaction, markets tend to drift in whichever ever direction the market originally moved; and Shiller (1981) and de Bondt and Thaler (1984) show that those initial market reactions exhibit "excess volatility". Clearly, then, markets react to other impulses – like Monday mornings – and not simply information arrival. Also, markets do not completely integrate the new information immediately and the continuous reinterpretation of information results in market drift. So the EMH does not hold up perfectly. But markets must react to information to some degree; how much volatility in markets is caused by investor sentiment and market micro-structure and what role information arrival plays is a source of continuing debate.

Finding numerous problems with trying to isolate the impact of information arrival in a modern context, Koudijs (2011) produces a brilliant study by using history as his laboratory. In the controlled environment of 18th century Europe, Koudijs finds an exogenous break in communication between London and Amsterdam that allows him to isolate the impact of price-relevant information on volatility levels. Following a similar methodology, my study leverages a telegraph workers strike in the United States in 1883. Using returns data for securities traded in New York and San Francisco, I am able separate the impact of information-induced volatility from volatility resulting from trade and other market factors on the New York Mining Exchange.

On 19 July at exactly 12 pm Washington, D.C time, Frank R. Phillips, a portly telegraph operator blew a sharp, shrill note on his nickel-plated whistle and thousands of telegraph operators across the United States stopped as one and walked out. This unprecedented display by organized labour against Western Union was, a month later, a complete failure. However, despite Western Union remonstrations to the contrary, for weeks the telegraph industry across North America was crippled. The impact that the telegraph had on 19th century financial markets is difficult to overstate. The ability to send and receive transcontinental messages within minutes, not weeks and transmit prices to practically every corner of the country revolutionized how financial markets functioned. So the loss of this essential service was devastating to the industry. But, happily for historians, the strike provides a useful, quasi-natural experiment.

Contemporary accounts of the strike do suggest that it was relatively severe. Messages took hours, and sometimes days to be delivered from the Midwest and California to the East Coast. And often, when messages did arrive, they were so inaccurate as to render them useless. In one more humorous example, The Washington Post quotes a South Carolinian state senator calling for the immigration of 2,000 Mormons to his state. The next issue of The Post contains an erratum column, stating plainly "he said Germans". Not all mistakes were harmless, however. Poor Mr. JD Lupher sent a telegram on the 24th of July to his business partner, Mr. CT Frazer, that arrived 9 hours late and was addressed to CJ Prusee – a completely separate person unbeknownst to either of the business partners. Mr. Lupher sued the Western Union for $500 dollars to recuperate the losses he sustained as a result of the botched telegram. More generally, exchanges across the continent were incandescent at the loss of business sustained from



the strike. From San Francisco to Montreal, exchange members signed memoranda and adopted resolutions denouncing the strike for its impact on business.

For this strike to be of any use in the context of financial literature, two conditions must hold. First, the shock does need to be exogenous – the break in communication cannot come as a result of market conditions, such as a recession. Second, and crucially, the flow of information from one market to another must be unidirectional. If price-relevant does not need a telegraph to be swiftly transmitted, then clearly, a telegraph workers strike provides no shock.

The striking body, the Brotherhood of Telegraphers, provides ample evidence that the strike came as a response to labour, and not market, conditions. Controlling over 90% of the telegraph industry, the WU certainly earned its nickname, 'The Great Monopoly'. It had used this monopoly power to cruelly crush a strike in the 1870s and force wages down for the following decade. The bill of grievances presented to General Thomas T. Eckert, the WU president, enumerated several wage-based demands. Namely, the Brotherhood sought performance-tied wages, with higher quality operators receiving more. Additionally, women were to be paid the same as men. This stipulation did not reflect the moral sensibilities of the operators; male telegraphers were merely afraid that the women, paid 20% less than men, would force male operators out of business. Finally, the operators demanded days fixed at 8 instead of 10 hours. Although, from this account, it is not impossible to rule out the possibility that economic conditions partly drove the strike, that the American economy had recently emerged from a recession and was growing in its wake, does suggest that the Brotherhood's concerns were exclusively with their treatment by the Western Union. The strike was exogenous.

In order to ensure that price-relevant information arrives in New York from elsewhere, I choose three Nevada mining stocks traded on both the San Francisco Stock Board and the New York Mining Exchange. Intuitively, price innovations could be expected to originate on the SF market before travelling across the country to merchants at the Mining Exchange in New York. I test this hypothesis in two ways. Using a vector autoregression (VAR) I find that NY returns for each stock are significantly and highly correlated with SF returns from the period before. This relationship does not hold for San Francisco – returns in the West are not correlated with previous NY returns. I also find that for all three stocks, SF returns cause NY returns, whereas the reverse is again not true. As a final check for robustness I calculate the Hasbrouck Information Shares for each stock on the respective exchanges. This indicator measures the relative importance of price innovations from the respective markets on the movement of each stock. For two, Union Consolidated and Sierra Nevada, a vast majority of information does indeed originate in San Francisco. Oddly, though, the price movements in New York are slightly more important than movements in San Francisco for the third stock, Consolidated Virginia. Nonetheless, I keep the stock as a control. For two of the three securities, information flow is unidirectional, travelling by telegraph to New York.

Having established that the strike was exogenous and that the New York Mining Exchange relied on information coming from San Francisco, I test what impact the strike had on volatility in the period. I do this by comparing the levels in volatility during the strike to an average level of volatility in the July-August period in 1882 and 1884, in order to account for seasonality. Two measures of volatility are calculated here: a simple ratio of variances approach and a comparison of kurtosis. The first measure simply takes a ratio of the average variance over the two periods and tests whether the result is statistically significant from 1. For Sierra Nevada and Union Consolidated, the ratios are 0.26 and 0.18, respectively. So, volatility decreased by 26% in the strike period for the Sierra Nevada stock and by 18% for Union Consolidated. Consolidated Virginia, less reliant on news from San Francisco shows an insignificant change in variance.

A comparison of kurtosis levels supports these results. Kurtosis measures how far removed from a normal distribution the data are. The level of kurtosis for a normal distribution is 3. The higher the kurtosis is, the more peaked the distribution is, and the thicker the tails are. For each of the three stocks, the levels of kurtosis are dramatically higher in the strike period when compared to the non-strike periods. Although it is somewhat strange that this pattern holds for Consolidated Virginia, it is likely driven by an anomalous stock assessment that resulted in a sharp, one time increase in the price of the stock. These results fit nicely with the story of the strike. The high peaks of the distribution indicate that returns were near or at zero for most of the strike period. While the long, and thicker tails reflect the price lurches resulting from the sporadic arrival of information. These kurtosis levels fit quite neatly with the expected impact of a widespread, but incomplete strike.

The Telegraph workers' strike was unprecedented in its scale and in its impact. Bankers and merchants had become completely reliant on the telegraph to conduct their business. For many, the strike left them without knowledge of prevailing securities prices on other exchanges and generally without information relevant to the pricing of a security. The cause of misery of 19th century financiers does have a happy 21st century outcome, however, in that the strike period provides fertile ground for a study on information-driven volatility devoid of many of the methodological problems faced by studies focused on the Information Age. The results from this study do largely conform to the literature, indicating that the arrival of information drives a significant portion of volatility levels. However, the majority of returns volatility is a function of other factors, including the markets' 'Animal Spirits'.

The mechanobiology of tendons

Russell Tucker DPhil Biomedical Engineering

Imagine you are on your morning run, or even just running for the bus. You are seamlessly putting one leg in front of the other, bobbing along, and listening to the most recent release from this week's chart toppers. Your body feels fine and this jog isn't too taxing; however, under the surface a cannonade of mechanical stress is putting your bones, cartilage, ligaments and tendons through their paces. These components of your body are known as musculoskeletal tissues and are at the heart of mechanobiology.

So, what is mechanobiology? Wrist bones of tennis players become thicker; Arnold Schwarzenegger's muscles were huge; and the bones of astronauts become weak and brittle. These are three of the best examples. They are evidence of bones and muscles responding to mechanical forces such as the thump from a 100mph tennis ball, or even the removal of gravity. Understanding how our bodies respond to mechanical forces is essential for the development of new clinical therapies, or for targeting new drug sites. After all, mechanical stimulation such as physiotherapy can improve joint strength, but what if we could achieve the effects of physiotherapy by just swallowing a pill?

You may be wondering why I focus on tendons. Well, tendons have been a bit like bow ties in the 21st Century. They have been unloved and discarded as scientists pursue sexy bone research funded by arthritis and cancer charities. Now that bone research has helped solve problems such as osteoporosis (porous bones), the miracle cure of bisphosphonates having been discovered in the very building I work in, research attention is starting to swing and bow ties (tendons) are coming back into fashion (see picture of yours truly). Some might think it is because David Beckham tore his Achilles' during a football match (figure 1), but this is only partly true. Tendon damage is hugely debilitating and incredibly painful (figure 2). It can take twelve months for a person to resume their normal routine after a rupture and even then, they are highly susceptible to a re-rupture as healed tendon is never as strong as it once was.

Figure 1: David Beckham ruptures his Achilles', destroying his World Cup dreams.

For a mechanobiologist (a person who fuses biology with engineering), tendons may make the ideal tissue to investigate. From an engineer's perspective, they are a bit like a rope in structure, connecting muscle to bone, and are therefore a good tissue to build models of in varying layers of complexity. From a biologist's perspective, little work has been done, and so there are plenty of opportunities to find new discoveries. Bridging both fields is often problematic, but could lead to huge advances in medical science.

Fig2: Fashionable tendon injury.

My research concentrates on just one aspect of tendon stimulus: fluid flow. Tendon sections called fibrils form the overall rope-like structure and in between them sits plenty of liquid that has properties similar to water. As the tendon experiences pulling, the fibrils slide causing tendon cells that sit on the fibrils to be dragged through the liquid. Have you ever stood in the sea and felt the waves rocking you forward and back while your feet stay still? That is the type of force experienced by the tendon cells and it is called fluid-induced shear stress.

Tendon cells are responsible for keeping the tendon healthy. The fibrils are made of collagen and cross-linked by proteoglycans. When there is damage, tendon cells respond by making and secreting new proteins (collagen and proteoglycans) to repair the damaged site. On a day to day basis, tendon cells will maintain the tissue by repairing any micro-damage that might occur, for example in your fingers when you type or write too much, or in your shoulder after a particularly strenuous rowing session.

Of course, this proposes a question: how do cells know what repair to do and when? The answer is that we don't know. Cells are incredibly complex. They have a variety of sensors in order to assimilate information from their surroundings. These sensors might detect a change in chemical concentrations, or in the exciting world of mechanobiology, they might detect a force. Sometimes, somewhat frustratingly for a researcher, they even do both. Detecting the force and passing it on to the nucleus (cell control centre) is the process of mechanotransduction and cells are equipped with a variety of transducers just for this purpose.

So which transducer detects fluid flow? Is it just one, or are there two, or maybe even ten? It is my hypothesis that each and every tendon cell has a small organelle called a primary cilium and that this structure is largely responsible for flow detection (figure 3a). The cilium protrudes proudly from the cell surface like a hair standing to attention. In figure 3b, I have stained the nucleus of a human tendon cell blue and stained the primary cilium red. The cilium can vary in length and in this case the primary cilium is huge – almost the width of the nucleus! Its role is not very well understood, especially in tendon, and I believe that this structure bends under flow conditions and sends signals to the nucleus to cause the secretion of new, tendon re-building proteins.

By understanding how the cell responds to fluid flow, it might be possible to fake these conditions in the body using drugs. This could cause healing proteins to be secreted and the regeneration process to speed up, which would mean that the likes of David Beckham would be back on the pitch quicker, and the whole world would be a much happier place.

In order to investigate how tendon cells respond to fluid flow I developed a new method of stimulating and accurately testing cell response to fluid forces.

A see-saw rocker was set up in a humidified incubator (figure 4a) and a layer of tendon cells seeded in a cylindrical dish (figure 4b) was subjected to fluid rocking over the top of them. As well as providing the nutrients that the cells need, the fluid rocks backwards and forwards over the cells and generates a shearing effect (just like the motion of the sea discussed earlier). Figure 5 is a side profile view of the dish with a central plane showing the depth of the added media (white) and its movement during one complete cycle. The base of the dish is also shown with a colour coded map of the shear stress.

Accurate shear stress maps at the cell layer were achieved using computational fluid dynamics (CFD); CFD is a modelling technique that requires the simplification of a problem and the development of certain assumptions that determine the fluid behaviour. These assumptions therefore need to be validated to ensure that the forces detailed in the CFD solution are representative of the real-life scenario. Validation was achieved in collaboration with the Zoology department using their particle image velocimetry (PIV) equipment. PIV is used by the Zoology team to capture the velocity patterns generated from the wing motion of dragonflies (figure 6) and so this application was slightly unconventional!

The rocking dish was seeded with 48 micron fluorescent spheres in order to capture fluid motion, (to give you an idea of size, 48 microns is approximately the diameter of a human hair). A laser created a 2mm sheet through the centre of the dish ensuring only microspheres sitting within the sheet were detected by high speed cameras, taking 2000 frames a second (figure 7).

From the acquired images, it was possible to work out the speed and direction of individual microspheres which was then directly compared with CFD modelling. This comparison showed similar velocities and therefore confirmed an appropriate selection of assumptions within the CFD modelling. This subsequently validates the shear stress maps which are derived from flow velocities.

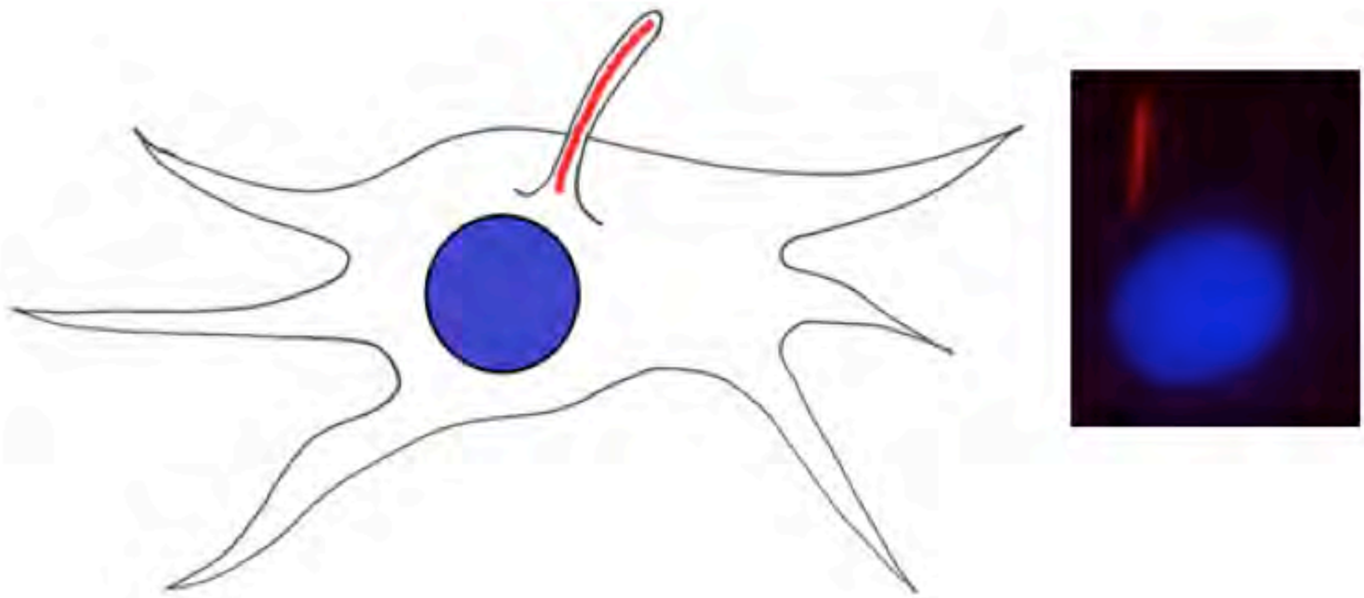


Figure 3: 3a (left) tendon cell cartoon. 3b (right) human tendon

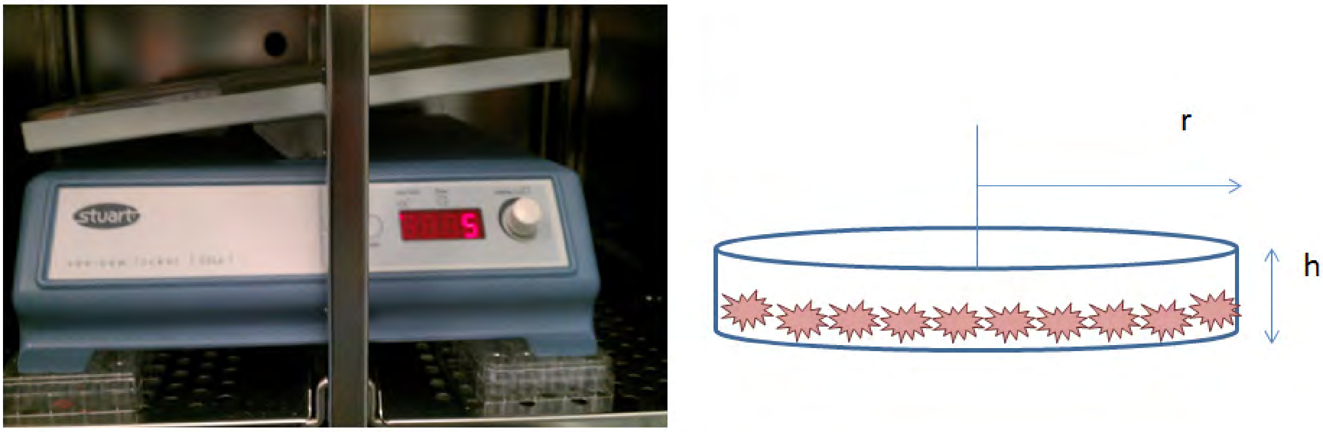


Figure 4: 4a (left) see-saw rocker placed in a humidified incubator. The incubator provides conditions similar to the human body, i.e. temperature of 37 °C and 5 % CO_2. 4b (right) tendon cells (red) are placed in a single layer at the base of a dish and covered in liquid.

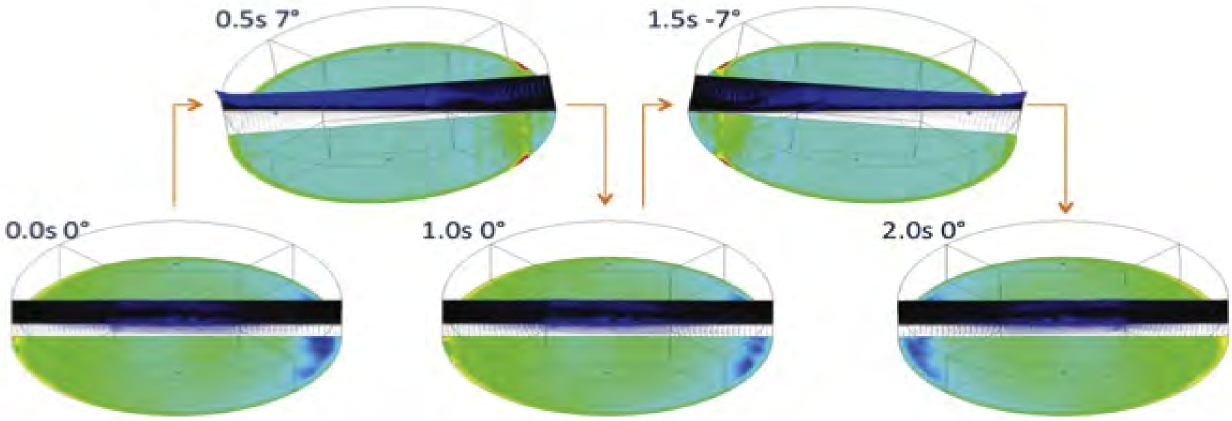
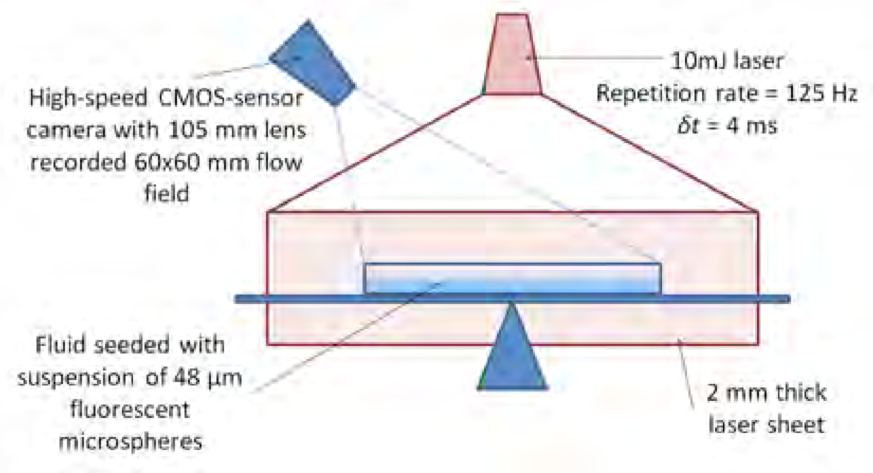


Figure 5: From left to right, the images show one cycle at 30 RPM. The CFD allows the modeller to identify accurate shear stresses in exact locations. Annotations on each image detail the time and the angle of tilt of the rocker. The maximum tilt that can be achieved is ± 7 °.

Figure 6: A dragonfly

Figure 7: PIV experimental setup.



So that is the mechano part sorted. Now for some of the biology…

Collagen secretion was measured in two tendon cell cultures after exposure to 48 hours of stimulation and 7 days of stimulation at a rocking frequency of 5 RPM. Figure 8 shows that an application of fluid-induced shear stress significantly increases the level of secreted collagen at the cell layer. Furthermore we can see that although cells stimulated for 7 days secrete more collagen than those stimulated for 48 hours, they do not secrete 3.5 times the amount. There are clearly mysteries to be solved.

Other work (not shown here) involves the chemical removal of the primary cilium to ascertain the impact on cell response to fluid forces. Perfecting this technique is currently on-going. I am also working in collaboration with several groups across Oxford as well as Queensland University of Technology and Sheffield University to produce joint publications on other tissues.

There is still much to be done, but that is what makes tendon mechanobiology such an interesting world to investigate. One day, we might be able to fix David Beckham's Achilles' overnight.

Now that would be exciting…

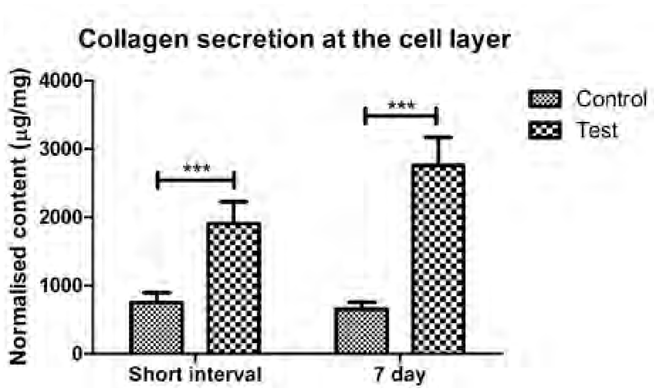


Figure 8: Secretion of collagen at the cell layer. Cells subjected to fluid flow significantly increase the amount of collagen secreted in comparison to controls. Stimulation for 48 hours (short interval) and 7 days are shown. Values have been normalised to cell number using double stranded DNA content.

Soft, flexible, and under control

Liyu Wang Dr Sc Biomedical Engineering

In the past 50 years, robotic technologies have increasingly benefited our society by automating more and more tasks, from mass production to domestic cleaning. Most of the presently deployed robots repeat predefined tasks in certain environments, offering higher efficiency than human beings.

While being faster and more precise, conventional robots are far inferior to us in terms of adaptability to changes in tasks and environments. For example, a Roomba©/TM cleaner cannot function reliably once the floor is covered with various objects, and an industrial robot arm will find it impossible to carry out tasks for which it is not pre-programmed.Since robots are a type of machine that interacts with the real world, an ultimate goal of robotic technologies is to enable these machines to cope with rich dynamics of the changing world independently of the programmer.

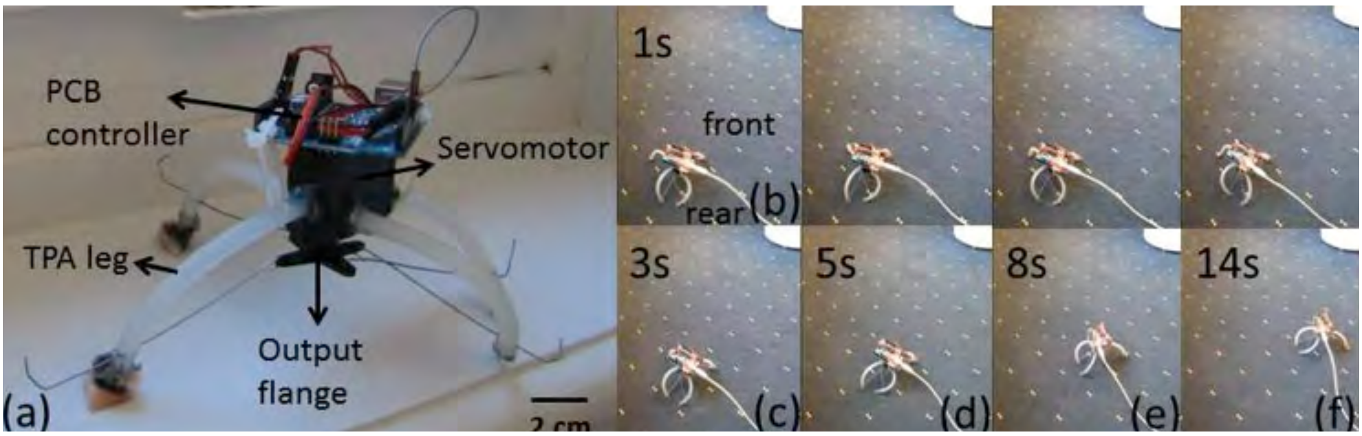
To make robots adaptive and autonomous, engineers have been attempting to implement techniques from 50 years' research in artificial intelligence (AI) to controllers of robots. Many exciting results have been shown using AI techniques such as evolutionary computation, machine learning, and simultaneous localization and mapping (SLAM), etc. Such learning algorithms allow a robot to be able to continuously infer its state in unknown environments based on sensory feedback. One of the latest examples is the demonstration of self-driving cars.

Intelligence at the physical level

Despite the progress in 'higher-level' functions, the level of adaptability of a robot is physically bound by its mechanical structure, which is conventionally rigid and fixed. In contrast, animals and plants have flexible body structures in the sense that, they start small and grow larger and stronger, replace damaged parts, and some even have several morphologies during their life time. In addition, their bodies contain 'soft' elements such as skins and muscles. These characteristics make it possible for living organisms to adapt to changes in their biological niche, e.g. for conquering complex terrains, responding to changes in environments, and ultimately for survival and reproduction.

Inspired by biological systems, a number of roboticists have been studying how the 'low-level' functions can help make robots flexible and adaptive. Several concepts have been proposed including mechanical intelligence, morphological computation, and embodied intelligence, (Pfeifer, Lungarella, and Iida 2007). In terms of technologies, robotic systems consisting of multiple mechatronic modules have demonstrated self-reconfiguration from chain-like structures to wheel-shaped or legged structures (Yim et al. 2007); and use of elastic elements such as simple springs has shown energetically efficient locomotion (Collins, Ruina, Tedrake, Wisse 2005) and impact reduction (Albu-Schaeffer et al. 2008), etc. Although these bio-inspired robotic technologies might mean a sacrifice of precision, they have created the possibility of robots coping with rich dynamics which cannot be pre-determined,

Figure. 1. A quadruped robot walks with a single motor and four legs made of TPA. (a) The quadruped robot Monomo. (b) Snapshots showing two steps. In the first step, the front left and the rear right legs move forward. In the second step, the front right and rear left legs move forward. (c-f) More snapshots of walking. The turning was caused by the force exerted from the USB power cable.



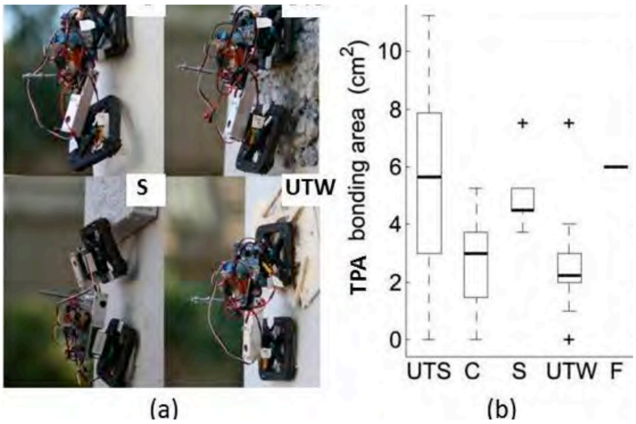


Figure. 2. A biped robot climbs in complex vertical environments with TPA bonds. (a) Four examples of complex vertical environments with their labels. (b) Result showing TPA bonding areas on five types of vertical environments. (F represents a flat vertical surface).

and thus have applications for tasks such as exploration into the unknown, new types of transportation and tasks involving physical interactions with human beings, etc.

Soft robots

Within the last decade, there has been increasing interest in using soft materials in robots. Although no agreement has been reached as to which materials are soft enough for robotics, it is safe to include those whose Young's modulus is under GPa level. These soft materials were used as actuators and/or body frames in robots, and by exploiting intrinsic material properties mechanical intelligence can be realized without complicated mechanisms. For example, electroactive polymers were used to actuate a quadruped robot, a gripper, and an artificial whisker; silicone rubbers were used as body frames of crawling robots, continuum manipulators, and a capsule endoscope robot, etc. Adaptive behaviours of these soft robots usually occur at the same time scale in the same place as the physical interaction, the so called 'here-and-now'. This is because the materials have a low yield stress, a large yield strain, and a large elastic region in response to external forces. With a small force, they can stretch quickly to conform to complex environments during interaction, and return to their original shape upon the release of the force.

I have been studying how to exploit soft materials to enhance the flexibility of robots by realizing adaptive behaviours at multiple scales. In this article, I will first present a simple case study related to the here-and-now scale aforementioned, and I will then take a step further to introduce two case studies on larger scale where parts of a robot can be automatically and permanently changed for multiple tasks or environments. Throughout my research, model material thermoplastic adhesive (TPA) has been used since it is cheap, easily accessible, and it has many interesting properties for robot tasks which will be explained along with the case studies. In the case where permanent change was needed, two thermo-mechatronic devices that can automatically hand the TPA material were included in robots. Further technical detail about the two devices, naming TPA Supplier and Thermal Connector, can be found in Wang and Iida 2012.

Flexibility at different scales

At the here-and-now scale, a robot called Monomo was built for demonstration of quadruped walking with only one actuator. As Fig. 1a shows, the centimetre scale robot consists of a position controlled servomotor, a print circuit board (PCB) controller generating a simple periodical signal of motor angles, and four cylindrical legs made of TPA. The four legs are connected at one end to the servomotor with an angle of 90° between neighbouring legs, and at the other end to the output flange of the servomotor through metallic tendons. The robot is powered by a USB cable linked to a laptop. Despite a very simple control signal of periodical rotation between 0 and 180°, Monomo managed to walk towards one direction on flat ground surfaces such as a coated chip board table and a carpet as shown by snapshots in Fig. 1., which would not have been possible without elasticity of TPA at room temperature. This is due to Young's modulus of TPA being between 10 to 100 MPa, and with a given length and diameter of each leg, the rotational motion of a single servomotor can cause deflections that make one pair of legs move forward, while the other pair move backward. The forwarding legs will go into a swing phase until they touch the ground again, while backwarding legs remain in a stance phase and exert forces onto the ground to generate static friction forces to avoid slipping. This case study shows that mechanical intelligence from the use of TPA can reduce the control complexity and actuation power assumption in patterned behaviours.

On a larger scale, where permanent change of body structure is needed for conformation, the plasticity of TPA can be exploited with the addition of devices that automatically handle the material. In a first case study, a robot called ThermsBond was built for climbing in complex vertical environments. Such environments contain macroscopic irregularity on vertical surfaces and are beyond the capability of existing climbing technologies. Four examples of such environments and their labels are shown in Fig. 2a, with the robot being attached in them with TPA. The 1.4-kg biped robot includes a number of Thermal Connector devices in each of its feet, which can repeatedly heat and cool pre-supplied TPA to induce phase transitions between solid and plastic. Further technical detail about design and control of the robot can be found in Wang, Graber, and Iida 2013. The fundamental working principle here is as follows: Upon heating TPA, the material becomes adhesive and plastic, and by pushing against the environments, the rheological properties of TPA enable it to conform the irregularity by filling gaps; then upon cooling, solid TPA bonds can be formed between the robot feet and the environments. The bonds offer shear forces to counter the weight of the robot and potential payload, and their magnitude is determined by the bonding area. Fig. 2b shows a boxplot of the resulting bonding area out of ten trials of a single-step climbing in each of the four environments plus a flat vertical surface (labelled as F) using the same amount of TPA. The result indicates that the median value of bonding area is the highest on a flat vertical surface, and the lowest in the environment UTW, which reflects the level of irregularity in the environment. Because the bonding strength of TPA at room temperature is as high as 1 MPa, 80%-100% of the trials succeeded in holding the robot's weight, and a payload-to-body-mass ratio of 500% has been achieved on a flat vertical surface, which surpasses all existing climbing technologies.

In a second case study at the larger scale, a technology called 'robotic body extension' was developed for versatile manipulation. Previous robotic systems for automatic manipulation of various objects include switchable tools such as ones used in machine tools, universal grippers, and dexterous robotic hands, etc. The approach we adopt takes one step further by enabling a robot to automatically form its own end effectors and integrate them into its existing body structure. In this way, the manipulation capability of a robot is no longer limited by its storage of switchable tools, nor constrained by the size of the grippers or hands. In more detail, a conventional robotic arm was modified by adding the two (aforementioned) TPA handling devices at the tip of the arm. Automatic formation of different end-effectors is enabled by a fast prototyping technique for thermoplastics, called Fused Filament Fabrication. With this technique, the robotic arm follows preprogrammed trajectories for different structures to deposit melted material from TPA Supplier point by point and layer by layer. Formed structures are later automatically connected to Thermal Connector as the end-effector of the robotic arm. Snapshots of an example scoop-shaped end-effector can be found in the news report Wrenn 2012. Technical detail is available in Brodbeck, Wang, and Iida 2012. Further demonstration shows that a robotic arm can form other end-effectors such as a compliant two-fingered gripper, and each structure can be adjusted in size. Our overall results suggest the technology can enable a conventional robotic arm to pick and place liquid, granular material, to rigidly solid macroscopic objects, covering a larger range than previous systems. One of the drawbacks of our approach is the time cost of structure formation, since it usually takes over half an hour to form an end-effector with a dimension of several centimetres.

Through the above case studies in robotic locomotion and manipulation, I hope I have delivered the message that mechanical intelligence of soft materials can simplify the design and control of robots for flexible behaviours in different scales in changing task-environments. By exploiting various properties of a single model material TPA, I have shown the capability of soft material in pushing the boundary of robotics. There are, of course, many challenges ahead in this research area in general, for example, how material modelling can contribute to more precise control of soft robots, and how higher-level learning algorithms could enable robots to autonomously determine what body structure is needed, etc. Solutions to these problems can be expected lead to increasing applications of these robotic technologies.

Reference

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‘Wonderfully awful’—Lo-Fi Pop Music and the Taste for Bad Recordings

Adam Harper DPhil Music

What makes the best folk and rock music so good? For many fans, perhaps most of them, it’s authenticity – the idea that the music is real, honest, and without compromise. And what makes the music so authentic? It’s that the music comes from the recesses of culture and the depths of the soul, sometimes warts and all: unpolished, rough, raw, dirty, maybe even ugly. Occasionally these hallmarks of authenticity extend even further, into the naive, the brutal and the barely coherent. Sooner or later, then, there comes the odd notion that the best folk and rock music is so good because it’s so ‘bad’. This is the paradox of ‘lo-fi’ popular music.

‘Lo-fi’, an abbreviation of ‘low fidelity’, is a term that has been regularly applied to alternative and underground popular music since it first began to appear in the early 1980s. At first it was used by music writers as a criticism and a warning to prospective listeners, but it soon became a term of affection and even celebration, representing not just symptoms of poor recording quality such as the hissing, distortion and muffled sound of cassette tapes, but a whole ethos of music-making heroically opposed to the standards of professionalism in the mainstream music industry. Folk art and music that appears ‘imperfect’ – nobly savage – in relation to the aesthetic norms of industrialised culture has been valorised in this way since at least the early nineteenth century, and this Romanticist sentiment finds one particular modern manifestation in a fondness for imperfections in the recording process that can be traced back to the 1960s.

In that era and before, the sonic drawbacks of using a makeshift field studio or reel-to-reel tape machine to record folk and blues music out in the sticks were a small price to pay for the (supposedly) pure, untouched, historic and, most importantly, authentic music they captured. Yet sometimes those sonic drawbacks came to represent the sound of authenticity itself, as what could have been a mere aural association transformed into a symbol of great and endangered music itself. Not only was this aesthetic

Figure 1 Daniel Johnston

often applied to the recordings of old interwar blues singers like Robert Johnson or those made or compiled by folk song collectors such as Alan Lomax and Harry Smith, it began to seep into new popular music too. Bob Dylan's bootlegged 'Basement Tapes', recorded in the singer-songwriter's home on a reel-to-reel machine in 1967, have a sketchy sound quality at best, but they became an underground phenomenon, hailed as some of Dylan's most precious material, and later described by the music critic Greil Marcus as evoking an 'old, weird America'.

However, it's after multi-track cassette recorders became so widespread and affordable in the late 1970s, permitting a kind of musician christened 'home-tapers', that a Romantic fascination with the social, cultural and aesthetic distance represented by popularly recorded 'lo-fi' music begins to take root, and when its paradox of great 'bad' music finds its most pronounced expression. In fact, the growth of lo-fi pop music in the 1980s is central to the beginnings of a non-commercial or independent ideology in pop music and the 'indie' tradition that subsequently developed. Yet looking at the genial guitar bands of today's more commercialised indie music, it's easy to miss the major role played by frequently acerbic punk philosophy and the growing popularity of avant-garde and other unconventional musics in establishing lo-fi recording as not just a necessary evil that allowed music to be made and disseminated, but a meaningful and valuable aesthetic experience in itself.

Some key figures to have prepared the way for the lo-fi aesthetic's combination of avant-garde and punk and the idiosyncratic idioms of so-called musical 'outsiders' were Frank Zappa, Captain Beefheart and founding member of Pink Floyd, Syd Barrett. Their blend of arty, freewheeling surrealism and vernacular music on intimate and sometimes erratic recordings saw the beginnings of a 'so bad it's good' attitude that is sometimes given the name 'anti-folk'. Soon musicians, music critics and fans were beginning to find and celebrate figures from the past that they retroactively incorporated into this 'outsider' punk movement. Brought into wider underground attention were groups like the Shaggs, a girl band from the late sixties whose one album was a particularly marked example of conventionally inexpert musicians making it onto record. The eighties fashion for a punk-like take on rockabilly music called 'psychobilly' was spearheaded by new band The Cramps, but they and their fans drew inspiration from Hasil Adkins, a fearsome one-man-band rock-n-roller who messily recorded songs about hotdogs and decapitation (sometimes both together) in his shed in the early sixties, and other country music eccentrics like The Legendary Stardust Cowboy, whose most famous song was entitled 'Standing in a Trashcan (Thinking About You)'. For some, all this music was a gritty, slimy, shambolic, often ironic, all-American foil to the po-faced sincerity of the aging folk music scene, to slick mainstream pop dominated by power-ballads and New Romantics and their 'yuppie' fans, and to the political frustrations of the Reagan years. And yet at the same time, for many listeners this music was truth and sincerity itself, and thus exceptionally valuable, however challenging and unpalatable.

Figure 2. Drawing by Daniel Johnston

While there were plenty of music critics who wouldn't put up with a shoddy recording, it's nevertheless around this time that the aesthetic paradox of lo-fi music begins to appear in the writing surrounding it. In 1985, one reviewer in Option magazine described the album Tea Room by a band called Crawling With Tarts as 'creepy low-fi minimalist garage experimental pop', proudly adding, 'that's a compliment'. For Sound Choice magazine in 1986, W Mueller said of a cassette by Balcony of Ignorance that it was 'probably recorded on a cheap walkmate style recorder. It's awful – wonderfully awful'. In the same year for the same magazine, noting that it was recorded 'in the kitchen' and that it featured 'incompetent musicianship', Jeff Wechter nonetheless concluded about The Dave's album Lois, 'I like this cassette a lot'. Also for Sound Choice magazine, in 1987, Brook Hinton described a cassette by Gunni as 'poorly recorded, at times unbearable but in the end utterly charming,' summing it up as 'derivative, damaged, and delightful'. And tellingly, back in 1985, writer Mykel Board begins a page of reviews by announcing that he won't make 'value judgements' on them, in an apparently passive concession to musicians unable or unwilling to match conventionally professional standards of taste and ability. Yet an active value judgement is precisely what he makes when, five hundred words later, he describes a compilation tape, indicatively called Flowers from the Dustbin, as 'raw and amateur in the best sense of the words'. 'Raw' was an especially popular descriptive term, as was 'primitive', 'cheap', and, collapsing honesty, modesty, provincial colour and the home-recording context too, the colloquial American phrase 'down home'.

It was in this atmosphere that a number of new lo-fi bands and musicians accrued an ecstatic cult following. One of the first to emerge was the figure known only as Jandek. Starting in 1978, this prolific but anonymous musician released album after album of a cold, haunting voice singing darkly surreal lyrics over detuned guitar. There was almost no personal information available about who Jandek was, why or how he did what he (or they) did, and by the mid-80s, the Jandek enigma had become a sensation. His records were described as 'torturous', 'discordant, out of tune, delirious, rambling and raging', 'dyslexic', 'sloppy', 'cacophanous', and yet such descriptions were almost always part of a review or article that expressed the utmost praise and regard. Such was his significance that the editors-in-chief of both Sound Choice and Option almost always reserved the pleasure of reviewing his records for themselves. 'Each Jandek release is perfect' was the surprising opinion of Sound Choice's editor David Ciaffardini. Elsewhere, he wrote 'it might sound like a mess, like a lost cause, but it's real, so real… the imperfections, the clumsiness… the music is beautiful, flesh and blood real, frail, imperfect, pathetic even, but human; music that you rarely hear but is always all around.'. Perhaps most interesting was how the almost total void of information surrounding Jandek gave ample room for the Romantic imaginations of music writers, which carried all kinds of assumptions about what sort of person might make Jandek's music, how and why. Nearly every writer assumed that his music served as a cathartic expression for strong and potentially terrifying emotions, or 'demons'. Others apparently thought nothing of assuming that Jandek was oblivious to contemporary music, that he was a member of the working class by day, that he was mentally ill, and even that the room he records his music in was 'bare and dusty'.

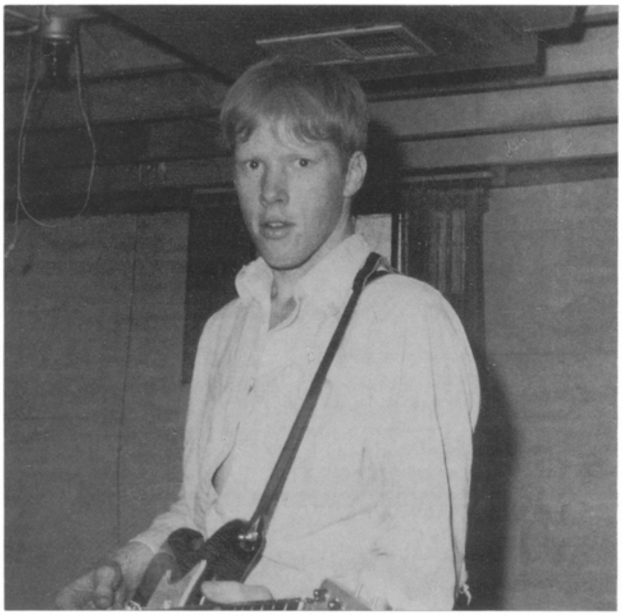

Figure 3. Jandek

Now of course, a lot of this fascination with artists like The Shaggs, Hasil Adkins and Jandek could be considered dubious – patronising, insensitive, mocking, and exoticising, even if unwittingly so. One artist in particular has been the subject to this kind of attention: Daniel Johnston, a home-taping musician whose rise to considerable fame in the late 80s coincided with debilitating episodes of bipolar disorder and schizophrenia. Johnston's considerably low fidelity recordings and inexpert playing ran alongside his obvious aptitude for melody and imaginative lyrics. The music blurred together with the figure and narrative of Johnston himself, his struggle against technological and technical shortcomings becoming an auditory metaphor for his struggle with mental illness and contemporary musical taste, and so was heard to be brimming with pathos, even tragedy.

Cashbox magazine called it 'the purest, sweetest cry from the heart of a musician that you are ever likely to hear'. In Sound Choice, cassette guru Robin James wrote of 'the master of crude recording and passionate songcraft… his clear angelic and hurtful voice buried in lo-fi hiss'. One writer for Melody Maker even went so far as to say 'listen carefully and you could become a better person'. Constantly referred to as a 'genius' and admired for his supposed innocence, writers made assumptions about Johnston similar to those projected onto Jandek, to the point where editors had to insert corrections. When one writer described the music as 'pure, simple, honest, with absolutely no pretensions of grandeur', Ciaffardini inserted 'Actually Johnston has said he wants to be more popular than the Beatles – ed.'. Ciaffardini's own first review of Daniel Johnston was an extended, ecstatic and angry declamation: 'You hear more emotion and raw nerve than you will hear from a million dollars worth of studio equipment, a million dollars more… Somehow, the long lost, painfully simple, emotionally unfathomable, demon infested, gut-twisting, brain-seething blues that struck Robert Johnson has infected Daniel Johnston, and it has hit him hard, possibly a mortal wound… Daniel offers something Springsteen doesn't: stark first person, all-American personal reality.'

As the late 80s became the 90s, a number of early indie bands with lo-fi beginnings became famous, either anticipating or following in the wake of the phenomenal rise of the 'grunge' rock band Nirvana, such as Beat Happening, Throwing Muses, Guided By Voices, Pavement, and Sebadoh. But the new media and industry attention to the alternative or underground scenes that followed Nirvana was displacing the need for or interest in home-tapers. The scene became more fashion-conscious, and fashions were changing. With the rise of the CD bringing with it a new degree of high fidelity sound, and the growth of dance and electronic music, lo-fi pop was driven much deeper underground.

Figure 4. The Shaggs album cover for 'Philosophy of the World'

So underground, in fact, that it exploded into fashion again in the late 2000s, this time among an indie scene now known up and down Western culture - for better or worse - as 'hipsters'. In the era of the CD and the mp3, the sounds of cassettes became more evocative than ever before, signifying not just cultural distance but now, specifically and overwhelmingly, nostalgia and the past. As a result, the new lo-fi home-tapers almost always imitated pop-musical styles from the 1970s and 1980s, often to the point of caricature.

This time, the sonic drawbacks of cassettes were much less the path of least resistance to releasing music, more an affectation, deliberate to differing extents, and a key part of the musical content itself. One of the first and most prominent musicians was Ariel Pink, whose sweet 1980s pop melodies were muffled in heavy tape noise, as if they'd just emerged from a badly sealed time-capsule buried in a back yard in Los Angeles. The rich new lo-fi scene that followed him found dozens of ways of bringing back the 80s, from the idiosyncratic synth-pop of John Maus to the trance-like funky muzak of Rangers and Matrix Metals, and from the grimy pop-art collages of James Ferraro to the deep, frail R&B of How To Dress Well.

Recently bringing me to the Library of Congress in Washington DC for a six-month AHRC placement, my research on the story of this fascinating, fifty-year long 'lo-fi' aesthetic and its development alongside the underground tradition has both refreshed and challenged the kinds of meanings I look for in popular music.