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Contents

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Introduction

From the Head of Scholarship

"Study hard what interests you the most in the most undisciplined, irreverent and original manner possible." *R. Feynmann*

The works of scholarship contained herein have nothing to do with examined curricula or taught materials, and everything to with the individual and singular academic passions of their gifted authors, and the considerable independent research required to produce them. Works in this publication are current in their topic, contrary in their stance and complex in their nature; they range from race relations in modern America to local environmental activism, from poignant poetry to complex mathematics and illustrate just what it means to exhibit our core value of *scholarship*.

Education is *so* much more than a series of examinations – and this publication shows that to us, at this school, a sense of learning for its own sake, and for sheer enjoyment is very much alive and well. I hope you find these works thought provoking, sometimes challenging and above all most interesting to read.

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Ocean pollution

As published in the Guildford Environmental Newsletter

Janek Czarnek

In the modern world pollution in the ocean, particularly that of plastic, is becoming a large issue when it comes to marine eco systems, as well as the aesthetics of the oceans, seas and beaches. Plastic is used in many products and often ends up getting dumped in rivers or falling from ships. Other sources of ocean pollution include oil from large ships carrying crude oil; when it washes up on beaches it can kill marine wildlife such as seabirds and affect local economies and tourism. In addition, fertilisers used by farmers wanting to maximise their crop production get into rivers and can eventually cause eutrophication.

However, plastics can cause harm in many ways to the environment, both as pieces of plastic in rivers, seas and oceans but also increasingly as microplastics. These can be eaten without intention to do so, these can then be in turn digested by predators of those animals, and can cause the death of a lot of wildlife. In 2014 it was estimated that there were between 15 and 51 million individual pieces of microplastics in our oceans, which proves that this is a largescale global issue that needs to be addressed to prevent great harm to marine ecosystems. Larger coloured pieces of plastic are also eaten by marine animals as they believe it to be food, instead it fills their stomachs with plastic and leads to death. This can severely damage the marine ecosystem, being the cause of death of millions of creatures each year. This applies in particular to albatross chicks on Midway Island that have died as a result of being fed pieces of plastic by adult birds.

To prevent this from continuing to happen we need to control and reduce the amount of plastic used and to monitor where it goes afterwards; we need to further current laws and to implement new laws to ensure this is controlled. Perhaps some sort of plastic tax can be put in place by governments across the globe to discourage and lower the usage of plastics. Instead we should be using materials that can be disposed of or recycled without causing harm to our environment and the oceans. If steps are not taken soon, we risk permanent damage to marine ecosystems as well as affecting our own fishing industries and the aesthetics of the ocean. We have to act now.

Were the germanic invasions a cataclysm *for the* Western Roman Empire?

Winner of the Peterhouse Cambridge Vellacott History Essay Competition 2019

Alexander Norris

The Germanic invasions, coming in a period of Roman history which immediately preceded the Fall of Rome, can be identified as playing a part in the problems the Western Roman Empire faced before its demise; however, these have been explained as merely an intensification of underlying faults within the Empire which were merely waiting to be exploited. Such faults include the political instability within the Roman state (when Roman politics in the absence of any strong authority degenerated into a power struggle), the changing nature of Roman attitudes towards immigration (which could allow for the accumulation of unsatisfied communities which could then be incited to rebellion, undermining the Empire), and the inherent necessity of local support for Roman rule (which, once that support was attenuating, would lose its control over those areas). On the contrary, though, each of these– rather than being an underlying liability intensified by the force of the invasions – in actual fact would not have been a liability if they had not occurred, and so the invasions themselves were together incredibly significant in the issues the Western Roman Empire faced. Further, a cataclysm is defined by the Oxford English Dictionary as 'a sudden violent political or social upheaval' – although it is largely undisputed that the Germanic invasions had extremely wide-ranging socio-political consequences in the Western Roman Empire, and that they were at least partly carried out with violence, their suddenness is disputed. Nonetheless, while it did take some time for their consequences to fully develop, and the invasions themselves were part of a wider trend of barbarian immigration, the upheaval that came as a direct result of them was so widespread and rapid in its short-term effects that the term 'cataclysm' can justifiably be applied to the Germanic invasions of the Western Roman Empire.

Previous to the time of the invasions, there had been a history of Germanic tribes, in particular the Goths, being generally hostile to the Roman Empire since the beginning of the Cimbrian War in 113 B.C., but after a major defeat at the hands of Emperor Constantine the Great in 332 A.D. there had been a period of widespread peace; in 376, though, two Gothic tribes of considerable size appeared on the bank of the river Danube (the traditional Roman border) seeking asylum. These, known as the Thervingi and Greuthingi, were apparently fleeing the onslaught of the Huns, a nomadic Eurasian people who were increasing their control over Eastern and Central Europe to the detriment of the mostly Gothic population, as chronicled by the Roman historian Ammianus Marcellinus.[1] The Eastern Roman Emperor, Valens, agreed to their resettlement in the Balkans within the borders of the Roman Empire, seemingly viewing them as a source of cheap soldiers[2] – later that year, however, the Goths revolted due in part to the poor living conditions they underwent under the Romans (especially an extensive shortage of food) and in part to the Romans' killing of their chieftains' escorts, and defeated the troops of Lupicinius at the Battle of Marcianople.[3] This particular instance illustrates the violence widely associated with the Germanic tribes and the speed with which they became an issue for the Roman Empire.

The Gothic rebellion quickly attracted much popular Gothic support, and by 378 was able to inflict a crushing defeat on the Romans at the Battle of Adrianople, which saw the death of Valens who was himself commanding the Roman forces.[4] Peace was finally negotiated in 382 with the help of the Western Roman Emperor Gratian, and the Goths were incorporated into the Empire, being given lands in Scythia, Moesia, and Macedonia on which to establish their autonomous communities.[5] Again, the significance of this settlement is not to be underestimated (in particular with reference to the Goths' ability to dictate Roman policy) and the change in Roman attitudes towards immigration that their agreement demonstrated was to have a huge impact socio-politically in regard to other aspiring settlers in the Empire.

A further Gothic invasion was launched over twenty years later, after a period of time when Roman politics was fraught with factionalism and growing internal instability in which the Goths under Alaric played a major part, when the Gothic chieftain Radagaisus attacked Northern Italy in 405. He crossed the Roman border with a large number of troops, but was defeated the following year at Fiesole and executed outside Florence on 23rd August 406.[6] On 31st December, various groups of barbarians comprising Vandals, Alans, and Suevi crossed the frontier of the river Rhine into Roman Gaul, meeting with no organised Roman resistance. The third wave of the invasions at the turn of the fifth century was launched by the Hunnic ruler Uldin in 408, but due to widespread desertions from his troops to the

1 Ammianus Marcellinus, *Roman History*, 31.3.1-4.2
2 Peter Heather, *Fall of the Roman Empire*, p. 158
3 Michael Kulikowski, *Rome's Gothic Wars*, pp. 131-4
4 Marcellinus, 31.6-13
5 Heather 2005, pp. 185-6
6 Ibid., p. 194

Romans was compelled to retrace his steps by March 409.[7] The three invasions between 405-8 (that of Radagaisus, the crossing of the Rhine, and Uldin) were separate incidents, but taken as a whole they combined to form a great disturbance to the borders of the Western Roman Empire within a short space of time.[8] These efforts on the part of Germanic tribes to expand their territory were a direct threat to the Empire, which relied on the lands it controlled to raise the money required for its political, military, and administrative upkeep – thus any losses of land revenue (either because of temporary damage caused by war or because of a permanent occupation of that territory) would have an adverse impact on the running of the Empire. Similarly, the Roman state relied on the cooperation of local elites within the Empire, who remained loyal to it out of the safety and legitimacy it gave them and the opportunities it presented for their financial gain. Anything that threatened to draw these elites away from supporting the Empire posed a great risk to the Roman state's existence, and so the fact that locals might find government by barbarians more convenient or appealing (or just the most pragmatic way of preserving their property and position in society) was seen as a dangerous subversion to Roman authority, as Peter Heather has shown. [9]

By 410, Germanic activity in Spain, Britain and Gaul had greatly increased (where there were now permanent Germanic colonies) with a growing number of groups previously subjugated to the Romans seeking independence, and matters in Italy had come to a head with the invasion of Alaric, which culminated in the sack of Rome.[10] These issues were dealt with under the general Constantius, who started by crushing the rebellions of Constantine II and Gerontius in 411, with the other rebels Jovinus and Heraclinus defeated in Gaul and Italy respectively in 413; he proceeded to make peace with the Goths in 416, using them to neutralise the Vandals and Alans by 418.[11] However, following his death greater division began to materialise as the Roman authorities lost control of what was happening in the more far-flung reaches of the Empire, and crucially involved in this were the tribes that had successfully invaded previously; thus the repercussions of the invasions continued until considerably after they had occurred.

The political fragmentation following the death of Constantius in 421 allowed the various immigrant groups to exploit the situation for their own benefit. These were halted at the accession of Aetius, who tried to bring this growing disintegration to an end, especially in Gaul and North Africa where the Germanic tribes were best able to exert their power, and employed a similar strategy to Constantius in eliminating political rivals before focussing on the external threat of the barbarians.[12] However, these (in particular the Huns and the Vandals) continued sporadically to raid the Western Roman Empire right up until the formal deposition of its last Emperor, Romulus Augustulus, by Odoacer in 476.[13] Again, all of these difficulties that the Empire faced from within its frontiers are clearly the results of the previous invasions, once more demonstrating the extent of their consequences.

7 O. J. Maenchen-Helfen, *The World of the Huns*, pp. 65-6
8 Peter Heather, *The Huns and the End of the Roman Empire in Western Europe*, p. 15
9 Ibid., pp. 21-2
10 T. S. Burns, *Barbarians within the Gates of Rome*, pp. 228–31
11 Heather 2005, p. 23
12 Heather 1995, p. 25
13 Heather 2005, pp. 25-36

Although the Germanic invasions (of which the most prominent examples were between 376-408) have often been linked to the socio-political upheaval of the time that led to the eventual demise of the Western Roman Empire in 476, there are two major objections to viewing them as so conclusive in its downfall: firstly, the large time period between the invasions and the collapse of the Empire would seem to demonstrate that they were not sufficient to bring it down. While they may well represent a major factor that in conjunction with others led to Rome's downfall, these invasions must be taken as one of a wide range of causes which on its own is not particularly significant. Linked to this, the second objection focusses on the disjointed and sporadic nature of the invasions, which implies that they ought not to be considered together as a phenomenon in their own right but rather as a loosely connected collection of similar attacks which happened to take place within thirty years or so of one another.[14] These two objections emphasise the position of the Germanic invasions as merely a marginally significant feature of the changing nature of Roman society at the turn of the 5th century, and not especially momentous in the long term, particularly in relation to the growing instability of the Western Roman Empire.

This position can be supported by examining the Romans' reaction to the Germanic invasions, and specifically the ones affecting the Western Roman Empire directly (i.e. those occurring between 405-8). The most noteworthy aspect of this response was the ease with which the Roman troops were able to put down those of the barbarians: the ringleaders, Radagaisus and Uldin, were captured with little ado and the military threats were quashed.[15] Apart from the anomalous Battle of Adrianople thirty years earlier, in fact, the Romans – and especially those of the West – did not lose any major military battle. Instead, in the *Roman History* of Ammianus Marcellinus there are recorded multiple victories for the Western Roman Empire, especially in the area of the Rhine.[16] Thus, the Roman imperial forces were so technologically, logistically, and tactically superior to those of the Germanic tribes that they were able to deal with them quickly and without much difficulty, downplaying the role of those invasions in the turmoil within the Empire itself at the time.

This turmoil can be ascribed much more clearly to the political instability prevailing in Roman society after the Emperor Theodosius' death in 395, when (with both of his sons too young to rule) there was intense rivalry between generals, politicians, and groups of society as they vied for power, which included the Goths within the Empire under the leadership of Alaric. These Goths were not the only ones who managed to exploit the insecurity of the Roman state, as were those tribes which crossed the Rhine in 406 without eliciting any substantial response from the Roman authorities.[17] Therefore, it is evident that the only reason the Germanic invasions were important at all was because of the underlying Romans' focus on their own internal problems rather than those they faced from outside the Empire.

Another way in which the Romans were themselves responsible for the scale of the potential danger posed by the Germanic tribes was in their shift of policy regarding the resettlement of foreign immigrants within the borders of the Roman Empire; up until the 370s any such resettlement would be agreed on the terms proposed by the Romans,

14 Ibid., pp. 4-5
15 Burns, p. 198
16 Cf. Marcellinus, 15.8-16.2, 16.11-12, 31.1-16
17 Burns, p. 215

and otherwise opposed. These terms mostly included a thorough political and military suppression of those immigrants' peculiarities, followed by as wide a dispersal as possible in small bands to minimise the risk that such an influx of foreigners would proffer to the Empire. This policy was changed after the Battle of Adrianople, when in 382 the peace terms with the Goths who had revolted included a certain degree of autonomy for their communities, which would be settled together in a large area in the Balkans (as Michael Kulikowski has demonstrated).[18] This acquiescence to the demands of the barbarians at the expense of Roman security naturally increased the power they had to the detriment of the Roman state, setting a precedent that was ripe for manipulation by figures such as Athaulf and Alaric, who was to go on to sack Rome in 410 – they were able to maintain control over their own territories while paying lip service to the Empire, and to such concepts as *Romanitas* (i.e. the Roman values – 'what it meant to be a Roman' – upon which Roman society was based).[19]

The fact that Roman control of this territory was reduced to a mostly nominal status put the power that Rome had in an extremely precarious position; because the state relied on the support of local elites and the control over their territory in order to be able to continue, this loss of territory control involved a weakening of the state's ability to function, and as such threatened the very existence of the Western Roman Empire. Moreover, this weakening was the result not of the invasions themselves, but a combination of the difficulties of the existing political situation in Rome and the specific policies put in place by the Romans themselves to deal with the invasions. Accordingly it can be argued that without bad handling by the Roman authorities and without the problems already rife in the Roman establishment the Germanic invasions would not have been nearly as significant as they turned out to be, and so did not in themselves constitute a cataclysm for the Western Roman Empire.

This view, that the decline of Rome was the result of a combination of long-term problems with the establishment and short-term ineffectual governance has been held by many historians, perhaps most notably Edward Gibbon when he writes: 'The decline of Rome was the natural and inevitable effect of immoderate greatness … the stupendous fabric yielded to the pressure of its own weight.'[20] In an attempt to give a lower profile to the invasions, some have toned down the scale of the invasions themselves (in particular Walter Goffart, Ralph Mathisen, and Danuta Shanzer), even going so far as to claim that 'the barbarian settlement of the west was accomplished with a minimal, relatively speaking, level of disruption' and 'barbarian populations were integrated … seamlessly into the old Roman world'.[21] However, the violence that accompanied the key invasions before 410 discounts this, since a sine qua non for the barbarians' being 'integrated' into Roman society was their presence in Roman territory, which was achieved by force.

On the other hand, the fact that the Western Roman Empire was in such a position of weakness by the turn of the 5th century was to a certain extent an outcome of the Gothic War of 376-82, which in turn only came about due to the Gothic invasion of 376. In actual fact, the treatment of those Gothic tribes was originally completely in keeping with traditional Roman policy on immigration, since they were to begin with disciplined severely by being deprived of their rights and exposed to terrible living conditions, after which the Romans kidnapped their leaders.[22] It was only their retaliation and military power that ensured the Romans treated them any differently than usual, and even after a peace had been agreed there was no change in Roman attitudes to immigration in general, as is evident from their handling of the crisis of 405-8 which conformed completely to previous treatment of barbarian invasions. The only difference between the situations was the numbers involved and the ease with which the Roman were able to overpower them, demonstrating that Roman policy only changed for pragmatic reasons in respect to the more large-scale of the Germanic invasions, and enhancing the view that these invasions were so significant and unexpected in Roman society.

Likewise, the fact that the Roman authorities were unable to exert any major control over the local communities of Germanic tribes which had been granted autonomy to some extent was a corollary of this, as it only occurred when the Romans were unable to act any differently because of the numbers involved on the Germanic side. It would seem then that the power the Germanic tribes enjoyed in terms of military and political control was hugely significant with regard to how the Romans would treat them, and the Roman political decisions were not mistakes per se made by the authorities, but rather a reluctant compliance with circumstances beyond their control. In contrast to this, the comparative strength of the Germanic invasions and their ability to determine the Roman policy developed as a reaction to them increases their significance in the problems the Western Roman Empire faced.

Furthermore, the efficiency with which the Romans were able to manage the crisis of 405-8 further highlights the strength of the Western Roman Empire against a common enemy, and how the internal political instability of Rome was relatively inconsequential in comparison to the external challenge presented by the Germanic invasions. In addition, the actual levels of instability in the Empire directly prior to them have been reappraised both in terms of its financial dependence on rural areas[23], its general economic flourishing through trade[24], and most importantly its control over the local elites.[25] These remained strong, thus diminishing the value of the argument that the only reason Germanic invasions had any significance was the existing instability within the Empire – on the contrary, historians such as Bryan Ward-Perkins have argued that they 'were undoubtedly the principal cause of the death of the Roman economy'[26], implying that without them the economy would have continued to prosper.

What is more, the apparent fragmentation of the various Germanic tribes made their invasions all the more extraordinary when they did begin to migrate into Roman territory, because while the Romans could have been quite capable at defeating them individually, the fact

18 Kulikowski, pp. 152–3
19 Heather 1995, pp. 20-22
20 Edward Gibbon, *Decline and Fall*, p. 621
21 R. Mathisen and D. Shanzer, *Romans, Barbarians, and the Transformation of the Roman World*, p. 4

22 Kulikowski, pp. 131–4
23 T. Lewit, *Agricultural Production in the Roman Economy*, ch. 9
24 C. Wickham, *Marx, Sherlock Holmes, and Late Roman Commerce*, pp. 183-93
25 J.F. Matthews, *The Letters of Symmachus*, pp. 58-9
26 Bryan Ward-Perkins, *The Fall of Rome and the End of Western Civilisation*, p. 134

that they had a similar purpose (i.e. relocation so as to remove the danger of the Huns to the east, according to Peter Heather)[27] ensured that their strength was too great for the Western Roman Empire to withstand in the end, and as such led to its downfall. Further, the periods of time involved have little bearing on the matter, because as more and more Germanic groups infiltrated the Empire it became gradually weaker and weaker until it collapsed; as a result, while the full socio-political consequences of the Germanic invasions required a certain amount of time to develop fully, it is clear that the invasions themselves were a cataclysmic event in the Western Roman Empire.[28]

This perspective is shared by numerous historians, in particular J. B. Bury, Peter Heather, and Bryan Ward-Perkins; for instance, J. B. Bury states that 'it may be said that a German penetration of western Europe must ultimately have come about. But even if that were certain, it might have happened in another way, at a later time, more gradually, and with less violence'[29] – in other words, the circumstances of the Germanic invasions meant that they were extremely significant. Here he is in agreement with Peter Heather, who posits that the crucial factor was that 'sufficient numbers of these new Germanic powers, which were not themselves politically united, [acted] in a sufficiently similar way at broadly the same time … in too short a space of time for the Roman state to be able to deal with them effectively.' Also, he draws attention to the fact that 'any substantial change in the strategic balance of power was prompted by the growing strength and cohesion of Germanic groups, not the enfeeblement of the Roman Empire.'[30] To sum up, Bryan Ward-Perkins concludes that 'the fifth century experienced a profound military and political crisis, caused by the violent seizure of power and much wealth by the barbarian invaders.'[31]

In conclusion, therefore, it may seem that most of the importance of the Germanic invasions arose from the weakness of the Western Roman Empire rather than their strength, pointing to the deeper underlying factors of political instability, a changing immigration policy, and an inherent need to secure the loyalties of local elites for the Empire to properly function; nonetheless, this is a purely superficial understanding of the problems that the Roman state faced. In actual fact, the Western Roman Empire was very strong, both militarily, financially, and politically, while the only potential weaknesses of their shifting attitude to immigration and difficulties with controlling local areas themselves emanated from (rather than intensified) the powerful nature of the invasions. Thus, given that it was the invasions which suddenly caused the Western Roman Empire's existing troubles to increase, even as they added to them problems which had not been there beforehand, and kept doing so right up until its fall in 476, these Germanic invasions were indeed a cataclysm for the Western Roman Empire.

27 Heather (1995) pp. 5-7, 10-11
28 Ibid., pp. 4-5
29 J. B. Bury, *History of the Later Roman Empire*, p. 313
30 Heather 1995, p. 41
31 Ward-Perkins, p. 183

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Dark Matter and Energy

Shaoyon Thayananthan

Amidst the whole universe, there are many things that humanity has yet to unearth. Wonders unknown to us are present all around the universe. One of these wonders is dark matter. The name itself is intriguing and has seems to hold an aura of mystery around it. It's all around the universe, and is crucial in the role of holding the universe together, but is not as showing as other important things like the sun. Even though it is paramount to holding the universe together by mass, many people aren't aware that it exists and think nothing of it. Per contra, dark matter makes a huge difference, even though most of the theories on it are hypothetical and no solid evidence has been found yet to point us in a direction that helps solve this conundrum.

WHAT IS DARK MATTER?

60% of the mass in the universe is made up of dark energy. The other 25% is dark matter and it is unable to emanate light nor energy. The delineation on the right shows Pandora's cluster. The blue is a map of the dark matter. This is where it gets its name from. Some scientists call it a "quintessence" or a fifth fundamental force of the universe, the other ones being gravity, electromagnetism,strong and weak nuclear forces. Dark matter is not able to be mistaken for normal matter, as normal matter is made up of baryons. Baryonic matter is made up of protons, neutrons and electrons in atoms. If dark matter was this way, it would be able to be found through any reflected light. Also, it would be detectable through the absorption of radiation levels passing through. However, there is a guess that it could still be baryonic matter if it was tied up in small chunks of heavy elements (Massive Compact Halo Objects (MACHOs)). However, a well-supported view is that it is made up of Weakly Interacting Massive Particles(WIMPs). It is also not antimatter as antimatter decimates matter and produces gamma rays on contact with it. There aren't enough gamma rays to compare to the theoretical amount of dark matter. Scientists know more about what dark matter isn't than what it is. This is because it is difficult to detect with the current instruments and technology available. An idea is that it could be something called "supersymmetric particles". The scientists at the LHC are striving to recreate dark matter if it is possible. Dark matter is thought to be made of smaller particles than atoms. However, this is also theoretical.

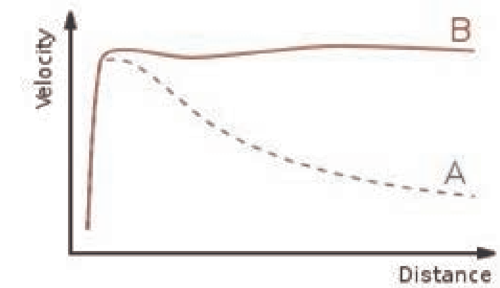
The Distribution of Dark matter in the universe 13.6 billion years ago.

WHAT IS DARK ENERGY?

In 1990, it was thought that the universe might have little energy density so it would never stop expanding, but gravity would eventually slow the augmentation. Gravity pulls all matter in the universe together. However, this was all theory because the slowing was never observed via telescope. In 1998, the Hubble Space Telescope observed supernovae far away that demonstrated the universe enlarging slower than it was today. Therefore, the universe had not been slowing to gravity, it was speeding up. Even though it was observable, there was no solid cause as to how this phenomenon was happening. There were 3 explanations after; one proposing that Einstein's theory was wrong in some parts, one related to a "cosmological constant" (describing the universe when it is static) and one that considered an energy-fluid in space. There is still no solid explanation, but theorists call it "dark energy" for now. Dark Energy could be a property of space. In fact, Einstein realised and proved that space has properties; It is possible for more space to be created. In one of his theories, space can acquire its own energy. If this energy is part of space itself, it would not get used up. Therefore, this gives us an idea as to why more and more energy appears. However, this theory relies on the cosmological constant and there is no proof as to why it should be there or to why it has the right values to help expand the universe. Another theory is from quantum theory where empty space has virtual particles that chronically materialize and disappear. However, scientists haven't been able to calculate it properly. Dark energy potentially could be a kind of dynamical energy fluid, which fills space but accelerates expansion instead of accelerating it. This was called "quintessence". However, like most of the other theories, there is no evidence as to what it is like, if it interacts, or how it exists. It is difficult to which of the theories is the most prevalent because of the lack of data.

HOW DO WE KNOW DARK MATTER IS EXISTENT?

Most people, when they think about space or related topics, think about what they can see with the naked eye such as stars or planets or the Moon. When astronomers look at space with telescopes, there are clearly many more star and galaxies. However, everything that we can see(through telescopes or just the naked eye) is made out of matter. Matter attracts matter using gravity. There are special formulas to identify orbits around space. These methods are also used when they need to send spaceships up to specific comets passing by, or where we are in orbit in relation to other planets. When observing a galaxy, astronomers calculate the speed at which the stars move. The astronomers use the principle that the net motion of the stars are because of all the other gravitational forces from other matter. Herein lies the problem; even when using different telescopes, the amount of matter is substantially less than how much it should be to explain all the motion. This problem could be addressed as some kind of anomaly for one or two galaxies, but this is a wondrous effect that happens all over the universe. Therefore, a proposal was put forward that there was something else that could not be seen, hence the name "dark" matter. It is easy to understand this concept. As an example, imagine a very dark background and visualize a coin that appears to be floating in front. Applying the laws of gravity on Earth, we know this is impossible. Therefore there is something holding it up, it could be a dark piece of string in this scenario. Dark matter doesn't have seem to absorb energy from matter or collide with it. Its gravity effect is the only proof of its existence. It can't The dark matter affects the visible matter therefore this is why we know it is there. It is revolutionary how most of the essence of



the universe is something we know nothing about instead of our normal matter we are used to.

An astronomer called Vera Rubin measured that stars in spinning galaxies rotate at the same velocity. Their distance to the centre was irrelevant. However, this is different to planets. Planets are affected by distance from the centre (eg our solar system with the sun and the outer planets rotating much slower than the inner ones). The curve shows this, A being the planets. However, curve B fluctuates, seemingly orchestrating the stars rotating around many centres. This is theoretically possible only with the presence of dark matter.

Another theory is gravitational lensing. Its basis is related to Einstein's theory on general relativity that mass bends light. Gravitational lensing is an effect of mass bending light. The bigger an object is, the bigger its gravitational field will outstretch. Gravitational lensing can happen with any mass, even with humans or animals. However, it is not substantial enough to measure.

The Audition

Ollie Billingham

As Rick Shaw stepped off the gondola the sights and sounds of Venice swarmed around him: the overcrowded restaurants, the softly lapping water and the jumbled side-streets. Quickly, Rick checked his audition letter. It had arrived just after a heart attack had almost robbed the dark haired, middle-aged actor of his life. Death still clung to him like cobwebs. He was ready for a fresh start.

He arrived at the theatre well past five o'clock. Shadows were eddying around Teatro Oscura but lights shone a dim welcome as Rick mounted ebony black steps, his feet drumming like heart beats, gradually slowing as he reached the summit. Automatically, he clutched his chest.

A shrill voice echoed down over blood red carpet towards him.

"Rick Shaw, your turn."

A deadly cold feeling froze his body as a hand grabbed his arm. Rick looked around and then down. His heart missed a beat. The person whose grip on Rick's arm was slowly tightening was half Rick's size, darkly hooded and staring straight ahead.

"Good luck!" Rick blinked towards another voice. The person looked familiar. Where had Rick seen him before? It had been at the hospital, in intensive care. How could that be? Rick opened his mouth but the hand pulled him on.

As the Renaissance interior began to lift his spirits, abruptly Rick stumbled. He glanced down and gasped. A sculpture of a man lying on the floor entwined his feet. The man was dead,

"Winners never cheat, cheaters never win," read the inscription.

"Have you cheated anything recently?" asked his hooded guide.

Rick didn't have time to answer. Wax masks of screaming faces stared directly into his soul.

"Does that look like me?" he thought.

A door swung open. A feeling of familiarity washed over him: an audition room. As he walked inside Rick could see no director, but a maggot of a niggling thought told him someone was there.

"Let's charge again! Let's give him everything!" Dread crept up Rick's spine. This was no Shakespearian audition script. This was his life; the words the very ones spoken around him as he lay dying in the hospital. His voice faltered. He couldn't recite it. He couldn't relive it. He shook his head. The audition was over.

Leaning back against his hotel room door, the sweat already dried to salt on his forehead, Rick chuckled to himself. What a fool he was! Glancing out of the window, he saw a coffin sitting on a black gondola. He squinted. He could make out the name. Could it be? The words 'good luck' rang again in his ears. No, it couldn't be him, his fellow survivor. Rick slapped himself. He needed a drink.

Ice clinking in his glass, Rick opened the envelope given to him at the theatre.

"Audition failed," was all the letter said.

The next morning Rick Shaw was found dead in his room.

Let's you and him fight

white America's stereotypes of Asian-Americans and African-Americans, and its effects on inter-minority race relations

Alfie Cherry

Racial discourse is an integral part of US history and contemporary society. It has played a key role in the formation of the nation. White America's attitudes towards minority groups have shifted over hundreds of years, but what remains constant is the use of racial stereotypes and the extent to which they dehumanise, creating diverging societal roles among America's many racial minority groups.

Two key influences formed distinctions between racial stereotypes. First, the history of how different minority groups entered the US, and their original roles in American society. Second, the history of the White majority's attitude towards them, and the discourse used to entomb them in a societal role which White society was comfortable with. These stereotypes continue to affect not only the relationship between White America and racial minorities, but also complex inter-minority relations. Nowhere has the history of dynamically changing racial stereotypes had more of an effect on inter-minority relations and socio-economic standing than between African-Americans and Asian-Americans.

One must first consider the origins of both minority groups arriving in the United States. The first African immigrants in the 1600s did not arrive through choice, looking for the American Dream as promised to Italian, Dutch, and Russian immigrants of the 1800s and 1900s, but through enslavement. African-Americans suffered over 200 years of slavery until the Emancipation Proclamation in 1863.

This is in stark contrast to the history of Asian-Americans, who first settled in America in noticeable numbers in the late 1700s — nearly a hundred years after African slaves were brought over. They primarily came from China and the Philippines, migrating by choice to look for work and to study. By the mid 1800s, when the Asian-American community had established a position of societal significance, a number of oppressive laws were put in place by the White majority in an attempt to quell their success. Court rulings and acts of Congress (such as the Chinese Exclusion Act of 1882) sought to pacify the growing prominence of Asian-Americans. However, despite the oppression that the Asian-American community faced in its formative years, both from institutionalised racism and societal prejudice, the extent of oppression and hardship never came close to that of the African-American community. These acutely different experiences are primarily the result of the age-old stereotypes put upon Africans and Asian societies by White societies.

The stereotype of Asians (specifically East and South-East Asians) is that of a reserved but calculating people, alien to White civilisation (Yang, 2004). Their religion, cuisine, fashion and language were all considered to be not just different to White society, but directly opposed and hostile to it. This myth is widely referred to as 'Yellow Peril' (Yang, 2004).

The stereotypes of Africans fall into a strange duality — the first being the "Sambo" and the second the "Savage" (Green, 1999). The 'Sambo' stereotyped Africans as "simple-minded, docile" (Green, 1999), whereas the 'Savage' portrayed them as irrationally violent and "primitive" (Eiselein, 1996). During the colonisation of Africa, 'Savage' took prominence, but as the slave trade expanded, 'Sambo' took over. Conversely, as the slave trade dwindled (in particular due to the Emancipation Proclamation of 1863), 'Savage' regained prominence. Therefore, to White America, the African is docile and childlike when enslaved, but savage and animalistic when free.

The threats White America saw from African-Americans and Asian-Americans were different. From the Africans, the fear was of savage brutality and bloodshed. From the Asians, the fear was of cultural domination and intellectual takeover.

With the Jim Crow era officially ending in 1965 due to the extremely prominent Civil Rights Movement, White America's attitude towards African-Americans and Asian-Americans was considerably more positive than during these two communities' formative years. However, as the notion of the 'savage' became unacceptable, the image of the 'thug' rose— a modern-day iteration of 'savage', twisted to suit White suburban America's fear of Black urban America. In their essay, From "brute" to "thug": The demonisation and criminalisation of unarmed Black male victims in America (Smiley & Fakunle, 2016), Smiley and Fakunle explain how the 'criminalisation of blackness' has come about in contemporary America through terms such as 'thug', with 'images and myths that reinforce this criminalisation' being commonplace throughout mainstream social discourse.

White America's attitudes towards Asian-Americans shifted dramatically even before the Civil Rights Movement, notably after the Second World War, moving from seeing them as a calculating threat to a docile and hard-working people who were not seeking to take over America as once feared. The most prominent explanation for this is the strong conscious attempt of the Asian-American community to prove themselves as upstanding citizens, going above and beyond the standard expected of White America. This effort was also made by African-Americans, but it was ignored. White America realised it would be beneficial to listen to Asian-Americans in the context of the Cold War diplomacy race between the United States and the Soviet Union. It "provided a powerful means for the United States to proclaim itself a racial democracy and thereby credentialed to assume the leadership of the free world" (Wu, 2013). The 'model minority' theory was created through the mainstream media of the 50s and 60s, with "newspapers often glorifying Asian Americans as industrious, law-abiding citizens who kept their heads down and never complained" (Guo, 2016).

White America's attitudes towards Asian-Americans and African-Americans began to cause rifts between the two minority communities. As the Asian-American community began to be praised and noticed for the same efforts for which the African-American community were ignored, the socio-economic gap between the two groups grew exponentially. According to the United States Census Bureau, as of 2016, the median income of Asian-American households is $80,720, whereas the median income for African-American households is $38,555. With Asian-Americans in the present day having overtaken even white households (who have a median of $61,349), the economic gap between Asian-Americans and African-Americans is abundantly clear.

With the brutal legacy of slavery, Jim Crow, and institutionalised discrimination at the hands of employers and law enforcement, Black America's attitude towards White America as discriminative and oppressive was and is well-founded. This was compounded by the economic divide between the two. However, when Asian-Americans began to match (and surpass) the income levels of White Americans in the 1980s, they too joined 'the oppressor' in the minds of some African-Americans. They were often seen as the "middleman minority" (Wong, 1985) — an intermediary 'buffer' group between the oppressed and the oppressor, linking producers and consumers by being small business owners.

Resentment and violence directed from Black America towards White America for systemic injustice is also, occasionally, redirected towards Asian-Americans: middlemen are a more accessible target of frustration and anger. This is most demonstrable in the 1992 Los Angles Riots, and the legacy of the Korean-American community. The riots began on April 29th, 1992, when four LAPD officers were acquitted after being filmed beating an African-American motorist, Rodney King. The rioters, primarily African-Americans and Latino-Americans, were spread throughout Los Angeles, and looted for six days. Over 2,300 Korean-American businesses were ransacked, with media and social commentators at the time suggesting that the resentment against the Korean-American community was due to the 'middleman minority' theory. Reverend Edgar Boyd, the pastor of an African Methodist church in Los Angeles during the time of the riots, said that there was "tension between those who were marginalised and those who seemed to be surviving." (Fuchs, 2017)

Before the riots, various instances of L.A. Korean business owners shooting unarmed African customers, incorrectly accusing them of shoplifting, further wedged a divide between the two minority groups. The 'thug' stereotype of African-Americans that post-Jim Crow White America created had permeated into the Asian-American mindset. As they rose up the socio-economic ladder, their attitude towards the Black community (whose socio-economic position resembled that of the Asian community just decades before) was one of fear. Arguably, the L.A. Riots were the material culmination of hundreds of years of changing racial stereotypes in America. The 'model minority' stereotype, perpetrated by politicians and the media, gave rise to the 'middleman' status of Asian-Americans, causing Black frustration to expand towards them.

To conclude, it is evident that White America's stereotypes of Asians and Africans have not only caused mass oppression and institutional racism in American society, but also divided the two communities against each other. As White America pragmatically changed its stereotype of Asian-Americans after the Second World War for its own self-interests, Black America was left behind. Even after the Civil Rights Movement, the socio-economic divide between the two communities caused inter-minority relations to deteriorate. Asian-Americans believed the 'thug' rhetoric White America was using against inner-city Black America. This culminated in racially-charged conflict, such as the 1992 Los Angeles Riots. Whilst Asian and Black race relations have since healed, the negative effects of White America's stereotypes on the relationship between these two minority communities persist beneath the surface of US society.

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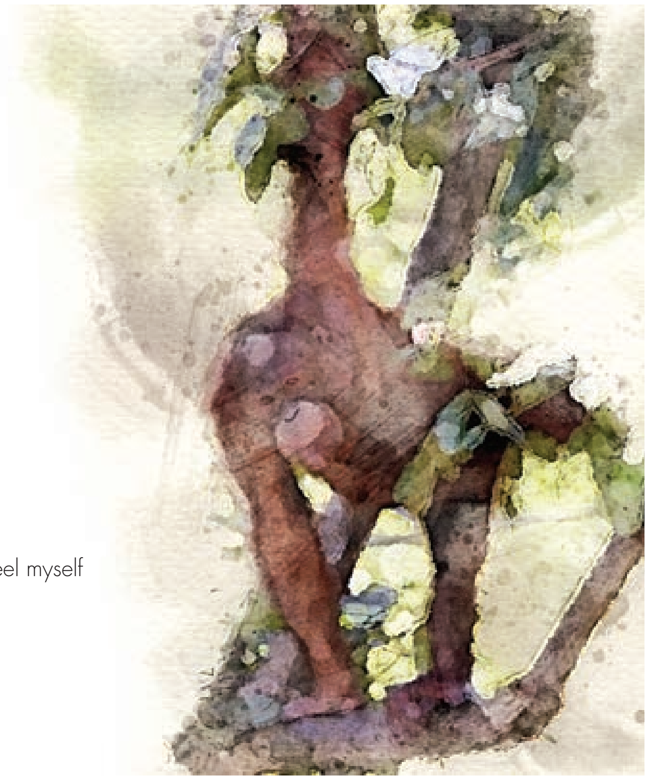
The song of the orangutan

Sam Heatley



They came just before dawn,
Orange jackets, big machines.
My mother and I were in the tree
that holds all the birds and fruit
and is always the dampest in the rain.
The small ones shout
and fire three at my mother …
BANG BANG BANG
Ringing in my head …
BANG BANG BANG.
I jump off her back,
and then I see her,
Falling, falling, falling.
I peek over the edge of the branch,
To watch her body thrown into a black bag.
One points at me,
Then a red feather of a dart is stuck in my leg, as I feel myself
Falling, falling, falling.

I wake up in a metal box,
One side has bars thin enough for me
to fit my fingers through.
I see two of them,
One in the same orange jacket,
The other handing over green bank notes,
And that's the last I remember.

Now I live in that metal box.
Sometimes I swing on the bars of the grilled side,
And screech:
"Where's my mother? Where's my mother?"
The man walks in,
And shouts at me and hits the top of the box.
I bare my teeth and ask him again,
For good measure.
He doesn't seem to hear me.
I show him what I mean by banging my head
Against the side of the cage …
BANG
BANG
BANG.

Is it possible to create a self-stablizing rocket?

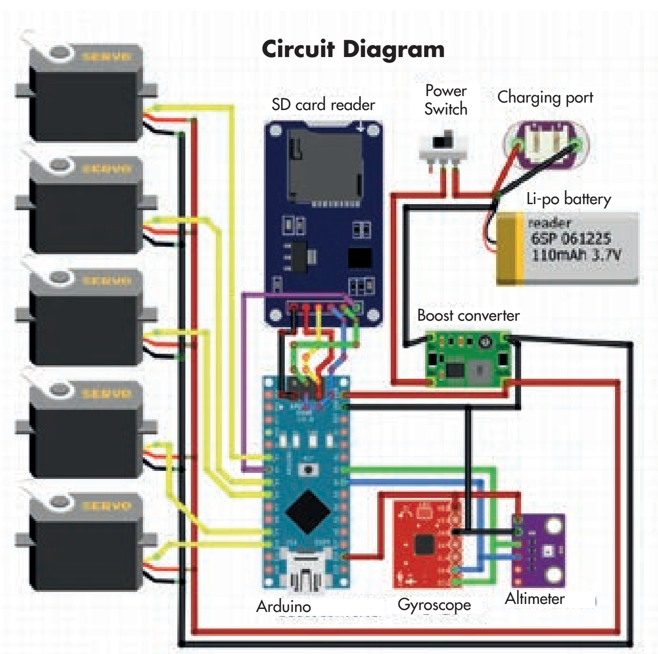
Tian Fang

Well yes of course, nowadays almost all missiles have a guidance system that allows for trajectories to be calculated and finely controlled. Despite the widespread use of this technology, it is mainly restricted to large corporations with huge RnD departments however, the rise of consumer electronics recently had given the ability for individuals to create complex circuitry and controllers. This will be the focus of this endeavour, is it possible to create a self-stabilizing model scale rocket?

THE CONTROL SYSTEM

The brainbox of this operation will be the Arduino, a small programmable micro-controller (essentially a very small computer) which will read the pitch, yaw and roll as well as the altitude of the rocket and use that to control the angle of four fins mounted to the top of the rocket.

Secondary aims include to calculate the altitude of the rocket from atmospheric pressure readouts and to hopefully extrapolate velocity from it. Another aim is to use a SD card to record the data from the rocket and be able to act as a datalogger for analysis after launches.



DATA INPUT AND OUTPUTS

Firstly, powering the components:

1) The voltage from the lithium polymer (li-po) battery is boosted from 3.7v (nominal cell voltage) to 6.0v since the other electronics run on 5v logic. The additional 1v is needed since there will be a small 0.7v voltage drop from the power regulator on the Arduino.

2) The Arduino then powers the gyroscope and altimeter at 3.3v since they run on 3.3v logic and will most likely become damaged when powered at 5v.

3) The servos are connected directly to the boost converter's 6v as it means that no current needs to run through the Arduino to get to the servos. This is important as the servos will be drawing about 100mA under no load, and up to 500mA at full which the Arduino cannot supply without burning up.

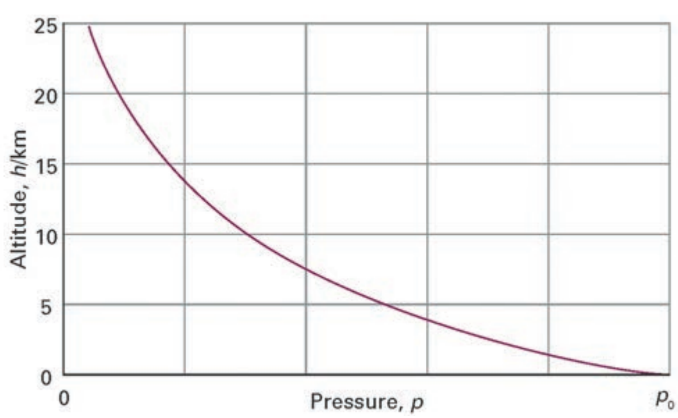
Secondly, the controls:

1) The Arduino communicates with the modules and reads the angles off the gyroscope and the pressure off the altimeter, receiving data in the format of:

```
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 211
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 211
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 211
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.601 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.634 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.634 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.634 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
18:44:09.634 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 211
18:44:09.634 ->  Pitch = 9.68   Roll = -14.25   Yaw = 11.62   Altitude: 210
```

2) Since the altimeter outputs pressure in pascals, it needs to be converted into a altitude above sea level in

$$\text{Altitude (m)} = 13504.985 \times \left(1 - \left(\frac{Pressure_{Pa}}{101325}\right)^{0.190289}\right)$$



3) From the angles received, the Arduino will then send a signal to the servos along the yellow wires, instructing them to move to a different angle if necessary.

At this point, emerges the main problem of control, how much should the servos change angle?

PID CONTROLLERS

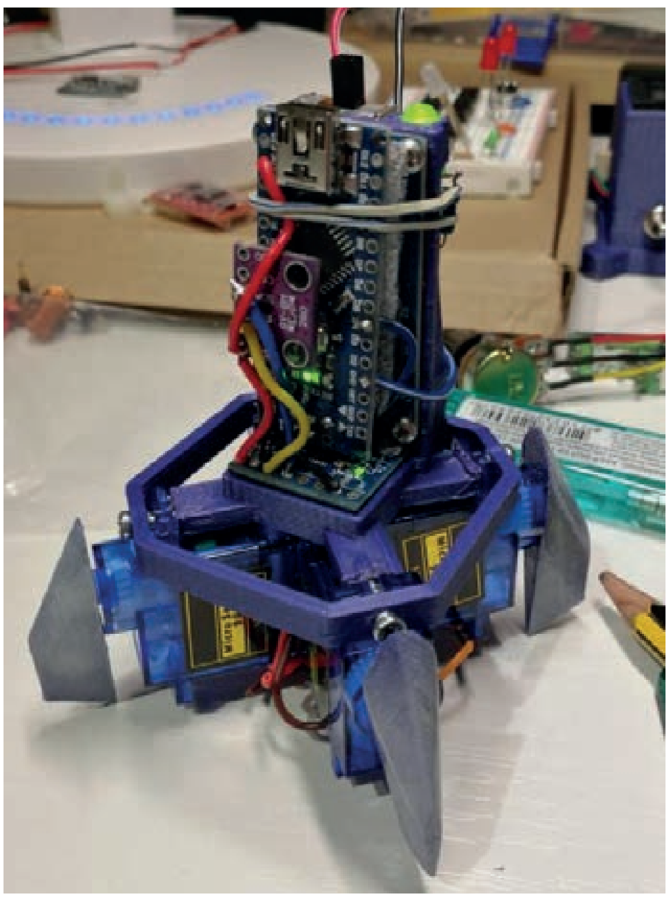
If the angle change is too much, it will cause the rocket to over-correct, leading to the servos swinging back to correct the over-correction. This leads to a system that rapidly loses stability essentially balancing on a knife's edge. What is needed is a system that actively measures the change in angle and corrects for it. Systems like this are called PID controllers and are used in inherently unstable scenarios such as self-balancing robots, temperature regulators or in this case, a model rocket.

PID controllers work by taking the difference in desired angle and current angle(called the "error") and computing a needed angle change (called the "solution") which is sent the servos to achieve that while monitoring the error constantly.

The 3 components of a PID controller are:

1) Proportional –

The controller takes the error and sets the solution to be proportional to that difference. If this is set too high, it will cause the problem as mentioned above and cause rapidly growing oscillations but set too low there will be little change in the error. Thus, something is needed to dampen the oscillations.



2) Derivative –

This considers the magnitude of the solution computed by the proportional and decreases it according to how small the error is. It is effectively a damper to the proportional part of the controller and stops the oscillations by lowering the solution according to how small the error it. However, another problem arises, if this is set too high, it will dampen the solution too much that the error will never be 0 (the system will never reach its desired value) as the dampening effect will become greater than the solution, leading to an equilibrium achieved just below the desired value. Thus, the last part of the PID controller is needed.

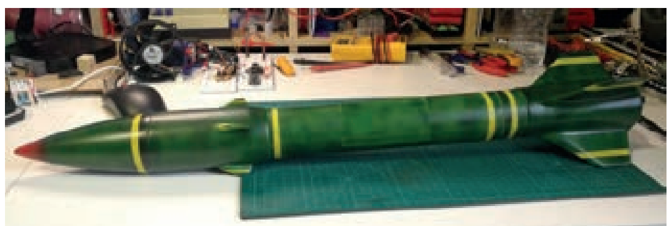
3) Integral –

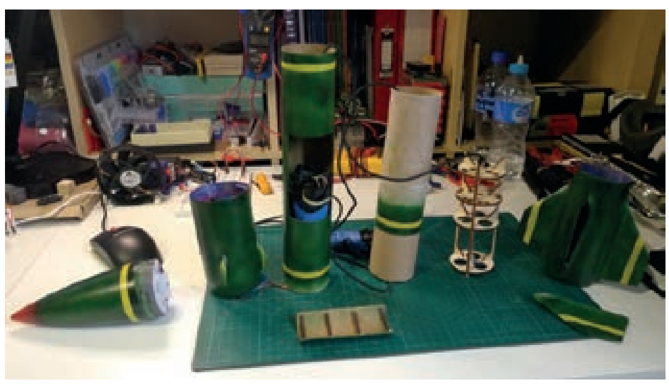
This finds the integral between the current angle and the desired angle. The smaller the error, the larger this component becomes. It essentially pushes the solution just enough that the solution will become zero when the error is zero, thus achieving the desired angle.

Component	Too high	Too low
Proportional	Rapid oscillations	Changes very slowly
Derivative	Equilibrium achieved below desired angle	Rapid oscillations
Integral	Small, rapid oscillations	Never reaches desired angle

The main problem with controllers like this is that it requires extensive testing and tuning the constants for each of the components. Additionally, they constants would most likely need to change according to the relative wind speed, creating further problems.

Coupled with the need for complex calculations on the Arduino's part just to compute the solution, as well as the resulting decreased refresh rate of this systems means that it is not very suitable for small scale rockets. It is possible to get around this hardware problem by using better micro-controllers however the prices for a control board rises very rapidly.





Left to right:
Nosecone, electronics bay, middle tube section, bottom stage, motor mounts, fin support structure.

THE ALTERNATE SOLUTION

The method of stabilization used in the end is a relatively simple system which has many advantages over a PID system. The process is:

1) Determining the angles of pitch, yaw and roll of the rocket.
2) Moving the servo motors so that they always are perpendicular to the ground, resulting in almost no further calculation needed as well as negating the opportunity for over-correcting to occur.

Working in 2 dimensions, if the rocket is angled slightly to the left, the fins pitch to the right (relative to the rocket) but remain perpendicular to the ground. This results in the rocket experiencing a force which pushes it to zero degrees or vertical.

In the end, we opted for this solution since it make the code a lot easier as well as being less demanding on the Arduino. This also meant that we did not need to perform any wind tunnel experiments to adjust the controller, also a highly time-consuming task. As stated above, the settings would most likely need to change according to wind speed and with the rocket reaching up to $70ms^{-1}$, it would be impossible to simulate this in the wind tunnel setup we had.

RESULTS

Following the launch on the 4th March, we saw that the entire system functioned perfectly with the rocket overshooting the desired height as it was our first launch. Unfortunately, due to the rocket reaching a high altitude of 371m, the rocket drifted on the parachutes for a very long distance away from the launch site, resulting in the bottom part of the rocket being lost.

On the truth-values *of* analytic propositions

Apropos Question 5: What is Truth?

Sam Cherry

In this essay I will consider the truth-value of analytic propositions, i.e. those propositions concerned with a priori relationships between concepts (Kant, *Critique of Pure Reason*), only. I will attempt to demonstrate what it means to say that an a priori statement is true.

1. Propositions are statements about relationships between concepts that have truth-value:

   a. Propositions are statements about the relationship between concepts (Russell, *Mathematics and Logic*).

      i. A set is a group of concepts that share at least one predicate, but also have at least one predicate not in common with other concepts.

      ii. Analytic propositions have many linguistic forms, but most, if not all, are logically reducible to stating either that:

         1. x is predicatively identical to y_1, i.e. both x and y_1 are concepts that share all the same predicates (this shall be known as predicate α);

         2. x is predicatively distinct to y_2, i.e. x and y_2 do not share all the same predicates.

         3. x is an element of the set A, i.e. x has the predicate α and the set A is defined as the set of all concepts that contain the predicate α;

         4. All elements in set A are elements of set B, i.e. the predicate α is contained in the predicate β, and Set B is defined as the set of all concepts that contain the predicate β (set A is a subset of set B);

         5. x cannot be an element of the set C, i.e. predicate α is mutually exclusive with predicate $\neg\alpha$, and set C is defined as the set of all concepts that contain the predicate $\neg\alpha$;

         6. All elements in set A cannot be elements of set C, because the predicate α is mutually exclusive with predicate $\neg\alpha$;
         Or some combination of the above. (It is assumed here that $x=x$ and that $x\neq\neg x$)

      iii. In set notation:

         1. $x = y_1$
         2. $x \neq y_1$
         3. $x \in y$
         4. $x \subset y$
         5. $x \notin y$
         6. $[A \cap C = \varnothing] \rightarrow [A \not\subset C]$

      iv. The following should be noted about comparative statements:

         1. Statements of the sort '2>1' are analytic propositions, because they relate different concepts, on the basis of the definition of the concepts alone.

         2. Analytically comparative statements of this sort are only possible where two concepts both have distinct complex predicates (i.e. predicates formed from the combination of two (or more) more fundamental predicates) of the following sort: a fundamental predicate (here, that they are numbers), and a predicate that modifies the fundamental predicate (here the predicate that distinguishes 2 from 1).

         3. This comparison is only meaningful because the modifiers are defined such that the statement is tautological. The modifier of 2 includes by definition that 2>1, and, vice versa, the modifier of 1 includes the definition that 1<2.

         4. In this way comparative propositions are still relations of concepts and their predicates.

      v. This is sufficient to demonstrate that so far all known analytical propositional structures relate the predicative definitions of one concept with another.

   b. Propositions express truth claims. As such, they have truth-value, i.e. they can be 'true' or 'not true'.

   c. Truth functions as a predicate of propositions rather than concepts (Ramsey, *Facts and Propositions*).

i. Individual concepts (such as bachelor, unmarried or man) can neither be true nor false in and of themselves. It is nonsensical to say 'bachelor is false' or 'man is true'.

ii. Complex concepts (concepts formed from the combination of two (or more) distinct concepts) can be incoherent. One can attempt to form a concept from two mutually exclusive ones (e.g. 'married bachelor') in such a way that the concept cannot be meaningfully understood, but this concept in and of itself contains no truth-value.

c. To say that something is true or not true in an analytic sense is to make a claim about the relationship between concepts.

2. <u>Language is a way of signifying concepts:</u>

a. Signifiers are sense-data that impart the thought of a concept:

i. This includes written and spoken words, mathematical and logical notation, pictures etc.

b. Language is a system of cognition whereby a signifier is related to a concept. Language is used to attempt to communicate thoughts between individuals (Russell, *The Uses of Language*).

c. Signifiers are distinct from the concepts they signify.

i. I cannot meaningfully claim that the statement 'tous les célibataires sont des hommes' is true if I do not know French, as I do not know which concepts these signifiers signify, so I cannot understand it.

ii. This affirms Wittgenstein's claim *'The limits of language mean the limits of my world'* (Wittgenstein, *Tractatus Logico-Philosophicus*).

d. All expressed propositions are expressed in the form of signifiers. This is the only way we can attempt to communicate our thoughts to another individual.

3. <u>To claim that a proposition is true is therefore to assert a relationship between concepts:</u>

a. It is to make one (or some combination) of the following claims:

i. Two concepts are predicatively identical;

1. This is no more than a language game. If two concepts are predicatively identical they are in fact the same concept (Frege, *On Sense and Reference*).

2. e.g. 'an unmarried man is a bachelor' is the same as saying: 'a bachelor is a bachelor'.

3. To say that such a statement is true is therefore to state that two different signifiers signify the same concept.

4. This is therefore the only analytic truth claim that is about the relationship between signifiers and concepts rather than two or more concepts.

ii. Two concepts have mutually exclusive predicates;

1. To say such a statement is true is to say that that concept x has the predicate α and concept y has the predicate $\neg\alpha$.

iii. A concept has a predicate that is the defining predicate of a set, making it an element of that set;

iv. A set has as its defining predicate a predicate that is contained in the defining predicate of another set;

v. A concept cannot be an element of a set because it does not contain the defining predicate of that set.;

vi. All elements of a set cannot be elements of another set because their defining predicates are mutually exclusive.

4. <u>Claims about analytic truth-values do not correspond to an objective or external reality:</u>

a. Truth claims about analytic propositions are accepted or rejected based on how an individual comprehends the relationship between predicates of subjects, or the relationship of signifiers to subjects.

b. If an individual comprehends the relationship, they label the assertion as 'true'. If an individual is unable to comprehend the relationship, they label the assertion as 'not true'.

i. To say that an analytic claim is true is not to make a claim about external reality, but rather a statement about an individual's psychological processes.

c. The process of determining if a proposition is true is therefore a fundamentally solitary and subjective process.

d. When attempting to comprehend the truth-value judgements of others, I could be mistaken in my understanding of which concepts the signifiers refer to.

i. For example, while two people may refer to an object as having the colour 'red', i.e. they may agree on the signifier, they have no way of ascertaining that they have been imparted with the thought of the same concept.

1. This problem can never be overcome. The only way I could ever attempt to clarify which concepts the signifiers refer to is through some form of discussion with the individual making the truth claim, which inescapably involves the use of other signifiers.

ii. The source of much dispute in philosophy comes from individuals arguing past each other. They agree on fundamental concepts, but do not realise this because they misunderstand each other's signifiers.

iii. The usual problems related to the epistemic gap1 (between that which appears to be and that which is) also applies to how signifiers are used to transfer the thoughts of concepts.

1 Like the systematic doubt of Descartes (Descartes, *Meditations*), or Kant's noumena/phenomena distinction (Kant, *Critique of Pure Reason*).

   iv. Because of these issues related to the ability of language to facilitate communication between people, a priori truths are only true within the language game itself.

 e. Because we are not able to show each other how we relate one concept to another, but can only attempt to express signifiers to that effect, it is impossible for truth to be an objective property in any meaningful sense. Because truth is a label that we apply to the relationship of concepts as a consequence of our own thought patterns, it cannot be independently verified.

   i. In this sense, the truth-value of an analytic proposition does not meaningfully correspond to an external or objective reality.

5. Conclusion:

In so far as I understand, even in a priori statements, truth is the product of an individual's thought process when considering the relationship between concepts in a proposition. As such analytic truths do not in fact correspond to an external, objective reality.

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Do the Vikings deserve their bloodthirsty reputation?

Marcus Woodhouse

Many reports we have on the violent Norsemen seem to suggest that all the Vikings did, and were capable of, was fighting. It is true – lots of Vikings at the time were warriors and their daily lives were centred around plundering, burning and killing. However, new evidence forces us to consider a different side of the story. These new discoveries prove that Vikings were exceptional craftsmen and inventors, creating things such as the Longboat. Also, they used many of these extraordinary ships for exploration and settling. So, the question is: Were *all* Vikings just brutal and bloodthirsty warriors with a desire to kill, or was that not the case? Did the Vikings deserve their violent and bloodthirsty reputation? Well, this essay will show you that they really don't.

Some proof that the Vikings do deserve their reputation is their wild beliefs in religion. For starters, instead of Heaven, the Vikings had Valhalla; a place of fighting, drinking and feasting. This shows how highly the Vikings approved of these three actions. Also, you only went to Valhalla if you died in battle, where as if you died a 'cow's death', as it was called, you went to Viking Hell (called Hel). Viking gods consist of many violent deities as well as multiple warlike giants, such as Thor, Odin and Loki. Human sacrifices occurred in Viking Scandinavia and to top it all off, the die-hard believers of their religion were called berserkers, who tended to be deranged, vicious men that did crazy things, such as drinking tree sap to psych themselves up for battle.

More evidence for the stereotypical Vikings includes their vicious actions, much of which involves their seemingly heartless approach to warfare. One such action was when the Vikings captured King Edmund of East Anglia, proceeding to severe his ribs from his spine and pull the lungs the lungs up through the new opening – creating 'The Blood Eagle'. Often, Viking raiders were granted many riches from their enemies, only to later come back and pillage the city anyway. There are multiple examples of this happening: a Viking raid on Paris when the current French King (Charles the Bald) provided a ransom only to have Viking raiders back on his shores almost immediately and when Vikings had control of all Britain apart from Wessex. At the time, the king of Wessex was King Alfred the Great who made a deal with the Vikings for them not to attack him. King Alfred provided them with as many hostages as they wanted and made the Viking invaders do the same. However, the Vikings killed all the hostages and proceeded to attack King Alfred the Great to attempt to wrest control of Wessex. Thus, all the Viking hostages were killed, but the invasion force took no notice. Finally, Viking warriors had a tendency to leave their wounded to die on the battlefield, which would now be considered utterly unethical and dishonourable to their comrades.

All these points may be true, but often these tales were exaggerated or not telling the whole story. One reason for this is that most of what we know about the Vikings comes from a certain book called the Anglo-Saxon Chronicle. Not only is this written by Anglo-Saxons, who had a strong dislike for the Vikings, it was written by the churchmen of Anglo-Saxon England, who were the people that the Vikings seemed to be targeting the most. Also, the book only has a few sentences for each year, so our information from that time is limited. Another Anglo-Saxon, called Asser, also wrote a book featuring the Vikings and their sinful ways, but he was King Alfred the Great's best friend and advisor, so that isn't much better either. One example of not telling the whole story is about Viking religion. Anyone can admit that Viking beliefs were quite violent and war-centred. However, Vikings soon converted to Christianity in around 750 AD, which put an end to their warlike religion. Another example of where the Anglo-Saxons have not told the whole story, is why the Vikings were raiding and conquering England. The Anglo-Saxons seem to believe that the Vikings were only raiding them for spite and pleasure. However, this new evidence implies that because of the rising sea levels and Viking population, the Norsemen *needed* more land, and the discovery of Britain provided the opportunity to gain some more. Another related point is that fighting seemed to be the norm at that time in history. The Romans don't have such a violent reputation, yet they killed many more people than the Vikings ever did.

Contradicting popular myths, the Vikings appeared to have a civilized side as well as the battle-hardened side that stands out in the stereotypical Viking. These Scandinavians were not just warriors; they were also settlers, explorers, craftsmen and traders. Their tactics for battle were quite sophisticated and organized and there have been times where the Vikings have spared their enemies that beg for mercy, rather than put them to the sword. The Viking civilization also connected the European world to many Eastern civilizations through trade and warfare together. Most of what we have heard about the Vikings probably comes from when they were not Christians, but when they were converted, Viking morals suddenly became a lot less warlike and quite a bit more peaceful. When they conquered new places, the Vikings settled there, and established wealthy cities such as York. These cities had civilized places like law courts and in the city, trade and bartering happened all the time, proving that the Vikings were trustworthy and kept their word when dealing with members of their own civilization.

Ultimately, the Viking Longboats and their voyages prove that the Vikings can't have just been fighting all the time, as fashioning an engineering masterpiece such as the Longboat would take considerable time effort, along with immense skill and brainpower. These Longboats were narrow enough to travel upriver and wide enough to cross the Atlantic Ocean! Even by modern standards, this invention would still be a marvellous form of naval transport. With these masterpieces, Vikings such as Eric the Red and his son, Leif Ericson could discover far-flung places like Greenland, Iceland and even America. Agility was another feature of the Longboat, as it was very swift and could steam ahead of any boat in its vicinity if it needed to. As well as the technological side to it, Viking astronomers must have been extremely skilled to navigate their ships to all these places.

As a summary, the Vikings were about as violent as the Anglo-Saxons themselves and no less innocent. Obviously, their enemies thought bad of them, but if we look more closely, the Vikings seem to be honourable, ethical people, just like any other major civilization. Taking into account both sides of the story, the conclusion is this: The Vikings do not deserve their foul reputation and should be treated at least as equals to the Anglo-Saxons in history.

Should be:

'In the light of evidence that modern humans have a mixture of genes from Neanderthals and other species, can we really define ourselves as a species'

Jonathan Gathercole

Homo sapiens, the species in which all modern humans belong, stands alone within the genus *Homo*. It was not always this way; 70 thousand years ago when our *Homo sapiens* ancestors migrated out of their evolutionary home in Africa, travelled across the Red Sea and fanned out across the Eurasian continent, they found themselves face to face with ancient hominids, fellow members of their genus, *Homo neanderthalensis* in Europe, and *Homo denisova* in Asia. Genetic and archaeological evidence suggests our *Homo sapiens* adventurers lived alongside and even interbred with their Neanderthal cousins in Europe as well as their Asian counterparts. According to traditional definitions, this interbreeding questions whether modern humans, Neanderthals and Denisovans are in fact distinct species.

To address this question, we will first discuss what it means to be a species, focusing on three main characteristics that span most modern definitions; morphology, behaviour and genetics. Thus, we will examine each of these criteria in relation to our species and as a result conclude that *Homo neanderthalensis* and *Homo denisova* never truly became distinct species from modern humans, therefore meaning that we can define ourselves as a species.

WHAT IS A SPECIES?

The concept of a species is a human, linear construct to attempt to explain a transient process to classify and identify life on earth. There is still no uniformly agreed definition for what constitutes a species even 150 years on from Darwin's popularisation of the matter.

The most widely accepted species definition seems to be that of Mayr (1970) which is that 'species are groups of interbreeding natural populations that are reproductively isolated from other such groups'. Mayr believed that members of the same species will be able to recognise each other as their own, then breed and produce fertile offspring, whereas members of different species will not recognise the other as a potential mate, or, in the unlikely situation of mating, the offspring would be infertile. This definition works soundly and relatively simply when discussing existing populations where reproductive abilities can be monitored and offspring fertility can be measured. When discussing extinct hominids however, this definition is harder to apply conclusively due to an inability to conduct breeding experiments, although we can infer information about their breeding habits from genetic data. Mayrs's definition encounters further difficulty when applied to mating between members of different populations that result in hybrids with low (or zero) fertility.

Several scientists have also proposed a genotypic criterion for species (Mallet 1995) so that within a local area, separate species are genetically isolated populations recognised by morphological and genetic differences rather than a capability for interbreeding. Modern genetic sequencing technology allows us to examine this definition with respect to extinct populations. However, the problem with this definition is that species may hybridize, resulting in gene flow between two populations which makes genetic distinctions harder.

A behavioural or ecological definition of a species is defined as a population occupying the same ecological niche. This is an appealing definition when differentiations applied to *Homo sapiens* and Neanderthals as it may resolve some of the complexity generated by hybridization events. An ecological niche, however, may be hard to define, especially in a population so adaptable as *Homo sapiens* and in light of the limited evidence available from the fossil record. This idea may be useful with respect to explaining why only one member of the *Homo* genus remains today.

Morphology has historically been used to classify species based on the phenotypic differences between populations. While obviously dependent on a populations underlying genetic composition, this method of characterisation remains useful today in palaeontology. Even with modern genetic sequencing the effects of a given mutation or variation and its significance can be hard to predict. After all, the relationship between genotype and phenotype is rarely direct and often complicated by factors such as epistasis and epigenetics. It also allows us to shed further light on the ecological niche that a population occupies. However, the morphological approach can fall short when faced with cases of convergent evolution and cryptic species.

It is not a surprise that our attempts at a universally applicable definition are imperfect. With the mechanism of evolution relying on slight variation among populations and continual miniscule change over time, it necessitates shades of grey that do not sit well with our attempt to definitively characterise organisms. Acknowledging these imperfect definitions it seems reasonable to consider evidence relating to the genetic, morphological and behavioural definitions of what it means to be a *Homo sapiens* when trying to reach a conclusion. Thus, we will consider whether humans and Neanderthals were able to maintain genetic, morphological and behavioural differences after their migration out of Africa indicating that they were indeed a distinct species. It appears then that Darwin may have been right in his declaration that the categorisation of species 'relied on naturalists having sound judgment' (Darwin 1871).

It is suspected that the last common ancestor of these three hominids (*Homo sapiens*, Denisovans and Neanderthals) left Africa to travel across Europe and Asia to become Neanderthals and Denisovans around 300,000 years ago, whilst other members remained in Africa who over the next 200,000 years developed into anatomically modern humans. Archaeological records indicate that modern humans left Africa around 50-70 thousand years ago, this coincides with the last fossil record of Neanderthals which is dated at 40,000 years ago (Klein 2013) which indicates a time in which the existence of *Homo sapiens* and *Homo neanderthalensis* overlapped.

MORPHOLOGY

The morphological differences between Neanderthals and modern humans have been recorded across the few specimens that have been recovered. Interestingly, however, the first Neanderthal recovered was originally misidentified as an anatomically modern human and it was not until 60 or so years later that the skeleton was re-classified, thus highlighting the basic similarity corresponding to modern humans. It has been documented that the Neanderthals differ morphologically from their African counterparts in that they were physically more robust, they had a receding forehead with prominent brow ridges, a short and stocky body with an oblong skull that was larger in proportion to their body than is seen in modern humans. We modern humans by contrast are considered to have a flat and near vertical forehead, a lighter build, taller with a smaller brain relative to the body, a high round cranium and globular skull, a chin as well as reduced masticatory apparatus and brow ridges.

However, it should be considered that fossil records of the last million years are variable and indeed considered to be early modern humans are by no means homogenous with there being a wide range of phenotypic variation across modern human and Neanderthal species alike. The implication of this is that we could be comparing a phenotypic extreme of a Neanderthal with the phenotypic extreme of a *Homo sapiens*, thereby creating a false picture as to the actual extent of differences between each population. Moreover, there have been very few fossils documented over a 160 thousand year time span and the implication of this is a potentially flawed picture of what Neanderthals look like. This begs the question as to whether one can really be sure of what we are comparing.

Even further questioning must be delivered when considering hybridization amongst the hominins which is likely to result in a range of morphological variations, as hybridized offspring may possess phenotypic traits common with one group and others common with another group. Knowing this, can we really draw comparison between anatomically modern humans and our archaic cousins based on only approximately 350 Neanderthal fossils found, the majority of which are not complete skeletal structures. Resultantly, the distinction between the two 'species' is less apparent.

One area of shared morphology between Neanderthals and anatomically modern humans is the hyoid bone. The hyoid bone is a horseshoe shaped bone located in the midline of the neck between the chin and thyroid cartilage. The hyoid bone plays a crucial part in the formation of language for modern humans, this is because the tongue's movements that influence the morphology of the vocal tract in sound production are the result of the hyoid movements controlled by activity in both the hyoid and the extrinsic tongue muscles. However, shared similarity in overall shape does not necessitate that the bone was used in the same way as in *Homo sapiens*. D'Anastasio et al (2013) conducted a comparative study between the hyoid bones of Neanderthals and that of modern humans. The findings concluded very similar internal architectures and biomechanical behaviours using methods such as histology, musculature reconstruction and biomechanical analysis with models considering micro-geometry. Overall, due to the bone architecture strongly reflecting the loading a bone is subject to their findings strongly suggested a capacity for speech in Neanderthals. When considering this evidence alongside factors such as the FOXP2 gene variant which is discussed later, it seems fair to suggest that the most defining characteristic of the *Homo sapiens* species was shared with our hominid cousin, blurring the line between the two populations as distinct species.

BEHAVIOUR

Behaviour is considered part of what separates a species from closely related forms (Mayr 1963). There is an impression that the *Homo sapiens* who expanded out of Africa must have been intellectually and behaviourally superior to *Homo neanderthalensis* feeding into the narrative that modern humans outsmarted and drove Neanderthals to extinction. However, Neanderthals were more advanced than popular opinion would have you believe, the Neanderthals in fact had a well-established stone tool tradition amongst other intellectually advanced behaviours like burying their dead and complex weapon creation. The popular theory for a long time was that the believed superiority of the modern humans allowed them to evolve complex cultural traditions and become equipped with an adaptive cognitive ability that allowed them to out compete Neanderthals and eventually lead to their extinction (e.g. Klein 1995). However, most experts today acknowledge that it was not that simple and that some evidence now suggests that the behaviour of the modern humans who inhabited Africa between 100,000-50,000 years ago was more similar to that of their Neanderthal contemporaries than originally thought. This has come from developments in our understanding of Neanderthal diet, subsistence, technologies, artistic activity and personal adornments.

For example, there is evidence of Neanderthal artistic activity. Ochre is a substance combined with other natural products to make pigments. The use of ochre has also been reported in association with Neanderthals specifically finds in the Netherlands (Roebroeks et al 2012) dated to 200,000-250,000 years ago. This suggests that Neanderthals, like humans, had a propensity and appreciation for art and beauty. Neanderthal personal adornment has been found in marine shellfish with evidence of pigmentation, comparable to

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evidence of modern human personal adornment found in the form of 65 shell beads that were found in Blombos cave (Henshilwood et al 2004). It can be argued that these artistic behaviours seen in Neanderthal populations are a result of mimicking the behaviours demonstrated to them following their encounters with *Homo sapiens*, however, the ability to understand, appreciate and subsequently replicate intricate tool making and artistic techniques is clear evidence of an advanced intellectual capability that cannot be so easily dismissed.

The linguistic ability of modern humans is unlike no other demonstrated by a species on earth. Our use of language to convey complex ideas is undoubtedly our most defining feature as a species. Evidence that Neanderthals may too have possessed alleles thought to be instrumental for the development of language suggests our unique linguistics may have been shared by Neanderthals as well. The gene causing the discussion lies in chromosome 7 and is known as FOXP2. It is the only gene to have been shown to have a clear role in the development of language. Mutations in FOXP2 have been noted to cause a severe disorder called developmental verbal dyspraxia which creates deficits in facial movement which prohibit speech greatly, thereby highlighting the genes contribution to language development. FOXP2 is highly conserved in mammals with a mere 2 amino acid substitutions separating the allele in modern humans with that of chimpanzees and other mammals. Further analysis of mutation variation in the gene suggests this FOXP2 variant was subject to a selective sweep, outcompeting other allele variants and leaving it dominant in the human population for the last 200,000 years. As such it seems fair to conclude that FOXP2 was important for human evolution, subject to strong selective pressure whilst simultaneously important for language development.

With relevance to our discussion, the sequencing of Neanderthal DNA by Ernard et al (2002) demonstrated the same 2 substitution FOXP2 variant was present in Neanderthals as it is now in modern humans. This information therefore implies that the same language capability present in modern humans was also present in our archaic European cousin. Given the nature of linguistic comprehension as such a defining characteristic of what it takes to be a member of our species, the categorisation of Neanderthals as a separate species becomes harder when noting the prevalence of this gene and their possible linguistic capabilities. It is worth noting that the genetic regulation surrounding language development is incompletely understood and it is hard to say conclusively that the possession of FOXP2 endowed Neanderthals with complex language abilities. However, when combining this with evidence surrounding the hyoid bone similarities between modern humans and Neanderthals, as well as evidence of Neanderthals artistic prowess, there is a compelling indication of the intelligence and cognitive ability of Neanderthals, which seems not to be dissimilar from our own.

In light of these behavioural overlaps it again becomes harder to see how the two groups, aside from geographically, can be viewed as different species. Perhaps, the distinction between the two comes down to DNA.

GENETICS

The genomic definition of species focuses mainly on the genetic isolation of an interbreeding population. Modern genome sequencing techniques have revealed the presence of shared DNA sequences between modern humans and Neanderthals (as well as Denisovans). This evidence of gene flow suggests that interbreeding occurred between Neanderthals and *Homo sapiens* as well as Denisovans with *Homo sapiens*. This leads us to the apparent conclusion that these hominin groups are in fact members of one species that has differentiated due to geographical isolation.

The Max Planck Institute underwent the Neanderthal Genome Project and extracted the DNA from femur bones of three 38,000 year old Neanderthal specimens. In 2010 their examinations of DNA demonstrated a range of genetic contributions to non-African modern humans ranging from between 1-4% but found zero or near zero in people from African populations. However, Neanderthals are not the only archaic hominin to dwell in the genome of humans today. In the sub-region of Oceania lies an area known as Melanesia, its inhabitants, Melanesians, are found to possess 4-6% of Denisovan DNA. Vernot et al (2016) surveyed archaic genomic sequences in a worldwide sample of modern humans including 35 people from the Melanesian islands. The non-African genomes contained Neanderthal DNA which is consistent with the findings from the Max Planck institute study but a significant Denisovan component was found only in those from the Melanesian islands suggest that the Neanderthals bred with modern humans multiple times but the Denisovans far fewer and predominantly with the ancestors of the modern day Melanesians.

Although it is now known that some modern humans contain genetic information from Neanderthals and in rarer cases, Denisovans, this begs the question as to what these genes are and what their significance is. Sankararaman et al (2014) looked at the genomes of 1004 present day humans and found that regions that have a high frequency of Neanderthal alleles affect keratin filaments influencing hair and skin tone. Supporting this are signs of positive selection for chromosome regions containing genes affecting the cellular response to ultraviolet radiation. This suggests that Neanderthal alleles may have helped modern humans adapt to the colder, darker environments. Ackermann et al (2016) suggests that gene flow across these lineages may have been essential to *Homo sapiens* wide spread survival through the transference of HLA genes from the local populations of Denisovans and Neanderthals who were better adapted to pathogens in their respective environments. A 2011 study by Stanford University concluded that many modern humans carry ancient variants of immune related genes involved in the recognition of pathogens that arose after we left Africa, the likely source of these genes lies with archaic hominins with whom we interbred. Ackermann et al (2016) also proposes the idea that the magnitude of gene exchange between Neanderthals and modern humans may be considerably larger than is reflected by the genetic data, unsurprising considering the very small number of sequenced Neanderthal genomes. The presence of Neanderthal DNA in modern humans clearly points to interbreeding between the two groups and interestingly the fact that genetic transference between the two populations was possible and led, at least in some cases, to fertile offspring, seems to suggest that the groups had not yet fully diverged into distinct species.

The importance of hybridization in shaping both the genotype and the phenotype of *Homo sapiens* is outlined by Ackermann et al (2015) to be essential in the establishment of the adaptable *Homo sapiens* species today. It is also important to recognise the likelihood of many fossils discovered and identified as Neanderthals and modern humans in fact being hybrids between the groups, especially when considering largely modern skeletons sometimes possessing isolated features that are similar to that of a Neanderthal (Ahern et al. 2013). The nature of misleading hybrid fossils is highlighted through the discovery of modern human remains in Romania by Dr Fu et al (2015) thought to be 37-42,000 years old. Subsequent analysis of the genome had 6-9% of Neanderthal ancestry genes and was assessed to have a direct Neanderthal ancestor removed by only 4-6 generations.

Despite the evident similarities in genetics between the populations of Neanderthals and *Homo sapiens*, its not to say that the 200,000 year geographic isolation did not encourage divergence in the groups that was undeniably approaching speciation. In 2016 a genetic study of more than 50 *Homo sapiens* fossils of between 7,000 and 4,500 years old were analysed and thus demonstrated that the proportion of Neanderthal DNA in modern humans lessened as the fossils were more recent. This is suggestive that Neanderthal genes may have been non-advantageous to modern humans and were weeded out from modern human gene pools. The Sankararaman (2014) study also showed large gene deserts of Neanderthal ancestry supporting the idea that some genes were weeded out from the *Homo sapiens* gene pool. The same study showed that Neanderthal ancestry genes are significantly reduced in expression in the testes and that there is a Neanderthal ancestral gene reduction of five times on chromosome X, this chromosome is known to contain a high fraction of male hybrid sterility genes. This is suggestive of the fact that either the offspring of interbreeding between Neanderthals and homo sapiens were infertile or at least less fertile highlighting the nature of their biological incompatibility. It is important to also note the fact that due to modern humans containing DNA from Neanderthals, not all hybrids could have been sterile therefore providing evidence for the nature of the diverging yet overlapping speciation's of the two groups.

CONCLUSION

The geographic separation of approximately 200,000 years between Neanderthals and early *Homo sapiens*, undeniably led to divergence in morphology, behaviour and genetics. Considering the genetic evidence for reduced hybrid fertility it seems reasonable to assume that these populations were on the cusp of speciation and it is likely that had these groups remained isolated speciation would have occurred. As it stands, however, examination of the morphological, behavioural and genetic evidence suggests that Neanderthals and modern humans remained one species. Indeed, archaeological evidence suggests the two populations were able to live aside one another as social and cognitive equals; and there is clear genetic evidence of interbreeding between the two populations suggesting that they did not constitute genetically isolated populations. Moreover, it seems that morphological variation can be better explained as a result of phenotypic variation amongst both groups and the incomplete nature of the fossil record. It is also worth considering the social and ethical consequences of excluding Neanderthals from our species; are we to consider modern populations or individuals possessing larger amounts of Neanderthal DNA to be somehow less human or more primitive?

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A look at Lagrangian Mechanics

Freddie Floydd

1. INTRODUCTION

Lagrangian Mechanics is a branch of classical mechanics which uses energies rather than forces to produce equations of motion. This is often superior to Newtonian Mechanics when dealing with complex situations, as it is easier to consider an object's potential and kinetic energies, which are both scalars, than to work out the directions and magnitudes of the forces acting on it. By using the Lagrangian of a system we can obtain a set of equations for the second derivatives of the system's variables in terms of the variables themselves and the first derivatives, the equations of motion. By solving the equations of motion for the system either analytically or via numerical methods we can model how the system evolves over time. In general, the Lagrangian of a system is defined as

$$L \equiv T - V\,,$$

where T = Sum of Kinetic Energies and V = Sum of Potential Energies.

This definition may seem arbitrary but it leads to a very useful result, called the Euler-Lagrange equation:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{x}}\right) = \frac{\partial L}{\partial x}\,.$$

The proof of this result is frankly over my head mathematically, but that will not stop me from using it to have some fun with mechanics. For those interested it depends on the principle of stationary action.

2. APPLYING THE LAGRANGIAN

To see this equation in action, let's look at the simple situation of a pendulum.

We can see in Fig.1 that the potential and kinetic energies are:

$$V = mgr\left(1 - \cos\theta\right)$$
$$T = \frac{1}{2}mr^2\dot{\theta}$$

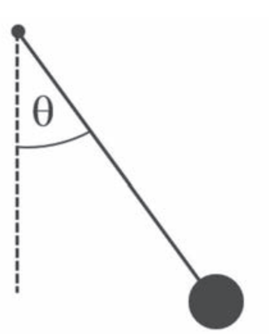

Figure 1: A simple pendulum

So the Lagrangian is

$$L = \frac{1}{2}mr^2\dot{\theta} + mgr\left(\cos\theta - 1\right).$$

From this we can differentiate with respect to θ and $\dot{\theta}$ to obtain the following expressions:

$$\frac{\partial L}{\partial \theta} = -mgr\sin\theta$$
$$\frac{\partial L}{\partial \dot{\theta}} = mr^2\dot{\theta}$$
$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) = mr^2\ddot{\theta}$$

Using the Euler-Lagrange equation from above, we get

$$\ddot{\theta} = -\frac{g\sin\theta}{r}\,.$$

This is the equation of motion for a simple pendulum which can be obtained through Newtonian mechanics, via resolving forces on the pendulum bob for a given angle θ. A differential equation is very useful for any mechanical system, as it tells us how a system will change over time given a set of initial conditions, for example the initial speed at which the pendulum is projected and its initial angle. Note that for small values of we can use a small angle approximation here to give

$$\ddot{\theta} = -\frac{g}{r}\theta\,,$$

which is by definition simple harmonic motion. This method is much simpler than the Newtonian approach however, as we do not have to deal with the directions of forces acting on the pendulum bob. This allows us to look at much more complex situations, such as a double pendulum.

3. MORE COMPLEX SITUATIONS

In more complex situations there are often more variables to keep track of than just a single angle. We are able to form differential equations for each variable by performing the same process as above on the Lagrangian for each of the variables, allowing us to model the situation with a system of multiple differential equations, which can be solved simultaneously. While these systems are very rarely analytically solvable, we can employ computers to find numerical solutions. (I have written a few programs modelling complex mechanical situations, based off differential equations formed using the Lagrangian method, which can be found on Github.) Now, as promised, let's look at something more interesting.

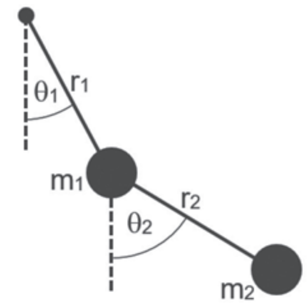

Figure 2: A double pendulum

A double pendulum, while at face value not appearing much more complex than a single pendulum, is a completely different scenario in that as well as gravity providing a constant downward force on each of the bobs, the motion of each bob will exert a force on the other, making the system extremely chaotic.

Our first step is to identify the Cartesian coordinates of each mass.

$$(x,\, y)_{m_1} = (r_1 \sin\theta_1,\, -r_1\cos\theta_1)$$
$$(x,\, y)_{m_2} = (r_1 \sin\theta_1 + r_2\sin\theta_2,\, -r_1\cos\theta_1 - r_2\cos\theta_2)$$

We can now differentiate each of these positions with respect to time to obtain the velocity of each mass.

$$(\dot{x},\, \dot{y})_{m_1} = (r_1\dot{\theta}_1\cos\theta_1,\, r_1\dot{\theta}_1\sin\theta_1)$$
$$(\dot{x},\, \dot{y})_{m_2} = (r_1\dot{\theta}_1\cos\theta_1 + r_2\dot{\theta}_2\cos\theta_2,\, r_1\dot{\theta}_1\sin\theta_1 + r_2\dot{\theta}_2\sin\theta_2)$$

We now have all we need to make expressions for the potential and kinetic energy of the system. As we know,

$$V = mgh$$
$$T = \frac{mv^2}{2}\,.$$

From these we can form the Lagrangian.

$$V = -r_1 m_1 g\cos\theta_1 - m_2 g\,(r_1\cos\theta_1 + r_2\cos\theta_2)$$
$$T = \frac{1}{2}r_1^2 m_1\dot{\theta}_1^2 + \frac{1}{2}m_2(r_1^2\dot{\theta}_1^2 + r_2^2\dot{\theta}_2^2 + 2r_1r_2\dot{\theta}_1\dot{\theta}_2\cos(\theta_1-\theta_2))$$

$$L = \frac{1}{2}r_1^2 m_1\dot{\theta}_1^2 + \frac{1}{2}m_2(r_1^2\dot{\theta}_1^2 + r_2^2\dot{\theta}_2^2 + 2r_1r_2\dot{\theta}_1\dot{\theta}_2\cos(\theta_1-\theta_2)) + r_1 m_1 g\cos\theta_1 + m_2 g\,(r_1\cos\theta_1 + r_2\cos\theta_2)$$

We can now find a number of derivatives, which can be used to form a pair of coupled differential equations.

$$\frac{\partial L}{\partial\dot{\theta}_1} = r_1^2\dot{\theta}_1(m_1+m_2) + r_1r_2m_2\dot{\theta}_2\cos(\theta_1-\theta_2)$$
$$\frac{\partial L}{\partial\theta_1} = -r_1 g\sin\theta_1(m_1+m_2) - r_1r_2m_2\dot{\theta}_1\dot{\theta}_2\sin(\theta_1-\theta_2)$$
$$\frac{d}{dt}\frac{\partial L}{\partial\dot{\theta}_1} = r_1^2\ddot{\theta}_1(m_1+m_2) + r_1r_2m_2\ddot{\theta}_2\cos(\theta_1-\theta_2) - r_1r_2m_2\dot{\theta}_2(\dot{\theta}_1-\dot{\theta}_2)\sin(\theta_1-\theta_2)$$
$$\frac{\partial L}{\partial\dot{\theta}_2} = r_2^2 m_2\dot{\theta}_2 + r_1r_2m_2\dot{\theta}_1\cos(\theta_1-\theta_2)$$
$$\frac{\partial L}{\partial\theta_2} = -r_2m_2g\sin\theta_1 + r_1r_2m_2\dot{\theta}_1\dot{\theta}_2\sin(\theta_1-\theta_2)$$
$$\frac{d}{dt}\frac{\partial L}{\partial\dot{\theta}_2} = r_1^2\ddot{\theta}_1(m_1+m_2) + r_1r_2m_2\ddot{\theta}_2\cos(\theta_1-\theta_2) - r_1r_2m_2\dot{\theta}_2(\dot{\theta}_1-\dot{\theta}_2)\sin(\theta_1-\theta_2)$$

Using the derivatives we can form the differential equations for the system.

$$r_1\ddot{\theta}_1(m_1+m_2) + r_2m_2\ddot{\theta}_2\cos(\theta_1-\theta_2) + r_2m_2\dot{\theta}_2^2\sin(\theta_1-\theta_2) = -g\sin\theta_1(m_1+m_2)$$
$$r_2\ddot{\theta}_2 + r_1\ddot{\theta}_1\cos(\theta_1-\theta_2) - r_1\dot{\theta}_1^2\sin(\theta_1-\theta_2) = -g\sin\theta_2$$

While these differential equations cannot be solved analytically, we can solve them numerically by rearranging to eliminate $\ddot{\theta}_2$ from the first equation. This gives us an expression for $\ddot{\theta}_1$ in terms of $\theta_1, \theta_2, \dot{\theta}_1,$ and $\dot{\theta}_2$. We can also rearrange to give a similar equation for $\ddot{\theta}_2$. Using these equations we an substitute in values for these variables and obtain an angular acceleration for each of θ_1 and θ_2. We can then add this acceleration to the corresponding angular velocities, and add the angular velocities to the angles, repeating this process millions of times per second will give a very close approximation to how an analytic solution to the equations would behave. To visualize this system I programmed a simulation to model the equations. As can be seen in the trace of the pendulum below, the system is very chaotic.

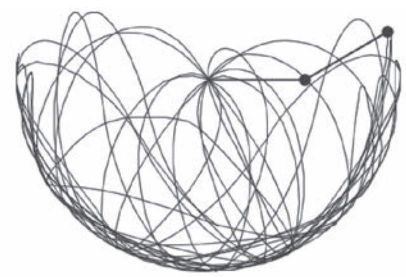

Figure 3: The trace of a double pendulum, with the initial conditions shown

4. TAKING THINGS FURTHER

There are many more situations that can be investigated using Lagrangian mechanics, such as triple (or even more!) pendulums, making special relativistic corrections to systems, or virtually any convoluted mechanics problem you could think of. Below are a number of situations I looked at in addition to those above, with the relevant differential equations describing the systems. I have made simulations of the special relativistic pendulums to illustrate the differences in the system due to the correction at low and high speeds.

4.1 THE TRIPLE PENDULUM

Despite only having one more bob than a double pendulum, the triple is significantly more complex to model using the Lagrangian, due to having three differential equations to form, and there being more inter-bob forces at play. It is also significantly harder to model computationally, without doing some clever work with matrices, though more will be explained about that later.

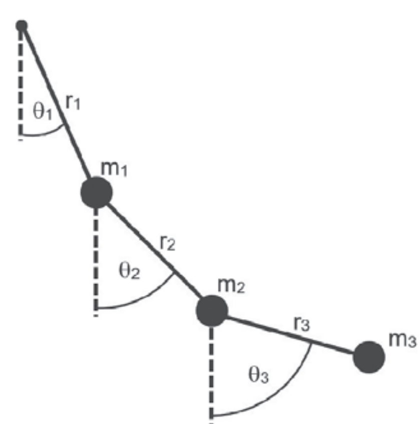

Figure 4: A triple pendulum

The system can be described by the following equations:

$$
\begin{aligned}
r_1(m_1+m_2+m_3)\ddot{\theta}_1 &= -g(m_1+m_2+m_3)\sin\theta_1 - r_2(m_2+m_3)\left(\ddot{\theta}_2\cos(\theta_1-\theta_2)+\dot{\theta}_2^2\sin(\theta_1-\theta_2)\right)\\
&\quad - r_3m_3\left(\ddot{\theta}_3\cos(\theta_1-\theta_3)+\dot{\theta}_3^2\sin(\theta_1-\theta_3)\right)\\
r_2(m_2+m_3)\ddot{\theta}_2 &= -g(m_2+m_3)\sin\theta_2 - r_1(m_2+m_3)\left(\ddot{\theta}_1\cos(\theta_2-\theta_1)+\dot{\theta}_1^2\sin(\theta_2-\theta_1)\right)\\
&\quad - r_3m_3\left(\ddot{\theta}_3\cos(\theta_2-\theta_3)+\dot{\theta}_3^2\sin(\theta_2-\theta_3)\right)\\
r_3\ddot{\theta}_3 &= -g\sin\theta_3 - r_1\left(\ddot{\theta}_1\cos(\theta_3-\theta_1)+\dot{\theta}_1^2\sin(\theta_3-\theta_1)\right)\\
&\quad - r_2\left(\ddot{\theta}_2\cos(\theta_3-\theta_2)+\dot{\theta}_2^2\sin(\theta_3-\theta_2)\right)
\end{aligned}
$$

At this point you may be able to spot a pattern in the equations which was also present in the equations for the double pendulum. It is in fact possible to generalize these equations of motion to larger numbers of pendulums, allowing more complex systems to be modelled without the need to derive the equations of motion by hand each time.

4.2 BLOCK AND PENDULUM ON A SLOPE

This was one of the first problems I attempted to model using the Lagrangian, and is a good one to have a go at yourself should you feel inclined. This is an interesting situation because while looking at this using forces would be very complicated, the Lagrangian approach greatly simplifies it.

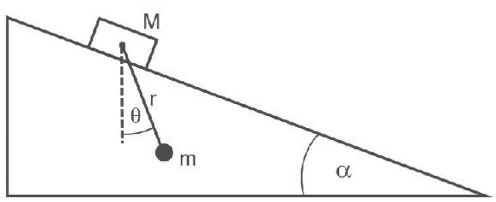

Figure 5: A complex mechanical system

If we take z to be the distance moved down the slope by the block, then the equations of motion for the system are:

$$
(M+m)\ddot{z} + mr\left(\ddot{\theta}\cos(\theta+\alpha)-\dot{\theta}^2\sin(\theta+\alpha)\right) = (M+m)g\sin\alpha
$$

$$
r\ddot{\theta} + \ddot{z}\cos(\theta+\alpha) = -g\sin\theta
$$

4.3 RELATIVISTIC CORRECTION FOR A SINGLE PENDULUM

In a standard single pendulum, the bob will move nowhere near the speed of light, but it is interesting to consider the effects special relativity would have if the speed of light was much lower. Using Special Relativity, we arrive at the following equation for an object's kinetic energy

$$
KE = m_0c^2\left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}-1\right),
$$

where is the 'rest mass' of the object, the mass it has when it is not mcm_0J, v is the speed of the object and c is the speed of light. When $v << c$, this expression simplifies to Newtonian KE, but diverges greatly from this as v approaches c. The differential equation for the relativistic pendulum is similar to the simple one, but has a multiplying factor which reduces the acceleration as the speed of the bob increases.

$$
\ddot{\theta}\left(\gamma^3+\frac{3r^2\dot{\theta}^2}{c^2}\gamma^5\right) = -\frac{g}{r}\sin\theta
$$

$$
\text{Where } \gamma = \frac{1}{\sqrt{1-\frac{r^2\dot{\theta}^2}{c^2}}}
$$

4.4 RELATIVISTIC CORRECTION FOR A DOUBLE PENDULUM

In the same way the Lagrangian of the double pendulum is significantly harder than that of the single pendulum, applying special relativity to a double pendulum is much, much more complex than any of the previous situations, and is a good way to end this investigation into how far Lagrangian mechanics can be taken. It should be noted that when $v << c$, these differential equations simplify to the same as those obtained in the earlier derivation.

$$
\begin{aligned}
-(m_1+m_2)g\sin\theta_1 = m_1r_1\ddot{\theta}_1 &\left(\phi^3+3\phi^5(r_1\dot{\theta}_1+r_2\dot{\theta}_2\cos\alpha)\left(\frac{r_1\dot{\theta}_1+r_2\dot{\theta}_2\cos\alpha}{c^2}\right)+\frac{3r_1^2\dot{\theta}_1^2\gamma^5}{c^2}+\gamma^3\right)\\
+ m_2r_2\ddot{\theta}_2 &\left(\phi^3\cos\alpha+3\phi^5(r_1\dot{\theta}_1+r_2\dot{\theta}_2\cos\alpha)\left(\frac{r_2\dot{\theta}_2+r_1\dot{\theta}_1\cos\alpha}{c^2}\right)\right)\\
+ m_2r_2\sin\alpha &\left(\dot{\theta}_2^2\phi^3+3\phi^5(r_1\dot{\theta}_1+r_2\dot{\theta}_2\cos\alpha)\left(\frac{r_1\dot{\theta}_1\dot{\theta}_2(\dot{\theta}_2-\dot{\theta}_1)}{c^2}\right)\right)
\end{aligned}
$$

$$
\begin{aligned}
-g\sin\theta_2 = r_2\ddot{\theta}_2 &\left(\phi^3+3\phi^5(r_2\dot{\theta}_2+r_1\dot{\theta}_1\cos\alpha)\left(\frac{r_2\dot{\theta}_2+r_1\dot{\theta}_1\cos\alpha}{c^2}\right)\right)\\
+ r_1\ddot{\theta}_1 &\left(\phi^3\cos\alpha+3\phi^5(r_2\dot{\theta}_2+r_1\dot{\theta}_1\cos\alpha)\left(\frac{r_1\dot{\theta}_1+r_2\dot{\theta}_2\cos\alpha}{c^2}\right)\right)\\
- r_1\sin\alpha &\left(\dot{\theta}_1^2\phi^3-3\phi^5(r_2\dot{\theta}_2+r_1\dot{\theta}_1\cos\alpha)\left(\frac{r_2\dot{\theta}_1\dot{\theta}_2(\dot{\theta}_2-\dot{\theta}_1)}{c^2}\right)\right)
\end{aligned}
$$

$$
\text{Where } \gamma = \left(1-\frac{r_1^2\dot{\theta}_1^2}{c^2}\right)^{-\frac{1}{2}},\ \phi = \left(1-\frac{r_1^2\dot{\theta}_1^2+r_2^2\dot{\theta}_2^2+2r_1r_2\dot{\theta}_1\dot{\theta}_2\cos\alpha}{c^2}\right)^{-\frac{1}{2}} \text{ and } \alpha = \theta_1-\theta_2.
$$

5. A FINAL LOOK AT PENDULA

If you look carefully at the above equations of motion for the double and triple pendulums, you may spot a pattern. It turns out that we can generalize the equations of motion for an n-bobbed pendulum, and instead of forming a large number of differential equations, each of which must be rearranged to give a given angular acceleration, we can instead form a matrix equation which can be solved to give all the angular accelerations at once. This works because matrices can be used to solve linear systems of equations, and the equations of motion for the system are linear in terms of the angular accelerations. We can feed this matrix equation through a computer program and solve it in a similar manner to how the equations were solved for the double pendulum earlier.

$$
\begin{pmatrix}
a_1\cos(\theta_1-\theta_1) & b_1\cos(\theta_1-\theta_2) & \dots & z_1\cos(\theta_1-\theta_n)\\
a_2\cos(\theta_2-\theta_1) & b_2\cos(\theta_2-\theta_2) & \dots & z_2\cos(\theta_2-\theta_n)\\
\vdots & \vdots & \ddots & \vdots\\
a_n\cos(\theta_n-\theta_1) & b_n\cos(\theta_n-\theta_2) & \dots & z_n\cos(\theta_n-\theta_n)
\end{pmatrix}
\begin{pmatrix} r_1\ddot{\theta}_1\\ r_2\ddot{\theta}_2\\ \vdots\\ r_n\ddot{\theta}_n \end{pmatrix} =
$$

$$
-g\begin{pmatrix} a_1\sin(\theta_1)\\ b_2\sin(\theta_2)\\ \vdots\\ z_n\sin(\theta_2) \end{pmatrix} -
\begin{pmatrix}
a_1\sin(\theta_1-\theta_1) & b_1\sin(\theta_1-\theta_2) & \dots & z_1\sin(\theta_1-\theta_n)\\
a_2\sin(\theta_2-\theta_1) & b_2\sin(\theta_2-\theta_2) & \dots & z_2\sin(\theta_2-\theta_n)\\
\vdots & \vdots & \ddots & \vdots\\
a_n\sin(\theta_n-\theta_1) & b_n\sin(\theta_n-\theta_2) & \dots & z_n\sin(\theta_n-\theta_n)
\end{pmatrix}
\begin{pmatrix} r_1\dot{\theta}_1^2\\ r_2\dot{\theta}_2^2\\ \vdots\\ r_n\dot{\theta}_n^2 \end{pmatrix}
$$

All of the values $a_1 ... z_n$ are simply sums of masses which follow a simple pattern, while the equation can be rearranged to give an expression for the vector containing the angular accelerations. By solving this equation numerically we can make very accurate models of n pendulum systems.

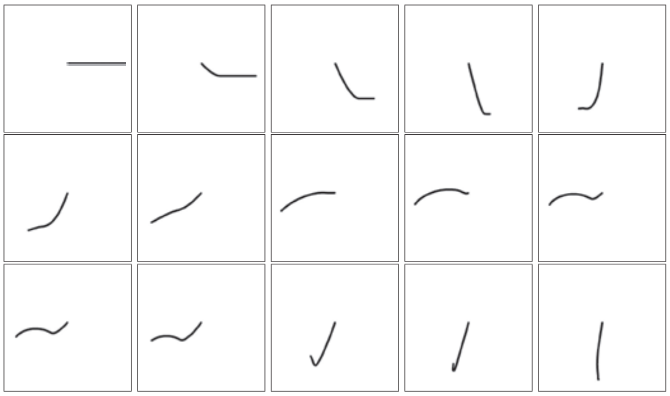

Figure 6: Frames from a rendering of a 100 pendulum system, giving an approximate simulation of a rope

6. CONCLUSION

From the examples above, I hope it is clear that Lagrangian Mechanics is a very powerful tool when looking at challenging mechanical situations. The ability to form equations of motion is always valuable, whether they are solvable analytically or not.
An interesting extension of Lagrangian Mechanics is Hamiltonian Mechanics, where instead of obtaining a single second order DE, two first order DEs are obtained. The Hamiltonian also looks at momentum and position, instead of position and velocity, and therefore is a more general form of the Lagrangian. Both Lagrangian and Hamiltonian mechanics are used in very high level physics, such as in quantum mechanics where the action of one object will affect all others, creating an extremely complex system which could not be modelled with forces.

From the Headmaster

Scholarship could easily be regarded as a rather solitary concept, an isolated activity where an individual immerses himself in academia: hours spent poring over books or time spent on systematic research. Indeed, the Greek comic playwright Aristophanes coined the phrase *pale faces* to describe those students starved of natural sunlight who have devoted themselves solely to the pursuit of their studies at the expense of any interaction with the outside world.

Scholarship is at the very heart of our School Values at the RGS; however, rather than being a divisive concept, the exclusive domain of a select few, scholarship is in fact a quality which unites our whole community. Shared aspiration, mutual collaboration and communal celebration result in an environment where scholarship is embedded in our way of life. Debates, discussion, seminars, lectures, talks all serve to challenge our students, to allow them to reassess their views in the light of others, and to provide enrichment from a range of ideas and perspectives. This dynamic, interactive approach is just one of the reasons why scholarship is flourishing throughout the corridors of the RGS.

This, the third edition of *The Annual*, reinforces just how vibrant, inclusive and creative scholarship is at the RGS. Just by looking at the *Contents* page alone, the sheer diversity, originality and topicality of the research tasks are plain to see, equally spread between the Maths and the Sciences, the Humanities and associated subjects, and the Creative Arts.

I would like to take this opportunity to congratulate my Head of Scholarship, Mr Bradford, and the many students who contributed to *The Annual*. I hope that all who read it are inspired and impressed in equal measure; this is something of which we all should take ownership and in which we should all take pride.

Dr Jon Cox
Headmaster
Royal Grammar School Guildford

"Study hard what interests you the most in the most undisciplined, irreverent and original manner possible."

R. Feynmann

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