Adaptive Mobile Sensing: Leveraging Machine Learning for Efficient Human Behavior Modeling

(Technical topic)

Effects of Ocean Plastic Pollution on Society and the Environment and Potential Solutions

(STS Paper)

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Peer Review and Comments

Over the course of my research and progress, I have received various pieces of information regarding my thesis prospectus. I would like to thank those who have taken the time to read my paper and provide feedback for construction. The first piece of advice I received came from my colleague and fellow student in Systems Engineering.

Robert Donnan read my original draft for my STS Thesis Prospectus, and provided me with the following feedback. He claimed he had done some research on this topic in years past, and informed me of the company known as Bioplastech, which is researching ways to convert plastic which is a nonbiodegradable material into a biodegradable material, which would significantly assist in resolving this issue. He also helped advise me on how my paper should be organized, and I adjusted based on this recommendation. Per his recommendation, I have briefly included this concept in my prospectus, and will incorporate analysis of this method in my final report, as well as my technical topic.

The next piece of advice I was provided was from Professor Gorman after submitting my first draft. I was advised to incorporate Actor Network Theory into my thesis prospectus, as per my topic, this problem requires several actors cooperating in conjunction with one another. I took this advice, and incorporated it into my thesis as described below. Furthermore, I was advised to look more into the scalability of the Dutch method, or Ocean Cleanup Project. After observing this, I incorporated a section analyzing the feasibility and scalability of this option, and gained further insight on how this potential solution might address this issue. Also, Professor Gorman suggested that one of the hardest problems involved with this issue is successfully motivating independent countries to work together in addressing this issue. This was an insight which I had pondered, but not successfully incorporated into my first draft. Thus, I have incorporated this notion in this final draft. Finally, professor Gorman mentioned the use of an iterative design method over time in order to ensure that this problem is mitigated over time. I had not considered this previously somehow, and I have since assessed and included this in my conclusion of this final draft.

Another piece of advice I received came from my classmate Ben Metzger. I also had him read my first draft after I had submitted, and he agreed with what Professor Gorman's suggestions, as did I. Furthermore, he advised me that I should focus more on the analysis of potential solutions with respect to my technical topic. I had rejected this suggestion, as I will incorporate sufficient analysis in my final thesis, and decided that focusing on Actor Network Theory was more important in addressing this issue.

Introduction

The problem of plastic pollution in the world's oceans has proven a threat to the environment, society, and the global economy. More than 300 million tons of plastic are produced across the globe each year; an extremely significant increase from the estimated 1.5 million tons produced worldwide in 1950 ("Plastic Pollution"). This increase in production can be explained from the properties inherent of the chemical composition of plastic. Since plastic is extremely versatile, strong, and cheap to produce; several applications and uses have been discovered and utilized by packaging firms and other distributors, causing plastic production to increase exponentially since 1950 (Lee, 2018).

The EPA defines packaging products, such as plastics, to be products which are assumed to be discarded the same year the products they contain are purchased ("Containers and Packaging", 2019). This definition is the result of the habitual behavior of humans to discard the packaging of a product once the product is consumed. Thus, plastic packaging is generally considered a by-product of what the packaging contains, since they are only utilized one time before becoming waste by the majority of consumers ("Why Is Plastic Harmful?", 2018).

A significant part of the problem here is due to the large number of products which are packaged using plastics, resulting in an excessive amount of plastic that must be managed by the institutions responsible in the specific area where the waste is discarded. While these institutions themselves may not be directly responsible for pollution of their oceans, they have a duty to enforce any laws in place pertaining to their citizens littering in that specific area. As a result of this waste management issue, approximately 8 million metric tons of plastic enter the world's oceans each year, on top of the estimated 150 million metric tons already circulating the marine environment (Jones et al., 2019). At this rate, it is projected that there will be more plastic than

fish by volume in the world's oceans by 2050 (Jones, 2019). Of the estimated 150 million metric tons of plastic in the ocean, 95% of this plastic is known as microplastic, or plastic that has broken down into a piece which is smaller than 5 millimeters (Lee, 2018). Macroplastic, or plastics which are greater than 5 millimeters in size, accumulate on the surface of the ocean, and are what the Great Pacific Garbage Patch is composed of ("The Great Pacific Garbage Patch"). The Great Pacific Garbage Patch is the largest accumulation of ocean plastic in the world, located between Hawaii and California, and is twice the size of Texas ("The Great Pacific Garbage Patch").

Problem Description

Plastics are derived from propylene, which is a chemical component of petroleum. When this chemical is heated up in the presence of a catalyst, monomers of propylene link together by forming extremely strong carbon-carbon bonds with each other, resulting in what is known as polypropylene (Wolchover, 2011). This manufacturing step turns this petroleum into a material unrecognized by organisms that normally break down organic matter. As a result, plastic products break down or degrade, however, they do not breakdown by natural decomposition, or biodegrade ("Microplastics", 2019). For this reason, every piece of plastic ever produced is still in existence, and will be in existence for at least another 500 years (Gonzaga, 2019). Once these materials flow into the world's oceans due to our issue described in the introduction, negative effects on the environment, society, and the economy ensue and are inherent of plastics non-biodegradability.

Focusing on the effect of this issue on the environment, plastics have proven to be a significant threat to ocean and freshwater ecosystems; and consequently a reduction in the benefits humans receive from these ecosystems (Lee, 2018). More specifically, this pollution

threatens the survival of hundreds of species, negatively impacting nearly 700 worldwide (Lee, 2018). These animals either ingest or become entangled in plastic waste. In many cases, ingestion of plastic causes blockages in the animal's digestive system which can prevent them from digesting other types of food, leading to starvation. Marine animals may also be entangled by plastic pollution which can cause either asphyxiation or entrapment. It has been estimated that 100 million marine animals are killed each year due to plastic pollution (Henn, 2019). Furthermore, as plastic breaks down over time, it becomes less buoyant and sinks to the ocean floor. This can cause hypoxia, or oxygen deficiency, dead zones, and a shift in the sediment properties necessary for sex-determination in certain marine animal eggs (Henn, 2019). Dead zones also have a significant adverse impact on the ecosystem since these reefs support food networks of local marine life. The type of marine animal which humans benefit the most from are, as one might infer, fish. As a consequence of plastic pollution, economists and ecologists have predicted the oceans to be empty of marine life by 2048 (Marinelli, 2018). Thus, the negative impact of plastic pollution on fish may have a significant negative impact on the benefits in which humans derive from the ocean over time.

Now focusing on the impact of ocean plastic pollution on society, we will first observe how the negative impact of plastic pollution on the fish population affects the benefits humans derive from the marine ecosystem. When plastic is mistaken as food and ingested by a marine animal, this plastic moves through the food web through a process known as bioaccumulation (Lee, 2018). For example, in the North Atlantic, is has been estimated that 11% of North Atlantic fish ingest plastic regularly ("Plastic Ingestion by Fish", 2016). Thus, when humans eat seafood, there is a chance that the consumer of that fish is also consuming this microplastic as a result of bioaccumulation of plastic contaminants present in the food web. An article from the

Student Conservation Association claims that humans are still at risk of consuming microplastics even while avoiding seafood ("Microplastics", 2019). This is due to the complexity of Earth's food chain. The food chain most affected by ocean plastic pollution includes sea birds, mollusks, marine mammals, and a variety of animals that prey along coastlines ("Microplastics", 2019). Since this food chain has become so permeated with microplastics, it is likely that the majority of humans have ingested some form of plastic pollution at some point ("Microplastics", 2019). Furthermore, the oceans of Earth are considered the primary life support system for humans, and thus, the survival of our species would be significantly threatened if the oceans become extinct (Hodal, 2019). Besides the possibility of humans ingesting microplastics, as well as the long run threat to human survival, there are also adverse impacts on the economic aspect of society.

Finally, focusing on the economic impact of ocean plastic pollution, there are several individuals, communities, institutions, and industries which experience the consequences of this issue. First focusing on individuals, several commercial and local fisherman experience lower revenues due to the decreasing number of fish available, as well as fish caught being contaminated with plastic or other types of pollution (Nash, 2003). In some cases, this had led to fisherman seeking alternative occupations as a result. When observing how this affects communities, plastic pollution on beaches lower the aesthetic value associated with the area, and consequently, revenues for coastal communities and the tourism industry (Lee, 2018). For example, a local beach shop may be forced under due to decreased sales as a result of decreased tourism due to pollution within the community. Many institutions attempt to deter this problem within their region at a cost. Beach cleanups are an attempt to make a dent in the severity of the issue, and these events cost coastal communities millions of dollars every year. However, the largest economic impact inherent of ocean plastic pollution is present in the financial impact on

industries which are dependent on the marine ecosystem. For analysis of the financial impact of this issue on industries, I will incorporate the effect from all forms of pollution in order to find a more accurate measure of total economic consequences. It has been estimated that damage to the environment from all forms of pollution forces the global economy to incur an estimated $2.5 trillion a year in sunk resources within the marine environment. This value was calculated based on the approximate 1-5 % ($) reduction of economic benefits experienced by humans from the marine ecosystem as a result of environmental damage from pollution and anthropology (Hodal, 2019). This is the consequence of declining market value of marine ecosystem services as a result of this pollution, and affects marine industries across the globe.

Analysis of Potential Solutions

While this issue may never be completely solved due to the sheer amount of plastic which already exists on Earth, there are still measures which can be taken in order to decrease the negative impact on the environment, society, and global economies. In order to effectively address this problem, there must be action taken in order to reduce the flow of plastic into the ocean, as well as cleaning the existing pollution. The first idea one might have regarding the mitigation of future pollution is a ban on the production of polypropylene products such as plastics. However, certain plastics like disposable plastic bags require much fewer resources to produce when compared to paper, cotton, or reusable plastic bags (Stanislaus, 2019). For example, a paper bag would have to be reused 43 times in order for it to have an environmental impact equal to or less than that of a disposable plastic bag (Stanislaus, 2019). Thus, banning production and consumption of plastic may negatively affect the environment in other areas, creating further problems on top of the existing ocean plastic pollution issue. Another idea for deterring future contributions to plastic pollution is raising awareness of the issue. Several

programs have been created in order to inform the public about environmentally friendly waste disposal habits, however, they have not proven significantly effective in years past as a means of solving this issue. This leaves the responsibility on the institutions in place within that region. However, when observing the U.S., hundreds of towns and cities have cancelled their recycling programs due to the cost of collecting recyclables skyrocketing. This is due to China refusing to import used plastics and paper (Corkery, 2019). The plan of attack provided by the World Resources Institute is to have the teaming of federal and state governments with private industry in order to address more systemic issues (Stanislaus, 2019). Another idea presented in this article is the redesign of plastics in order for the material to have the ability to be readily broken down by natural processes. Finally, another idea presented is the redesign of waste management facilities in order to filter out reusable containers, reprocess them, and redistribute them. In order to be brief, I will include further analysis of these solutions in my final thesis.

When considering potential solutions regarding the collection of existing ocean pollution, one specific idea is known as the Ocean Cleanup Project, which is a nonprofit organization located in the Netherlands. The Ocean Cleanup Project has an ambitious technological strategy with the objective of collecting 90% of the plastic pollution in the ocean ("The Great Pacific Garbage Patch"). The system consists of a floater that sits at the surface of the ocean, as well as a "skirt" which hangs beneath it. The "skirt" is essentially a net, which prevents the debris from escaping underneath. The floater harnesses the power of natural forces such as wind, waves, and the current ("The Great Pacific Garbage Patch"). Speed is also a factor which is considered in the system design, as if the system were moving too fast, debris may not be effectively collected. Therefore, there is a sea anchor in place in order to slow down the system. This system will capture the debris over time, and then will be effectively removed from this

concentration over time ("The Great Pacific Garbage Patch"). Furthermore, the Ocean Cleanup Project has claimed that it has developed and tested a scalable method of mitigating the flow of plastic pollution from rivers, claiming to filter out 80% of plastic pollution from countries' rivers within five years. While this may be technologically scalable in the sense that it is physically feasible, and may produce this intended result, this project still requires far more funding than it currently has in order to achieve the goals in which it claims. The Ocean Cleanup Project has currently accumulated approximately $35 million in donations, however, they require far more in order to accomplish their objective. Thus, in order for the Ocean Cleanup Project to be scalable, it will require a large amount of capital funded from outside sources. Therefore, in order for this to work, it will require the cooperation of several independent parties who are motivated to spend a large amount of capital in order to address this issue, which could be countries who are interested in the long term benefits of this investment. While this method of addressing this issue may be significantly effective, it will require cooperation of these countries to reduce their flow of plastic pollution, in order to avoid further hindering progress. Other solutions to collecting the existing plastic waste could be certain countries taking initiative at addressing the issue, or potentially a coalition between countries to work together on addressing the issue. Further analysis on the physics and dynamics of the system, as well as a thorough analysis of these proposed solutions will be included in my final thesis.

Actor Network Theory Framework

As previously described, I believe the most efficient and effective way to address this issue requires the cooperation between several different independent parties. Using the analytical framework inherent of Actor Network Theory will provide insight on how different countries may interact with each other with the objective of mitigating the flow of plastic

pollution into the ocean from their respective territory, as well as attempting to clean their coastal waters. The actors or actants present in this framework would be leaders, representatives, institutions, and citizens of several countries capable of expending resources, as well as other independent parties such as the Ocean Cleanup Project, and Bioplastech, which are operating under the same objective. The countries which I will incorporate into this network will be the large plastic producing countries which exist on the coast of the world's oceans. For example, the following countries, along with their respective institutions and citizens will be included in this network for analysis: the United States, China, Russia, India, Australia, Canada, Mexico, Brazil, Argentine, and Chile. This network will be constructed under the assumption that these countries are motivated to address the issue, and are each willing to cooperate with one another and expend their own resources. In my final thesis, this complex network will be constructed in order to effectively describe how these actors and actants operate in conjunction with one another with the objective of mitigating the flow of plastic pollution into the world's oceans as well as removing the massive amounts of plastic debris which already exist in the world's oceans.

Conclusion

This problem is by no means a small one in terms of scale, however, an analysis of the previous potential solutions discussed above may provide some insight on the effects of implementation of certain combinations of these strategies. A further analysis of the feasibility of these alternative solutions will be also be included from the perspective of cost-benefit analysis. While this problem has mostly socioeconomic and environmental dimensions, I believe a thorough analysis of the Ocean Cleanup Project system and how it works will be an interesting technical piece of this topic. I will also observe the progress and feasibility involved in the

redesign of plastic materials which may potentially be broken down by natural processes. In conclusion, many countries are not currently motivated to expend resources regarding this issue, because extreme adverse effects have not been yet experienced by said countries, and this expenditure may reduce a country's economic competitiveness. Thus, the largest issue inherent of this problem is the ability to motivate world leader's to commit to this effort. I believe one way to motivate the actors described above to address this issue is for a country similar to the United States to take initiative in attempting to form a coalition of these previously mentioned countries cooperating under this objective. If this occurs, an iterative design method must be utilized after employing strategies consisting of these potential solutions. This method must be observed, assessed, adjusted, and reimplementing until the issue is effectively mitigated in order to solve this global scale problem.

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