AI4D: Artificial Intelligence for Development

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ABSTRACT

In line with a long research tradition focused on the use of information and communication technology for development (ICT4D), we explore the role of artificial intelligence (AI4D). We start with a rather technical review of four of the characteristic traits of deep learning technologies, which leads to natural metaphors for international development. Based on the empirical evidence of 24 case studies, we derive four characteristics of the use of AI4D that align with the four technological traits. In isolation, each one of them presents a plethora of opportunities to contribute to international development, especially to the attainment of the Sustainable Development Goals (SDGs). However, in combination, they create a clear tension between a looming threat of a hegemonic intelligence indoctrination pushed by global economies of scale, and the potential promise to not only honor, but to celebrate local diversity with the help of flexible AI designs. We conclude that the latter cannot be achieved without an active public policy dialogue on the international level and a determined effort on the national levels, especially in developing countries. The study provides terminology and concepts to identify and frame the arising discussions.

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AI4D: Artificial Intelligence for Development

Information and Communication Technology (ICT) has long been recognized as an important tool for international development. Decades of thoughtful academic research, often grouped under the shortcut "ICT4D" (Heeks, 2006, 2017; Unwin, 2009), has fueled multiple generations of national and international policy agendas ("eLAC Action Plans," 2018; "World Summit on the Information Society," 2005; Hilbert, Bustos, & Ferraz, 2005). This active line of research grew out of work often grouped under the term 'development communication', which focused on the diffusion of mass media in developing countries and goes back to work from some of the founders of today's Communication discipline in the social sciences (e.g. Rogers, 1976; Schramm, 1979).

As the digital paradigm evolves so must the focus of this research. The most prominent recent change has been a shift in focus from the proliferation of communication (1970s & 1990s) and information (1990s & 2000s), to the extraction of knowledge from the resulting data. A shift from "'Information Societies' to 'Knowledge Societies'" (Hilbert, 2016, p. 139). Every 2-3 years, human kind deals with more technologically mediated information than it had since the beginning of human history (Hilbert, 2015; Hilbert & López, 2011). The only way to deal with the ensuing information deluge consists of fighting fire with fire: the use of digital machines to make sense of the information provided by digital machines. Therefore, we have started to outsource the important task of interpreting and filtering digital information to intelligent algorithms. The fact that the world's computational capacity has grown three times faster than our information storage and communication capacity (Hilbert & López, 2011), has allowed us to implement ever more complex, powerful, and flexible algorithms.

In this study, we develop a framework that allows us to reason about the role of artificial intelligence (AI) for international development. We start with a theoretical review of modern AI, i.e. deep learning techniques. We distill four main concepts, which we refer to as the 4 Rs of deep learning: representation, reuse, robustness, and regularization. Interestingly enough, reviewing these concepts leads to natural metaphors for the potential role AI can play to tackle pressing development challenges. After this theoretical evaluation, we continue with an empirical review of 24 case studies that illuminate how AI is currently applied to contribute to the fulfillment of 9 out of the 17 Sustainable Development Goals (SDGs). We crystalize another four general characteristics of the application of artificial intelligence for development (AI4D), namely (1) local intelligence, (2) distance intelligence, (3) augmented reality, (4) detailed reality. All of them have obvious positive effects on development outcomes, but upon second thought, their combination could also lead to some fundamental threats to developing countries. We finish our analysis with a reflection on such possible threats to global inequality.

AI: the Theory

We start with the historical context of artificial intelligence and then advance to its general architecture, all with the goal of identifing some of its main characteristics.

Current State of Affairs

Private sector companies agree that the global market for smart machines has been around US $15-20 billion in 2018, and that its contribution to the global economy is soon reaching several trillion (Bughin, Seong, Manyika, Chui, & Joshi, 2018; Faggella, 2016; IDC, 2018). To keep this in context, in 2017, the Gross Domestic Products of Russia, Brazil, and India were US $1.5 trillion, US $2 trillion and US $2.5 trillion, respectively. The five most valuable companies on the Fortune500 in 2018 are all main players in the use of AI (Apple, Amazon.com, Alphabet (Google), Microsoft, Facebook) (Fortune, 2018), and several of them see themselves as AI companies, as, for example, Google renamed its entire research division as “Google AI”.

The leading role of AI in today’s economy is pushed by dazzling advancements. Deep neural nets have managed to reduce the word-error rate in speech recognition from 26 to 4 percent just between 2012 and 2016 (A. Lee, 2016). This makes them much better than human transcribers (Xiong et al., 2016). Deep convolutional neural networks identify the most common human malignancy, skin cancer, with accuracy that matches that of trained experts (Esteva et al., 2017). Interpretive power like this has given rise to omnipresent online recommender algorithms (Ricci, Rokach, Shapira, & Kantor, 2011), which have already become so influential and have received much blame for creating filter bubbles and echo chambers that swayed democratic elections (Bakshy, Messing, & Adamic, 2015; Colleoni, Rozza, & Arvidsson, 2014; Hilbert, Ahmed, Cho, Liu, & Luu, 2018; Pariser, 2011).

Humanities main energy source (the electric grid) is in the hands of artificial intelligence (Ramchurn, Vytelingum, Rogers, & Jennings, 2012); three out of four transactions on the largest resource exchange of homo sapiens (U.S. stock markets) are executed by automated trading algorithms (Hendershott, Jones, & Menkveld, 2011); and with one in three marriages in America beginning online (Cacioppo, Cacioppo, Gonzaga, Ogburn, & VanderWeele, 2013), intelligent algorithms have also started to take an undeniable role in sexual mating and humanity’s genetic inheritance. Living in a society that outsources almost all of its energy distribution decisions, $^{3}/_{4}$ of its resource distribution decisions, and an average of $^{1}/_{3}$ of its procreation decision to machines, it is hard to deny how indispensably dependent human development has become on artificial intelligence already (Gillings, Hilbert, & Kemp, 2016).

A Short History of AI

While all of this progress seems to have happened in a historical blink of an eye, intelligent machines have occupied human thought for two to three thousand years, from depictions of robotic creations in the Talmud and Homer's Iliad, to Hobbes Leviathan and Da Vinci's visions. Most researchers place the birth of modern AI to the 1950s, related to Turing's famous formulation of the 'Turing test' (whether a human can distinguish between human and machine behavior), and the so-called Dartmouth workshop from 1956, an eight-week-long brainstorming session that informed many of the general directions in the field during the subsequent decades. Participants of this workshop, such as the AI pioneer Herbert Simon, predicted that, "machines will be capable, within twenty years, of doing any work a man can do." Another attendant, the AI pioneer Marvin Minsky, agreed, writing that, "within a generation...the problem of creating 'artificial intelligence' will substantially be solved" (Schreuder, 2014, p. 419).

This initial overexcitement ran into unfulfilled promises and withdrawing of funding, which is typical for technological paradigms (Perez, 2007). The 1970s are generally known as the 'AI-winter' (Russell & Norvig, 1995). The 1980s and 1990s saw some commercial successes with so-called expert systems, a form of artificial intelligence that simulates the knowledge and analytical skills of human experts. By 1985, the global market for AI had reached over a billion dollars. During the 1990s and 2000s, the world of technological progress focused on the proliferation of information diffusion solutions by means of internet connections, databases and phones. This resulted in an information overload, and researchers started to look for computational solutions to make sense of the data deluge. The current breakthrough in AI dates back to a result from 2012, when Geoffrey Hinton and collaborators surprised the academic world by showing the power of so-called deep convolutional neural networks (in this case for image classification) (Allen, 2015). These are not based on expert systems fed with identified patterns (knowledge, grammar, decision rules, etc.), but on machine learning (ML) algorithms that discover patterns.

Today's AI: Machine Learning

Traditional AI systems, called expert systems, focused on automating insights gained by humans. In order to recognize a car, one would teach the machine the rules that define a car (four wheels, certain size, etc.). In contrast, modern AI systems adopted a learning approach more akin to how children learn: by examples, not by rules. A child learns to distinguish cars from motorcycles not by evaluating a series of rules, but by seeing different examples of each. This aims at identifying new patterns in data, not to match patterns against a given decisionrule. The ability of AI to build their own knowledge is known as machine learning and it allows computers to make decisions that seem to be both situational and subjective. The resulting classification criteria are more flexible and natural than pre-defined rules (Halevy, Norvig, & Pereira, 2009).

Today, this kind of machine learning (ML) has almost become equivalent with the term 'artificial intelligence.' Machine translation is an epitome of this trajectory of AI. Since the 1950s, digital heavyweights like IBM, MIT, DARPA and others all worked on encoding the rules of grammar and vocabulary translation into expert systems, much like an automated textbook of translation between different natural languages. The results could, at best, be used to support, but not substitute, human experts. In 2006, Google Translate launched a statistical machine learning translation engine. Google Translate does not apply grammatical rules like an expert system would, but is fed with a bilingual text corpus (or parallel collection) of more than 150-200 million words, and two monolingual corpora each of more than a billion words (Och, 2005). The machine learns the relationships itself. The result is that Google Translate now supports over 100 languages at various levels and serves over 500 million people daily, placing human translators at the top of lists of human jobs being replaced by AI.

Future Outlook on AI

It is important to note that machine learning implies that machines may find patterns that are different from patterns usually assimilated by human brains. This leads to the often lamented fact that modern AI are essentially 'black boxes', which may achieve above-human performance without us truly understanding why. On the one hand, reverse engineering what is inside these black boxes can lead to new discoveries. For example, we know that humans are slightly better than random chance in guessing sexual orientation by simply seeing a single facial image: 61 % for gay men and 54 % for gay women (baseline is 50-50 % between gay and heterosexual). Trained with facial recognition software on Facebook images, machine learning achieves 81 % for men and 71 % for women, and increases its accuracy to 91 % and 83 %, respectively, with five facial images per person (Wang & Kosinski, 2018). In contrast to the tacit knowledge carried by humans, researchers could now open up the 'AI brains' and study what they were doing when detecting sexual orientation. It turned out that the focus of their analysis was consistent with the prenatal hormone theory of sexual orientation, as gay men and women tended to have gender-atypical facial morphology and expression. This advances our understanding of the origins of sexual orientation. It also questions and calls attention to the practices of several countries where same-gender sexual behavior is understood as behavioral misconduct and punishable by death (United Nations, 2015).

In this sense, advancements of AI lead us to understand that there are alternative definitions of intelligence to human intelligence. Using an analogy, human intelligence is the result of evolutionary selection, much like bird flight. Historically the only flying objects were birds. With the technological revolution of aviation, we started to better understand the field of aerodynamics, and discovered many alternative ways of flying, from helicopters, to Jet engines, to space rockets. Earth's nature never came up with a solution to fly to the moon. Technological progress achieved this in less than 70 years, from Gustav Weisskopf and the Wright brothers in 1901/3, to NASA's moon landing in 1969. It should not be surprising that we are discovering that the way evolutionary pressures designed human intelligence is just one out of many possible implementations of a much larger and broader concept. Machines are currently discovering alternative ways to be intelligent, which is the main driver behind the increasing complementarity between human and artificial intelligence.

Deep Learning Architectures

Having established that modern AI is basically equivalent with machine learning, we now review some of the theoretical characteristics at its most important implementation, so-called deep learning, or deep neural networks (DNN) (Goodfellow, Bengio, & Courville, 2016). We aim to identify technological characteristics that lend themselves to tackling development challenges. We focus on four concepts, what we will refer to as the 4 Rs of Deep Learning: representation, reuse, robustness, and regularization.

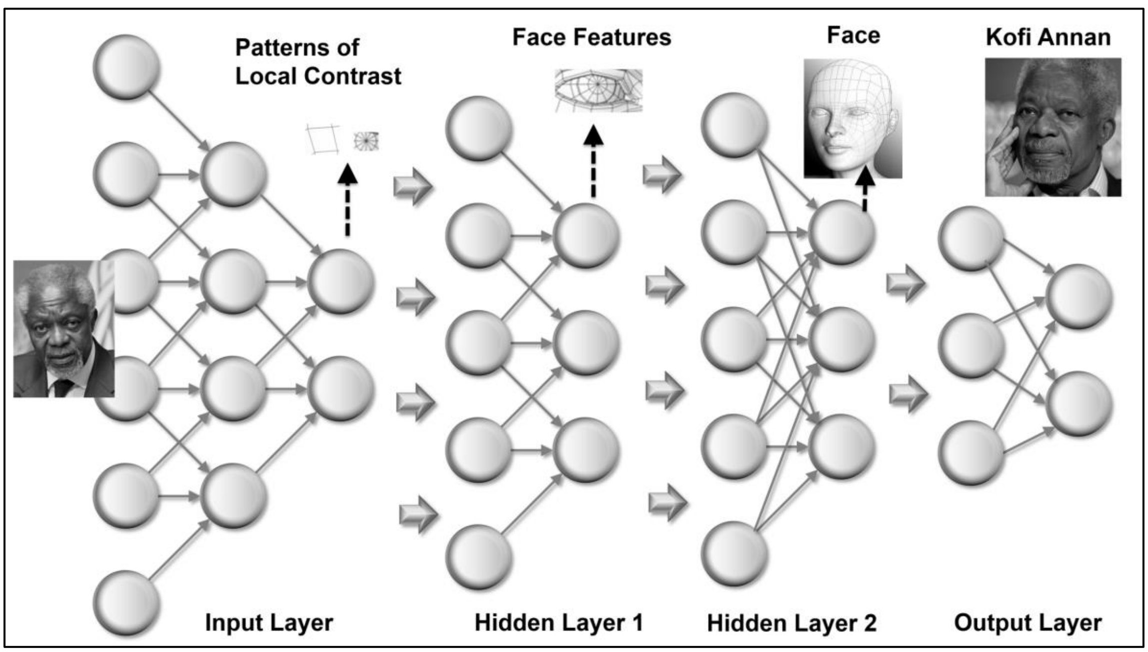
Deep Layers: Representation

One of the primary ways AI machines are able to understand the situational and subjective nature of data, is through representational learning. Representation learning is a set of methods that allows a machine to be fed raw input and to discover, from this input, representations that are needed for classification (LeCun, Bengio, & Hinton, 2015). Deep-learning methods are essentially representation-learning methods with multiple levels of representation that gradually result in representation at increasingly abstract levels.

Traditional machine learning algorithms are fed with certain features that represent some raw data. For example, a doctor interprets a scan image and feeds the observed features into the machine (the machine receives a representation of the image, not the image), which then makes suggestions for action (e.g. calculating the probability of requiring surgery). This requires doctors with specialization in medical imaging, which is costly and can be subjective. One solution is to use machine learning to discover not only the mapping from representation to output, but also the representation itself, which is called Representation Learning. Deep learning furthermore implies that the levels of features are learned from data and are not explicitly designed by human engineers. In other words, the machine is not only learning the data structure (traditional ML), but also part of its own high-level architecture.

Representation learning depends on particular factors of variation which help to separate each unique factor of the representation (Goodfellow et al., 2016). One of the central problems with this approach is that in many circumstances, some of the factors of variation influence multiple pieces of data, making it necessary to separate the factors of variation and ignore the ones that are insignificant. Deep learning solves the problem of separating the factors of variation by "introducing representations that are expressed in terms of other, simpler representations" (Goodfellow et al., 2016). For example, Figure 2 shows the example of face recognition, as done millions of times in social networks like Facebook and Instagram.

Figure 2. Schematic representation of face recognition through Deep Neural Networks (images: Wikipedia.commons).



Thus, a deep-learning architecture is essentially a multilayer stack of simple modules, which are subject to learning (LeCun et al., 2015). The classic example of a deep learning model is the feedforward deep network, or multilayer perceptron (Goodfellow et al., 2016). A multilayer perceptron is a function that maps some set of input values to output values using a series of hidden layers that extract abstract features from the input or visible layer (Goodfellow et al., 2016). As shown in Figure 2, different layers learn different aspects of the whole, introducing flexible and robust modularity. To move from one layer to the next, a set of units calculate a weighted sum of their inputs from the previous layer and pass the result through a non-linear function (LeCun et al., 2015). Backpropagation is often used to help achieve a goodness-of-fit optimum by giving a network the ability to form and modify its own interconnections.

Multitask- and Transfer Learning: Reuse

The important result of the multilayer, modular representation of knowledge is that it allows for better generalizations, as a "scheme for minimizing the generalization error of the prediction functions and deducing the biases with respect to the provided training set" (Yu, Zhuang, He, & Shi, 2015, p. 313). One can also focus on layer-by-layer training and then use the insights gained from one layer to improve tasks in another layer. The result is essentially a transfer of knowledge, whereas the modular nature allows for context dependent adjustments without the need to start from scratch.

The vast collection of methods referring to multitask learning shares those parts of the model across tasks that capture a common pool of structure. The underlying assumption is that among the factors that explain the variations observed in the data associated with different tasks, some are shared across different contexts. For example, image recognition DNN share learned features about lines, eyes and faces on lower levels (see Figure 2). Online recommender systems learn to transfer shopper preferences among books, music, and consumer electronics. "The notion of re-use… is… at the heart of the theoretical advantages behind deep learning, i.e., constructing multiple levels of representation or learning a hierarchy of features" (Bengio et al., 2013, p. 1802). When this idea is implemented in a semi-supervised setting, it is often referred to as multitask learning (Goodfellow et al., 2016, Chapter 7.7), while it goes under the name of transfer learning when implemented through supervised learning (Goodfellow et al., 2016, Chapter 15.2).[1]

This technique is extremely useful if there is significantly more data in one setting than in another, which seems useful when considering the inequalities typical for international development. The classical case in the literature is to train computer vision with images of house cats, and then use the extracted features to detect wild and rarely appearing snow leopards (Yosinski, Clune, Bengio, & Lipson, 2014). It can even be used to approximate

[1] ML is said to learn supervised, if the desired output is already known. One trains the machine to convert certain input into certain output through trial and error supervision. With unsupervised ML, the machine is given a certain theoretical framework, and is asked to pick up patterns. Traditional principal component analysis (PCA) is among the oldest unsupervised learning algorithms.

unprecedented scenarios for which no label examples are available (so-called zero-shot learning (Goodfellow et al., 2016, p. 529)).

Convolutional Neural Networks: Robustness

Convolutional neural networks (CNN) are one type of deep, feedforward network that is considered easy to train and generalize and is one of the most common implementations of deep neural networks (LeCun et al., 2015). CNNs are designed to process data that come in the form of multiple arrays, such as a color image made up of a 2D grid containing various pixel intensities. They have been tremendously successful in practical applications.

Convolutional nets are the greatest triumph of biologically inspired artificial intelligence. They are based on the Nobel Prize crowned insight that some neurons respond to very specific patterns, and hardly to others, while being very robust and detail invariant when doing what they do (Hubel & Wiesel, 1968). Convolutional nets implement this by systematically making use of parameter sharing that involves at least two types of layers: convolutional layers and pooling layers. While the role of the convolutional layer is to detect aggregations of features from the previous layer, the role of the pooling layer is to merge similar features into one: to literally *pool* the features. This way, even if an input image has millions of pixels, we can detect small, meaningful features, such as edges, with kernels that occupy only tens of pixels, and share these parameters. This is done by sliding overlapping windows of shared representation over the grid structure, which can be done from above or below.

The important result is that this particular form of parameter sharing in convolutional nets causes the layer to be equivariant to translation. This means that if the input changes, the output changes the same way. This assures that the order does not matter, since under equivariance: $f(g(x)) = g(f(x))$. One obtains the same representation of some input, even if it occurs earlier or later, or if it occurs shifted to the one side or the other. For example, this allows it to detect if a face is in an image, without getting lost in the details of which direction it looks, where exactly it is, what the background or context is, etc. (see Figure 2). For human development, the concept of equivariance provides assurance that different inputs are represented efficiently and can be detected even if they reappear in a highly context dependent and volatile setting, which is the norm for developing dynamics.

Overfitting: Regularization

The challenge of making learning both robust and flexible points to the main difficulty related to the output of machine learning: deciding when to stop learning. The algorithm might learn details that are particular to the specific dataset, but are not generalizable. In computer science lingo, this is known as the problem of overfitting, which stands for the idea that the algorithm learned more details than it should have learned. “Overfitting literally means ‘Fitting the data more than is warranted’” (Abu-Mostafa, Magdon-Ismail, & Lin, 2012, p. 119). It happens automatically with learning patterns and is often subjective. Often the final purpose of the application defines which aspects are warranted and which are noise; this is often a subjective decision.

For the machine learning community, the most common way to deal with overfitting is known as regularization. “Regularization is any modification we make to a learning algorithm that is intended to reduce its generalization error but not its training error” (Goodfellow et al., 2016, p. 117). Regularization is a broad term that includes many different methods, most of them being approximate heuristics. As a result, “regularization is as much an art as it is a science” (Abu-Mostafa et al., 2012, p. 126). It is an implementation of the similarly hand-wavy concept of Occam’s razor, summarized by Einstein as “everything should be made as simple as possible, but not simpler” (O’Toole, 2011).

AI4D: the Practice

Inspired by the achievements and architectures of modern AI systems, we now set forth to analyze how they relate to international development. We based our conceptualization of development on the United Nations Sustainable Development Goals (SDGs). We gathered 24 case studies of the use of AI for development. They happen to address 9 of the 17 different SDGs. Two of them address SDG.2 (zero hunger); 11 for SDG.3 (good health); three for SDG.4 (quality education); two SDG.5 (gender equality); one SDG.8 (economic growth); four for SDG.11 (sustainable cities); four for SDG.12 (responsible consumption and production); two for SDG.14 (life below water); and two of the case studies addressed SDG.15 (life on land) (some of them simultaneously addressing several goals) (see Table 1). The method of case collection was based on rather unstructured random-walk and snowballing principles, since we initially had not expected to find as many insightful examples.

We analyzed the case studies according to the previously identified 4 Rs of deep learning, and realized that the collected case studies lined up with four general characteristics to frame the effects of AI on development dynamics (see Table 1). The first two refer to the location of information processing with AI. The second two refer to the input and output of this processing with regard to empirical reality.

Transferring intelligence:

1. **Local intelligence:** AI systems can be autonomously applied locally, adjusting to local context and requirements.
2. **Distance intelligence:** modern telecommunication networks allow highly trained AI systems to be applied at a distance.

Manipulating reality:

3. **Augmented reality:** AI systems allow creating digital twins of aspects of reality, which enhance our understanding and allow to replicate aspects of reality.
4. **Detailed reality:** the digital footprint provides ever more detailed maps of reality, and AI allows to exploit the resulting details to foster development goals.

As shown by Table 1, the match between the 4 Rs and these four groups is not perfect, and sometimes subjective. By design, the different characteristics are not orthogonal to each other, but overlapping. For example, augmented reality can be implemented locally, or at a distance. Regularization is an important aspect of representation learning of new insights, and or reuse of existing ML results, etc. Our goal was to identify a general outlook to frame the AI4D discussion, not to elaborate an exclusive, objective, and exhaustive classification scheme. The framework aims at relating technological traits with development characteristics.

Table 1: Characteristics of Deep Learning and AI4D, with 24 case studies (see appendix), and corresponding SDG.

	REPRESENTATION	REUSE	ROBUSTNESS	REGULARIZATION
LOCAL	CS1 (SDG.2): Climate & crops analytics CS2 (SDG.3): Pharma research engines CS3 (SDG.4): Individualized education CS4 (SDG.4): Hidden learning patterns CS5 (SDG.5): Gender equality CS6 (SDG.11): Sustainable cities CS7 (SDG.11): Smarter cities CS8 (SDG.12): Risky pipe detection CS9 (SDG.12): Demand irrigation CS10 (SDG.15): Timber conservation	CS11 (SDG.3): Alleviating medical paperwork	CS1 (SDG.2): Climate & crops analytics	CS12 (SDG.8): Productivity enabler across sectors
DISTANCE		CS13 (SDG.3): Malaria screening CS14 (SDG.2): Diagnostic support CS15 (SDG.2): Analyses of Tuberculosis CS16 (SDG.2): Automated diagnosis CS9 (SDG.2): Cataracts detection CS17 (SDG.12): Real-time water supply		
AUGMENTED		CS18 (SDG.3&4): Informing and guiding pregnancies and girls' rights	CS19 (SDG.2&12): Plant-based replication of animal based foods CS20 (SDG.11): Road repair CS21 (SDG.14): Ocean ecosystems CS22 (SDG.15): 3D model of Earth	
DETAILED	CS14 (SDG.3): Chemical compound research	CS3 (SDG.4): Individualized education		CS20 (SDG.11): Road repair CS21 (SDG.14): Protecting endangered species CS23 (SDG.3): Predicting cardiovascular disease CS24 (SDG.3): Avoiding unnecessary surgeries

AI Representation for Local intelligence

One characteristic that we frequently found in case studies is the possibility to implement intelligence locally, using representation learning, which automatically embraces local conditions and necessities. This is very promising, since one of the most frequent critiques of international development work is the (often subliminal) 'one size fits all' or 'best practice' mentality (Tödtling & Trippl, 2005). Representation learning allows for the ad-hoc training of autonomous agents that consider the particularities of local conditions in remote areas. The digital footprint provides constant input of a steady pipeline that fuels new discoveries by exploiting regional variances, particularities and dynamics. This promises to enable innovative mechanisms sourced from local conditions. Having an automated way to learn about local particularities (i.e. representation learning) allows local actors to identify ever more tailor-made solutions for unique local conditions, augmenting economic and social efficiency domestically. This can facilitate unique solutions for local challenges.

An emblematic case is the local use of a machine learning algorithm (adopted from neuroscience) for the analysis of a weather and local rice crop data in Colombia to analyze the effects of climate change (CS1 (SDG.2), see Table 1). The results are highly localized and provided recommendations on the level of different towns. The foresight helped 170 farmers in Córdoba avoid direct economic losses of an estimated $3.6 million and potentially improve productivity of rice by 1 to 3 tons per hectare.

Another case that shows the potential to learn tailor-made representations of knowledge that fits specific local contexts is Benevolent.ai, an AI that distills insights from the vast collection of pharmaceutical research. The vast majority of the increasing numbers of scientific papers published each day is unread and unknown to most scientists. After searching vast databases for a neurodegenerative disease, the AI recently suggested to use compounds that researchers had never considered. Two of them unexpectedly worked better than the best available treatment drug at the time (CS2 (SDG.3)). There is the possibility that some pressing health problems faced by developing countries already have solutions, but, without such AI, the remedy remains lost in the scientific information overload.

In the realm of education, AI solutions allow us to automate education and tutoring systems, allowing for low cost solutions at scale. Especially highly structured subjects, such as language learning, software programming, or quantitative analytical skills, can be automated, including grading and performance tracking. Learning AI systems allow for the massification of an individualized education experience for structured course work (CS3 and CS4 (SDG.4)).

Other machine learning technologies are being used to promote gender equality in the local workplace and the classroom via local intelligence. Doberman.io has employed machine learning and speech recognition to create an app that helps promote gender equality in the meeting room (CS5 (SDG.5)). The app records and analyzes speech during a meeting and then provides a visualization of speaker contribution by gender as the meeting progresses. The app aims to heighten awareness of the gender equality issue.

Much has been written about Smart Cities (in Latin America and beyond), and the application of cutting-edge AI to tackle urban challenges related to traffic, safety and sustainability, which certainly falls into the category of localized intelligence (CS6 & CS7 (SDG.11)). Much in line with smart infrastructure in cities, HiBot employs an AI system designed to algorithmically locate where pipes are more at risk of failure and employs inspection of pipes that have already been replaced by evaluating soil dynamics and electromagnetic forces coming from power line (CS8 (SDG.12)). In the U.S., it has already detected hundreds of thousands of water breaks per year across the country. This allows for conservation of water through prevention of leaky pipes. The application applies the technology to local infrastructure conditions.

Naturally, efforts in environmental protection can also benefit from adjusting AI to local conditions. Ecological conditions are often too unique and complex to transfer models one-to-one. For example, AI governed drip irrigation system work by inserting a network of ground sensors into the soil to discover plants' irrigation needs, monitor demand, and optimize water use remotely (CS9 (SDG.12)). Neural nets are then used to effectively learn optimal irrigation schedules for the local conditions. The State Government of Rio de Janeiro used machine learning on documents, databases and satellite imagery to learn that more than 40 % of the forest management operations in a certain area likely involved severe breaches of the law between 2007 and 2015 (CS10 (SDG.15)).

AI Reuse for Distance Intelligence

Despite all tailor-made attention, which has certainly been neglected in many development projects in the past, it is also true that development dynamics contain a considerable common pool of shared factors. The arising synergies provide a fertile ground for the application of different kinds of multitask- and transfer learning methods. What we call distance intelligence is the ability for AI technologies to supplant resources in fields that were previously understaffed or under-researched with help of telecommunicated intelligence.

One of the pioneering applications of distance intelligence is the use of AI in the health sector, such as for automated distance education and distance diagnoses to treat a number of ailments including congenital cataracts, tuberculosis, breast cancer, and more. This can be used to provide access to medical intelligence in remote and underserved regions, be it nationally or internationally.

There are 300-500 million cases of malaria illness annually, of which 1.1-2.7 million are fatal. Of those fatal cases, a vast portion are children. In developing countries, the lack of access to accurate diagnosis is largely due to a shortage of expertise coupled with a shortage of equipment. Findings of a recent survey carried out in Uganda show that only half of rural health centers have microscopes, and of that half, only 17% have staff with the training necessary to use the microscopes for malaria diagnosis (CS13 (SDG.3)). Even when a microscopist is available, they are often in such high demand that they cannot spend long enough examining each sample to give a confident diagnosis. This has prompted an increased focus on finding a solution via using technology to diagnose malaria.

Image processing and computer vision techniques have been used to identify parasites in blood smear images captured through a standard microscope. Given insufficient training data, algorithms used in other imaging problems, such as face detection, can be transferred to recognize the malaria plasmodia in these blood smear images. Through a mobile phone application based on the morphological image processing algorithms, a complete malaria diagnostic unit is set up using the mobile phones attached to a portable microscope (CS13 (SDG.3)).

Enlitic is a medical start-up that couples deep learning with medical data to advance diagnostics and thereby improve patient outcomes. Its deep learning networks examine millions of images to automatically learn the identification of disease (CS14 (SDG.2)). This can provide important insights regarding early detection, treatment planning, and disease monitoring. Google’s DeepMind Health project works in the same field. It can be used to interpret test results and learn which types of treatments are most effective for different patients (CS14 (SDG.2)). While DeepMind was founded in London with the immediate goal of streamlining the United Kingdom’s national health system, the technology has the potential to influence communities worldwide, as it seeks to support an existing healthcare system and become a self-sustaining initiative.

The use of artificial intelligence to diagnose and process medical images does not have to be fully automated, and is also often used to complement the work done by medical professionals, which helps to both save time and eliminate costly misdiagnoses. Zebra Medical Vision (Zebra-Med) has created a service called Zebra AI1 that uses algorithms to examine medical scans for just $1 a scan (CS14 (SDG.2)). The deep learning engine can then automatically detect lung, liver, heart and bone diseases. The results are then passed on to radiologists, saving them time in making a diagnosis or requesting further tests. The system can currently detect almost twenty different ailments.

AI Robustness for Augmented Reality

The ability for AI to quickly learn new representations in different contexts in a robust way is perhaps one of the greatest promises of modern AI (Goodfellow et al., 2016). Many of the recent advances in artificial intelligence allow for AI to be used in a variety of new settings. The idea of robustness suggests that a shared representation of features can be examined from either the convolutional layer or the pooling layer. Because the convolutional layer detects aggregates of features and the pooling layer merges similar features, robustness allows one to examine similar or overlapping features either from above or below. The effect is that new cases do not exactly have to be identical to previous ones in order to be understood by the AI.

What we call augmented intelligence refers to a group of applications that replicate aspects of reality and thereby augment the information related to these aspects. This allows the machine to create additional meaning by cross-referencing related aspects and creating yet unseen scenarios on these aspects of reality. The ability to apply various applications requires that AI be both robust and adaptable in its managing of views and perceptions.

Autonomous cars are one of the most visible implementations. AI uses 3D maps to help vehicles make real-time decisions. By mapping scenarios on to the existing field, autonomous cars are able to reason between multiple options to determine the best course of action. Such applications require the robust and flexible processing of concepts, under equivariant translation. In an effort to improve safety, the same ideas can be applied to roads rather than cars with information gathered (sometimes by drones, other times by car-mounted cellphone cameras) about road construction and maintenance (CS20 (SDG.11)). AI cannot only be used to identify problems, but also to simulate new scenarios based on empirical driving behavior, leading to the development of new standards and infrastructure designs (CS20 (SDG.11)).

A company called Ocean Alliance is using AI guided drones to follow whales, and collect the actual “snot” which exits the whales’ blowholes when they surface to breathe. This “snot” contains DNA, hormones, bacteria and toxins, and allows one to get an augmented view on a prominent species that travels an average of 3,200 miles in a year (CS21 (SDG. 14)). The so-called SnotBot also eliminates any need for killing of whales in the name of science. Another ecological application projects holograms onto real-time images, thereby creating an augmented 3D model. EarthCube has developed a 3D living model of the Earth that depicts every layer that forms the atmospheric levels (solid, gas, and liquid) and uses machine learning to examine what happens when different parts of the cube interact with each other (CS22 (SDG.15)).

Going one step further, beyond augmented and virtual realities, AI is also being used to replicate the design of real world atoms- and molecule-objects. Food replication is being utilized to combat global hunger. NotCo developed an artificial intelligence program called Giuseppe, which uses and replicates the molecular composition of animal-based foods to determine which vegetables would create a food with similar taste, texture, and even smell (CS19 (SDG2&12)). *Not Mayo* is made mostly from basil, peas, potatoes, and canola oil, instead of eggs and canola oil, but is said to taste and have a texture almost exactly like normal mayonnaise. Additionally, NotCo's *Not Milk*, created from mushrooms and seeds, is sweeter and creamier than milk, while having the same nutrients, but with fewer calories and at a lower cost than alternative milks. The resulting products are economically cheaper and much less taxing on the environment than animal farming.

In many practical applications, the idea of augmenting reality is often implemented as a mix of local and distance intelligence. This shows that the categories in our classification system from Table 1 are not exclusive. An entire group of game-based simulations falls into this category. We studied two representative cases of this category (CS18 (SDG3&4)). For example, the "Half the Sky Movement" develops mobile phone simulation games to raise awareness of the general audience regarding issues that women and girls are facing. In 9 minutes, women and girls play out the adventure of managing a healthy and successful pregnancy, compressing the nine-month process into a short game experience, all guided by interactions with preprogrammed intelligent machines. In another intelligent game aimed at children 7 and older, players are tasked with keeping a growing number of boys and girls healthy by defeating the worms inside their tummies. They gain awareness of the dangers of intestinal worms and learn about simple de-worming solutions that have had a significant impact on children's health.

AI Regularization for Detailed Reality

Perhaps one of the most fundamental ways AI is able to provide detailed insight on specific areas of development is by fine-graining our understanding of reality by analyzing unprecedented big data sources in a new way with greater nuance. Advancing into a more detailed representation of reality increases the risk of overfitting. The machine might learn particular aspects of a circumstantial situation that was unique and will never reoccur exactly in this way. In short, the AI computes an exact description of a unique situation, not useful knowledge that can be generalized to other cases. Regularization allows the intelligent system to continue learning within specific contexts without overfitting to a specific situation. This allows a system to be more efficient while still accounting for the warranted details of the system input.

Collecting fine-grained detail has proven fruitful in a number of ways that all address development goals. By monitoring infrastructure, AI contributes to road safety, and leads to new road designs that can influence the way drivers behave (CS20 (SDG.11)). If these insights are sufficiently regularized to be generalizable, it allows us, for example, to collapse ecosystem models to map dependence on subsistence fisheries, thereby fostering sustainable development (CS21 (SDG.14)).

It is important to emphasize that the detailed data is necessary, but not sufficient to reap the benefits. Modern machine learning techniques, like deep learning, are necessary. For example, using the same data, CS23 (SDG.3) presents a case where neural nets correctly predicted 7.6% more patients who developed cardiovascular disease than other more traditional statistical techniques. With 31% of all deaths worldwide attributed to cardiovascular disease (WHO, 2017), this suggests that 2.4 % of all global deaths can be better predicted thanks to neural nets (an estimated 1.4 million deaths per year). Such accuracy can also be used to reduce health care costs. Our last case study, CS24 (SDG.3) shows a case where machine learning was able to reduce the number of unnecessary surgeries for breast cancer by more than 30 percent compared to existing approaches. It is this combination of detailed data with the power of machine learning which is able to generalize insights to new cases in a reliable way.

Discussion: Development at the AI crossroads

We started with a historical and theoretical review of modern AI, and identified four characteristics, the 4Rs of deep learning. Studying 24 case studies, we found that they align with four characteristics of international development. In isolation, each one of them provides ample evidence for bright opportunities to foster the development agenda with AI, especially the SDGs. However, in combination, it turns out that they lead to a tension between global efficiency and local needs. We discuss the arising challenges in this final section.

Global Efficiency and Local Diversity

In theory, the very nature of modern AI exemplifies the ideals of local context dependency and global coherence. Computer scientists meticulously balance representation learning of new patterns with multitask- and transfer learning of known patterns, and the regularization of noisy features with feature robustness despite varying details. The figurative balance between global synergies and local particularities is at the heart of the power of machine learning. Our application of these principles to the practice of international development does not only provide for an eloquent analogy, but also faces socio-economic pressures in the form of cultural and political transaction costs, economies of scale, and social cohesion.

Most machine learning is done within the industrialized context, since the process can be very costly. The effort to obtain enough medical images, detailed roadside maps, or agricultural landscapes can quickly scale to the millions of dollars. Naturally, the resulting intelligence learns the patterns of the data it was trained on. Notoriously, digital products have infinite economies of scale (Shapiro & Varian, 1998). This includes intelligence derived from costly machine learning projects. The cost advantage of centralized solutions over local training could lead to a trend where recommendations are clearly tailored to the historical and cultural contexts of the training sets. In the best case, their application to the problems of developing countries is less useful, in the worst case, harmful. Despite all theoretical ambitions of eradicating the ‘one-size-fits-all’ model with flexible AI, economies of scale create a strong pressure to adopt local conditions to the imported AI behavior for the sake of economic efficiency. The result is a digital indoctrination of ‘one-AI-fits-all.’

This starts with conflicting foci of the most urgent AI solutions. Different countries face different health epidemics. Priorities of developed and developing countries are *not* the same. Additionally, different countries face different variations of the same epidemic. Genetic mutations adjust to the genetics of the host, so an AI trained on cancer cells from hospitals in New York and Berlin might lead to dangerously confusing diagnoses when applied to remote regions of the developing world. Something similar accounts for many solutions that aim at improving safety. Roads are built differently in different regions of the world, so an AI trained at interpreting drone images from some regions, might reach dangerously unreliable conclusions when economic efficiency urges their application to developing contexts. Needless to mention that self-driving cars trained in Shanghai and London, will be utterly confused when entering many traffic situations of developing metropolis in Africa or South East Asia.

There are more subtle aspects to the ‘one-AI-fits-all’ approach. AI has learned from Western world training datasets that it is more beneficial to invite individuals to job interviews that have European-American names, than African-American names, and that women are to be associated with the arts rather than with the sciences (Caliskan, Bryson, & Narayanan, 2017). An unintended side effect of the pursuit of the opportunities offered by distance intelligence is that such biases are spread globally, often without explicit awareness of their presence.

History has provided countless examples where economic and cultural hegemony has led to the extinction of local values, culture, habits, and development goals. Even so modern AI provide the theoretical possibility to perverse and celebrate diversity, such designs are not favored by economic incentives, at least not at first. It is still cheaper to reuse a one-size-fits-all solution. The arising threat is a global indoctrination of intelligence from the producer to the consumer of AI, that is potentially even more harmful than any of the failed development indoctrinations of the 1980s and 1990s (Stiglitz, 2002).

Regulating international AI Regularization

The design of global AI systems that balances the trade-off between global efficiencies and local contexts comes down to finding the line between those results that are generalizable and those that are not. Taking an AI that works in one context and trying to apply it to other contexts without considering differences and limitations is a clear case of overfitting. For the machine learning community "regularization is our first weapon to combat overfitting" (Abu-Mostafa et al., 2012, p. 126). The term regularization is adequate for our purposes, because it carries the metaphoric double-meaning of the need for regulations of a process that assures global diversity in a world where AI solutions take an increasing share of all decisions.

If economic principles favor the 'one-AI-fits-all' model, economic incentives and social institutions would need to be designed to balance this pressure with context dependent automation and the adoption of local needs. This presents an uphill battle against the economic efficiency and therefore cannot purely follow market mechanisms. The machine learning community does something similar. The goal of dentifing shared parameters that fit many contexts is sometimes set as an a priori goal (e.g. Hinton et al., 2012). This "regularizes each unit to be not merely a good feature but a feature that is good in many contexts" (Goodfellow et al., 2016, p. 260). Of course, a solution that works for all cases is often as useless as one that works for none.

Taking advantage of synergies while not neglecting local particularities is usually solved with a multilevel approach, and deep learning lends itself to it (see Figure 2). Different levels identify communalities and differences. In analogy to international development, the international community might place common structures like human rights at the most basic level. They are taken to be "universal… inherent… and inalienable" (Assembly, 1948). Learning such shared factors largely facilitates the adequate and non-invasive application of distance intelligence. For example, an AI that has learned the insight that, "no one shall be subject to torture," (Art. 5, UDHR) is already effectively restrained to guide decisions in questions related to labor- and women's rights, and educational systems. Other, more concrete values might not be shared by different cultural or geographic regions. For example, Facebook offers to choose from 71 gender options, reaching from Asexual to Transmasculine (Williams, 2014). Some cultures might not agree with the details of these categories when used by intelligent algorithms to automate certain decisions. The reality in 2018 is that 30 % of human kind is connected to Facebook and exposed to this machine-facilitated categorization.

In theory, AI could learn about common cultural, social, and political norms. It can be programmed to complement restricted search spaces for specific constituencies among different populations. Over the coming years, intelligent machines will inevitably learn the hierarchical architecture that constitutes the complex multidimensional preference structures of what we call global norms. The promise is that the result will present a coherent, moral and ethical framework, with a certain level of shared beliefs and values, while at the same time emphasizing diversity and multiculturalism. The hierarchical layers of deep learning are a natural way to encapsulate the representation of both generic human values and specific human customs and preferences. Modern deep learning AI provides a tangible way to implement and celebrate this naturally existing hierarchy in socially embedded human preference structures.

While theoretically possible, the practical implementation of such nuanced hierarchical models faces the uphill battle against the brutal economic incentives offered by economies of scale of digital products. It is unlikely to emerge as the result of the evolutionary forces of market selection, at least at first. The silver lining is that, just like all other technologies before AI, AI does not comply with technological determinism. It can be socially constructed (MacKenzie & Wajcman, 1999).

Global Negotiations and Local Efforts

In this arising negotiation between global efficiency and local diversity, the only controllable variable for developing countries is the level of proactivity of their role. The question is about the weight they will bring to the anecdotal negotiation table about the hegemony of artificial intelligence. The combination of our theoretical and practical analyses results in the conclusion that developing countries will have begin investing aggressively into building their AI capacity if they want to avoid being swamped with solutions that will, in the best case, be inadequate and, in the worst case, damaging for them.

On the one hand, this is, in theory, facilitated by cloud services. Many aspects of AI solutions are openly available, including deep learning suites like Google's Tensorflow and Facebook's Pytorch. In theory, even if developing countries do not produce the technology, they could use it to produce local knowledge, which is what matters most for reaping the benefits of AI4D. The reality in developing countries places many self-inflicted roadblocks in the way of this opportunity. This includes institutional factors and data scarcity. As one example, a small startup called BlackBox solutions in Guatemala pursues the vision to take advantage of openly available tools like Google's Tensorflow to adjust machine learning to local contexts. Unfortunately, the legislation of their country prevents them from implementing remote work models to employ programmers and from fundraising a round of capital (Sandel, 2018). Even if those institutional hurdles are taken, their daily work often consists of trying to extract data from pdf documents handed to them from local municipalities.[2] It is ambitious to aspire to train globally competitive AI in such institutional settings and with such scarce and expensive data input. Ready-made imported solutions from developed countries might be more economically convenient.

On the other hand, the case of China is the counterexample to show that the level of development of a country must not be the main determinant of its standing in the AI revolution. With 41,000 publications from 2011 to 2015, China is the leading country in terms of AI related publications (compared to the U.S. with 25,000, while Japan was in third place with about 11,700 and the UK in fourth with about 10,100). The most cited argument for China's AI leadership is its size (Barton, Woetzel, Seong, & Tian, 2017). However, in terms of field-weighted citation impact in AI research (which allows for differences in citations according to subject and year), the first three ranks are occupied by small countries, namely Switzerland, Singapore and Hong Kong (Baker, 2017). Scale is useful, but not necessary for local transformation and for the buildup of AI capabilities. The leading AI executive Kai-Fu Lee argues that China's lead in AI is not merely due to its sheer size, but rather due to its approach to privacy, which leads to ubiquitous and multidimensional data to feed ML. He links China's approach to privacy to cultural outlooks and pinpointed political decisions (K.-F. Lee, 2018). The same decisions lead to controversial issues like the Chinese Social Credit System, a national reputation system being developed by the Chinese government, based on data analytics ("Social Credit System," 2018).

[2] Personal interview, MH with BlackBox Co-founder, Nery Fernando Guzman, at Hotel Barcelo, Guatemala City, Oct. 1, 2018.

These and many other policy tools will play a crucial role in shaping the identified tension, and therefore the aspirations of AI4D. Going further into the arising policy options is certainly beyond the scope of this study. It will require much more detailed and comprehensive consideration. This study aimed at presenting a general framework to approach the incipient discussion of the nascent field of AI4D. The discussion itself will accompany us for decades to come.

References

Allen, K. (2015). How a Toronto professor's research revolutionized artificial intelligence. *The Star*. Retrieved from https://www.thestar.com/news/world/2015/04/17/how-a-toronto-professors-research-revolutionized-artificial-intelligence.html

Assembly, U. G. (1948, December 10). Universal declaration of human rights. United Nations.

Baker, S. (2017). *Which countries and universities are leading on AI research?* Times Higher Education (THE). Retrieved from https://www.timeshighereducation.com/data-bites/which-countries-and-universities-are-leading-ai-research

Bakshy, E., Messing, S., & Adamic, L. A. (2015). Exposure to ideologically diverse news and opinion on Facebook. *Science*, *348*(6239), 1130–1132. https://doi.org/10.1126/science.aaa1160

Barton, D., Woetzel, J., Seong, J., & Tian, Q. (2017). *Artificial intelligence: Implications for China*. McKinsey Global Institute. Retrieved from https://www.mckinsey.com/featured-insights/china/artificial-intelligence-implications-for-china

Bengio, Y., Courville, A., & Vincent, P. (2013). Representation Learning: A Review and New Perspectives. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *35*(8), 1798–1828. https://doi.org/10.1109/TPAMI.2013.50

Bughin, J., Seong, J., Manyika, J., Chui, M., & Joshi, R. (2018). *Modeling the global economic impact of AI*. McKinsey Global Institute. Retrieved from https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy

Cacioppo, J. T., Cacioppo, S., Gonzaga, G. C., Ogburn, E. L., & VanderWeele, T. J. (2013). Marital satisfaction and break-ups differ across on-line and off-line meeting venues. *Proceedings of the National Academy of Sciences*, *110*(25), 10135–10140. https://doi.org/10.1073/pnas.1222447110

Caliskan, A., Bryson, J. J., & Narayanan, A. (2017). Semantics derived automatically from language corpora contain human-like biases. *Science*, *356*(6334), 183–186. https://doi.org/10.1126/science.aal4230

Colleoni, E., Rozza, A., & Arvidsson, A. (2014). Echo Chamber or Public Sphere? Predicting Political Orientation and Measuring Political Homophily in Twitter Using Big Data. *Journal of Communication*, *64*(2), 317–332. https://doi.org/10.1111/jcom.12084

eLAC Action Plans. (2018). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=ELAC_Action_Plans&oldid=844452921

Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, *542*(7639), 115–118. https://doi.org/10.1038/nature21056

Faggella, D. (2016, March 7). Valuing the Artificial Intelligence Market, Graphs and Predictions. Retrieved October 4, 2018, from https://www.techemergence.com/valuing-the-artificial-intelligence-market-graphs-and-predictions/

Fortune. (2018). Here Are the Fortune 500's Most Valuable Companies. Retrieved October 4, 2018, from http://fortune.com/2018/05/21/fortune-500-most-valuable-companies-2018/

Gillings, M. R., Hilbert, M., & Kemp, D. J. (2016). Information in the Biosphere: Biological and Digital Worlds. *Trends in Ecology & Evolution*, *31*(3), 180–189. https://doi.org/10.1016/j.tree.2015.12.013

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.

Halevy, A., Norvig, P., & Pereira, F. (2009). The Unreasonable Effectiveness of Data. *IEEE Intelligent Systems*, *24*(2), 8–12.

Heeks, R. (2006). Theorizing ICT4D research. *Information Technologies and International Development*, *3*(3), 1–4.

Heeks, R. (2017). *Information and Communication Technology for Development (ICT4D)*. Routledge. https://doi.org/10.4324/9781315652603

Hendershott, T., Jones, C. M., & Menkveld, A. J. (2011). Does Algorithmic Trading Improve Liquidity? *The Journal of Finance*, *66*(1), 1–33. https://doi.org/10.1111/j.1540-6261.2010.01624.x

Hilbert, M. (2015). *Quantifying the Data Deluge and the Data Drought* (SSRN Scholarly Paper No. ID 2984851). Rochester, NY: Social Science Research Network. Retrieved from https://papers.ssrn.com/abstract=2984851

Hilbert, M. (2016). Big Data for Development: A Review of Promises and Challenges. *Development Policy Review*, *34*(1), 135–174. https://doi.org/10.1111/dpr.12142

Hilbert, M., Ahmed, S., Cho, J., Liu, B., & Luu, J. (2018). Communicating with Algorithms: A Transfer Entropy Analysis of Emotions-based Escapes from Online Echo Chambers. *Communication Methods and Measures*, *0*(0), 1–16. https://doi.org/10.1080/19312458.2018.1479843

Hilbert, M., Bustos, S., & Ferraz, J. C. (2005). *Estrategias nacionales para la sociedad de la información en América Latina y el Caribe* (Information Society Programme No. LC/W.17). Santiago: United Nations ECLAC. Retrieved from http://www.cepal.org/cgi-bin/getProd.asp?xml=/publicaciones/xml/4/21594/P21594.xml&xsl=/ddpe/tpl/p9f.xsl&base=/socinfo/tpl/top-bottom.xslt

Hilbert, M., & López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, *332*(6025), 60–65. https://doi.org/10.1126/science.1200970

Hinton, G., Srivastava, N., Krizhevsky, A., Sutskever, I., & Salakhutdinov, R. R. (2012). Improving neural networks by preventing co-adaptation of feature detectors. Retrieved from https://arxiv.org/abs/1207.0580

Hubel, D. H., & Wiesel, T. N. (1968). Receptive fields and functional architecture of monkey striate cortex. *The Journal of Physiology*, *195*(1), 215–243. https://doi.org/10.1113/jphysiol.1968.sp008455

IDC. (2018). Worldwide Spending on Cognitive and Artificial Intelligence Systems Will Grow to $19.1 Billion in 2018, According to New IDC Spending Guide. Retrieved October 4, 2018, from https://www.idc.com/getdoc.jsp?containerId=prUS43662418

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436–444. https://doi.org/10.1038/nature14539

Lee, A. (2016, March 18). Geoffrey Hinton, the "godfather" of deep learning, on AlphaGo. *Macleans.Ca*. Retrieved from http://www.macleans.ca/society/science/the-meaning-of-alphago-the-ai-program-that-beat-a-go-champ/

Lee, K.-F. (2018). *AI Superpowers: China, Silicon Valley, and the New World Order*. Boston: Houghton Mifflin Harcourt.

MacKenzie, D., & Wajcman, J. (1999). *The social shaping of technology*. (D. MacKenzie & J. Wajcman, Eds.). Buckingham, UK: Open University Press. Retrieved from http://mcgraw-hill.co.uk/openup/

Och, F. J. (2005). *Statistical Machine Translation: Foundations and Recent Advances*. Presented at the Tutorial at MT Summit 2005, Phuket, Thailand. Retrieved from http://www.mt-archive.info/MTS-2005-Och.pdf

O'Toole, G. (2011). Everything Should Be Made as Simple as Possible, But Not Simpler | Quote Investigator. Retrieved September 7, 2017, from https://quoteinvestigator.com/2011/05/13/einstein-simple/

Pariser, E. (2011). *The Filter Bubble: What the Internet Is Hiding from You*. Penguin.

Perez, C. (2007). *Great surges of development and alternative forms of globalization* (Working Papers in Technology Governance and Economic Dynamics No. 15). The Other Canon Foundation, Norway and Tallinn University of Technology, Estonia. Retrieved from http://www.carlotaperez.org/pubs?s=tf&l=en&a=greatsurgesofdevelopment

Ramchurn, S. D., Vytelingum, P., Rogers, A., & Jennings, N. R. (2012). Putting the "smarts" into the smart grid: a grand challenge for artificial intelligence. *Communications of the ACM*, *55*(4), 86. https://doi.org/10.1145/2133806.2133825

Ricci, F., Rokach, L., Shapira, B., & Kantor, P. B. (Eds.). (2011). *Recommender Systems Handbook*. Boston, MA: Springer US. https://doi.org/10.1007/978-0-387-85820-3

Rogers, E. M. (1976). Communication and Development: The Passing of the Dominant Paradigm. *Communication Research*, *3*(2), 213–240. https://doi.org/10.1177/009365027600300207

Russell, S. J., & Norvig, P. (1995). *Artificial Intelligence: A Modern Approach* (1st ed.). Prentice Hall.

Sandel, A. (2018, October 2). Este emprendedor guatemalteco está reinventando la big data • Forbes México. *Forbes México*, (Centroamerica). Retrieved from https://www.forbes.com.mx/este-emprendedor-guatemalteco-esta-reinventando-la-big-data/

Schramm, W. (1979). *Mass Media and National Development 1979* (No. 42). UNESCO International Commission for the Study of Communication Problems. Retrieved from http://unesdoc.unesco.org/images/0003/000370/037073eb.pdf

Schreuder, D. A. (2014). *Vision and Visual Perception*. Archway Publishing.

Shapiro, C., & Varian, H. R. (1998). *Information Rules: A Strategic Guide to the Network Economy* (1st ed.). Harvard Business Press.

Social Credit System. (2018). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Social_Credit_System&oldid=861034115

Stiglitz, J. E. (2002). *Globalization and Its Discontents* (1 edition). New York, NY: W. W. Norton & Company.

Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203–1219. https://doi.org/10.1016/j.respol.2005.01.018

UN ECLAC (United Nations Economic Commission for Latin America and the Caribbean), F. (2018). *Data, algorithms and policies: Redefining the digital world*. Santiago Chile: United Nations Economic Commission for Latin America and the Caribbean. Retrieved from https://conferenciaelac.cepal.org/6/en/documents/data-algorithms-and-policies-redefining-digital-world

United Nations. (2015). *Discrimination and violence against individuals based on their sexual orientation and gender identity*. UN Human Rights Council. Retrieved from http://www.refworld.org/docid/5571577c4.html

Unwin, T. (Ed.). (2009). *ICT4D: Information and Communication Technology for Development* (1 edition). Cambridge: Cambridge University Press.

Wang, Y., & Kosinski, M. (2018). Deep neural networks are more accurate than humans at detecting sexual orientation from facial images. *Journal of Personality and Social Psychology*, *114*(2), 246–257. https://doi.org/10.1037/pspa0000098

WHO, (World Health Organization). (2017). WHO | Cardiovascular diseases (CVDs). Retrieved October 5, 2018, from http://www.who.int/cardiovascular_diseases/en/

Williams, R. (2014). Facebook's 71 gender options come to UK users. *THe Telegraph*. Retrieved from https://www.telegraph.co.uk/technology/facebook/10930654/Facebooks-71-gender-options-come-to-UK-users.html

World Summit on the Information Society. (2005). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=World_Summit_on_the_Information_Society&oldid=774075739

Xiong, W., Droppo, J., Huang, X., Seide, F., Seltzer, M., Stolcke, A., … Zweig, G. (2016). Achieving Human Parity in Conversational Speech Recognition. *ArXiv:1610.05256 [Cs]*. Retrieved from http://arxiv.org/abs/1610.05256

Yosinski, J., Clune, J., Bengio, Y., & Lipson, H. (2014). How transferable are features in deep neural networks? In Z. Ghahramani, M. Welling, C. Cortes, N. D. Lawrence, & K. Q. Weinberger (Eds.), *Advances in Neural Information Processing Systems 27* (pp. 3320–3328). Curran Associates, Inc. Retrieved from http://papers.nips.cc/paper/5347-how-transferable-are-features-in-deep-neural-networks.pdf

Yu, W., Zhuang, F., He, Q., & Shi, Z. (2015). Learning deep representations via extreme learning machines. *Neurocomputing*, *149*, 308–315. https://doi.org/10.1016/j.neucom.2014.03.077

Appendix: AI4D Case Studies

Table of Contents

1. Case Study: Agricultural productivity.

Addresses SDG 2
SDG Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG Goal 2.4: “By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.”

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The International Center for Tropical Agriculture is an organization that strengthens agricultural technologies, innovations, and new knowledge that help small farm owners improve their crop yields, incomes, and usage of natural resources. Scientists collaborated with Colombian Government, Agriculture and Food Security, and Colombia’s National Federation of Rice Growers to collect a big volume of data of weather and crops in last decade in Colombia. The initiative predicted upcoming climate change in Córdoba, a major rice-growing area in Colombia. The results are highly localized. In the town of Saldaña, for example, the analysis showed that rice yields were limited mainly by solar radiation during the grain-ripening stage. Meanwhile, in the town of Espinal, the team found that it suffered from sensitivity to warm nights. Solutions do not have to be costly, as such information can help farmers to avoid losses simply by sowing crops in right period of time. The climate change foresight helped 170 farmers in Córdoba avoid direct economic losses of an estimated $ 3.6 million and potentially improve productivity of rice by 1 to 3 tons per hectare. To achieve this, different data sources were analyzed in a complementary fashion to provide a more complete profiles of climate change. So-called ‘data fusion’ is a typical big data technique. Additionally, analytical algorithms were adopted and modified from other disciplines, such as biology and neuroscience, and were used to run statistical models and compare with weather records. With support from national and international organizations such as the World Bank and the Fund for Irrigated Rice in Latin America, the initiative has started to approach rice growers associations in other countries, including Nicaragua, Peru, Argentina and Uruguay.

Sources:
International Center for Tropical Agriculture (CIAT). (2016). http://www.cgiar.org/about-us/research-centers/international-center-for-tropical-agriculture-ciat/
Big Data for climate-smart agriculture.pdf. (n.d.). Retrieved July 20, 2016, from https://cgspace.cgiar.org/bitstream/handle/10568/65077/CCAFS%20BigData%20for%20Hubcast.pdf?sequence=8
Colombia rice growers saved from ruin after being told not to plant their crop | Diana Cariboni | Global development | The Guardian. (n.d.). Retrieved July 20, 2016, from https://www.theguardian.com/global-development/2014/sep/30/colombia-rice-growers-climate-change

2. Case Study: Pharmaceutical and scientific research engines.

Addresses SDG 3
SDG Goal 3.11: Support the research and development of vaccines and medicines for the communicable and noncommunicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all

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The research and development (R&D) process for developing drugs has remained unchanged for many decades; production of any medicine takes years and a hefty price of around $2 billion. Despite all the huge, already existent database of research over the years, and the increasing numbers of scientific papers published each day, this research is vastly unread and unknown to most scientists, meaning the information remains unused. Benevolent.ai intends to cumulate these scientific journals, genomic data, and various scientific sources in order to filter through the data and present it to scientists in meaningful ways, such that they may find insight to look at the most relevant information to develop meaningful hypotheses to treat illnesses.

A notable success is when Benevolent.ai scanned for studies related to treatment of ALS, a neurodegenerative disease that slowly paralyzes the body and often leads to death in three years. The AI found about 200 relevant materials, which scientists reduced to the top five compounds they wanted to test. The tests were performed on cells cloned from ALS patients' own cells. One of the five compounds did not work. Two worked as well as the current best drugs for ALS treatment, and the final two were unexpectedly *even better*. The four that worked were never compounds that the researchers had considered using, until the AI had suggested those as possibilities. CEO of BenevolentAI, Jackie Hunter, states the company is working towards finding better and more permanent solutions for other illnesses, including Parkinson's disease and Alzheimer's, as well as the encroaching issue of microbial resistance to antibiotics.

This AI is a step towards a revolutionized future of pharmaceutical development. Although the technology is still in its early stages, it shows promising results and the company is rapidly gaining attention and followers, especially in the stock market. Benevolent.ai could potentially be used to develop medicinal solutions for new bacterial and viral infections that affect both rich and poor countries. Another possible way Benevolent.ai may be of help is that it may provide insight to creating different alternatives to current medicines that may be 1) more effective than current medicines, and 2) cheaper to produce than current medicines.

Sources:

Conger, Kate. "BenevolentBio's artificial intelligence could discover a better treatment for ALS." TechCrunch. 06 Dec 2016. https://techcrunch.com/2016/12/06/benevolentbios-artificial-intelligence-could-discover-a-better-treatment-for-als/

Medeiros, Joao. Wired. 31 Aug 2017. "This AI unicorn is disrupting the pharma industry in a big way." www.wired.co.uk/article/benevolent-ai-london-unicorn-pharma-startup

Quach, Katyanna. "IBM's AI guru leaps over to Brit biz benevolent.ai" The Register. 09 Sep 2016. https://www.theregister.co.uk/2016/09/09/ibms_ai_expert_moves_to_benevolentai/

“Web Summit 17: How AI is revolutionising drug discovery” BenevolentAI. 09 Nov 2017. http://benevolent.ai/video/web-summit-how-ai-is-revolutionising-drug-discovery/

“Will artificial intelligence help to crack biology?” The Economist. 07 Jan 2017. https://www.economist.com/news/science-and-technology/21713828-silicon-valley-has-squidgy-worlds-biology-and-disease-its-sights-will

3. Case Study: Automating education

Addresses SDG 4:
4.A Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all
4.A.1 Proportion of schools with access to: (a) electricity; (b) the Internet for pedagogical purposes; (c) computers for pedagogical purposes; (d) adapted infrastructure and materials for students with disabilities…

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A February 2017 report, Artificial Intelligence Market in the U.S. Education Sector 2017-2021, predicts that the use of AI in the United States education sector will grow 47.5 percent through 2021 (cited in Ascione, 2017). This marked growth in the use of AI features on the education industry creates a number of avenues for new learning technologies.

AI has the potential to create adaptive learning features with personalized tools for each student's individual learning experience (Chisling, 2017). This directly addresses the UNs SDG 4 which strives for education facilities that are effective learning environments for all. Customized learning systems that are established as a result of AI systems would tailor lessons to different children's needs (Ghafourifar, 2017). This would radically shift the existing education system which focuses on standardization to minimize achievement differences between students. Changing the system to more tailored lessons would allow some students to naturally advance faster than others, which would reflect a shift away from the norm of standardization and centralization (Ghafourifar, 2017). This ability to offer tailored and customized learning systems is exemplified by VFS-Oxademy, a new global digital learning platform created via a partnership between VFS Global and UK-based Edtech Oxademy Technologies (Arab News, 2017). This new platform will offer a knowledge-drive AI cloud infrastructure which is able to identify each learner's strengths and weaknesses and is then able to generate learning paths based on individual behavior, thereby personalizing the learning to each individual student (Arab News, 2017).

AI can also be utilized in places where children receive subpar education in schools or have no access to education at all. IBM has approached the information access problem by launching Overcoming Illiteracy, a project which aims to use AI to decode complex texts and convey them to adults with limited reading skills via simple spoken messages and visuals (Bennington-Castro, 2016).

The usage of AI in the education sector extends beyond the student as it has the ability to help educators with both menial tasks and with developing activities and lesson plans (Bogardus Cortez, 2017). Third Space Learning, an internet based math tutoring service, has begun looking at what patterns exist around positive teaching outcomes and how teaching interactions can be optimized to promote greater learning (Wood, 2016). The company's goal is to create a platform that gives real-time feedback to help tutors become better teachers (Dickson, 2017). Additionally, researchers are examining how AI-enabled robots can help teach basic skills and take over menial tasks, like grading, so that educators can focus on more complex topics and develop engaging and creative classroom activities (Bogardus Cortez, 2017).

The ability for AI to assist in the advancement of SDG 4.A is further highlighted by Robota, a social robot developed by a team of students from Rutgers University that helps teachers in special-ed classrooms (Kolodny, 2017). Robota uses "computer vision and sentiment analysis" to identify students who appear to be distressed, then asks the students if anything is wrong (Kolodny, 2017). Robota is then able to evaluate their response to determine if it requires any immediate attention from an adult.

Sources:
Ascione, L. (2017, May 22). Brace yourselves: AI is set to explode in the next 4 years. https://www.eschoolnews.com/2017/05/22/brace-ai-set-explode-next-4-years/
Bennington-Castro, J. (2016, December 22). AI is a Game-Changer in the Fight Against Hunger and Poverty. MACH: The best and latest in Tech & Innovation. https://www.nbcnews.com//mach
Bogardus Cortez, M. (2017, July 12). AI in Education Will Grow Exponentially by 2021 [Text]. https://edtechmagazine.com/k12/article/2017/07/ai-education-will-grow-exponentially-2021
Chisling, A. (2017, September 11). 8 ways AI is helping industries today. https://blog.rossintelligence.com/8-ways-ai-is-helping-industries-today-1ff22619433a?wpnd_cid=6cea5b9736793ff8
Dickson, B. (2017, March 13). How Artificial Intelligence enhances education. https://thenextweb.com/artificial-intelligence/2017/03/13/how-artificial-intelligence-enhances-education/
Ghafourifar, A. (2017, July 23). 14 ways AI will impact the education sector. https://venturebeat.com/2017/07/23/14-ways-ai-will-impact-the-education-sector/
Kolodny, L. (2017, May 14). This robot helps kids with special needs to communicate. http://social.techcrunch.com/2017/05/14/this-robot-helps-kids-with-special-needs-to-communicate/
Wood, A. (2016, September 28). Artificial intelligence is the next giant leap in education. https://www.raconteur.net/technology/artificial-intelligence-is-the-next-giant-leap-in-education
World's first 'AI-based' online learning programs announced. (2017, July 28). http://www.arabnews.com/node/1136081/corporate-news

4. Case Study: Local Machine Learning on Learning Conditions

Addresses SDG 4:
SDG 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities.
4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes

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Big Data for universal education in Karnataka, India. Akshara Foundation is a Non-Government Organization in India that aims at narrowing the gaps in the universalization of pre-school and primary education in India. The organization has been collecting primary data from 40,000 schools and over one million students since 2006. The organization itself did not have sufficient capacities to make fully use of these data. HP data scientists helped to clean and organize previously messy and incomplete dataset of Karnataka, India. Together they created a custom dashboard that provides insights of the ratio of students and teachers and the adequate number of books per student. Machine learning algorithms were used to look for hidden patterns in the data. One of surprising finding is that the introduction of separate bathrooms reduces drop-out rates in school. Such insights allow administrators and policy makers to set any foresight and policy planning exercise on a more comprehensive outlook of reality.

Sources:
About Us | Akshara Foundation. (n.d.). Retrieved from http://akshara.org.in/en/who-we-are/about-us/

Gutierrez, D. (2015, March 11). HP Data Scientists Help Akshara Foundation Transform Education for Indian Students. Retrieved from http://insidebigdata.com/2015/03/11/hp-data-scientists-help-akshara-foundation-transform-education-indian-students/

How Big Data Is Helping Indian Schoolchildren. (2015, March 13). Retrieved July 29, 2016, from http://www.datanami.com/2015/03/13/how-big-data-is-helping-indian-schoolchildren/

5. Case Study: From Virtual to Real Gender Equality

Addresses SDG 5:
SDG 5: Achieve gender equality and empower all women and girls
5.b: Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women

Other machine learning technologies are being used to promote gender in the workplace and the classroom via autonomous intelligence. Autonomous intelligence is the ability for AI technologies to provide real-time feedback that can be used either by individuals or machines to make real-time decisions. Doberman.io has employed machine learning and speech recognition to create an app that helps promote gender equality in the meeting room. When a meeting starts, an app records what is being said and continuously shows the equality level of that meeting. When the meeting has ended and the recording stops, the user will receive a full report of the meeting. The app records and analyzes speech during a meeting and then provides a visualization of speaker contribution by gender as the meeting progresses. While recording, the app classifies audio chunks which are then sent to a server that segments the audio by speaker and identifies who is speaking. Based on the response data, the app can easily create visualizations to highlight speaker contribution by gender. The app aims to heighten awareness of the gender equality issue and demonstrate how solutions to wider problems can be addressed using innovative technology. In this context, we think about AI as an accountability layer that can be used to identify, analyze, and learn from bias.

Sources:
https://doberman.io/thoughts/promoting-gender-equality-using-ai

6. Case Study: Inclusive, safe and sustainable cities

Addresses SDG 11
11.1 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
11.2 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
11.3 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
11.4 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

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With all of the work that is being conducted on our technology, consumer items, and business, it is important not to forget about the infrastructure that supports our daily human lives—the cities that we inhabit. Artificial Intelligence can and should be implemented in a city because of the multiple variables and factors that occur in a city every day. From traffic lights, to pedestrians, to scaffolding on buildings from construction, multiple ongoing interactions are at play, and an automated, error free technology would be greatly beneficial to helping streamline the mass chaos that is a city.

One company spearheading the idea of a "smart city", as they call it, is the ICT group. Their take on a smart city involves, "Using smart software solutions, we enable fast, affordable and safe connections within and between infrastructural, logistical and distribution networks" (ICT.eu). The ICT group aims to unite food, water, energy, mobility, waste, and environmental obstacles that a city might face. This is turn will increase a city's efficiency, make it more environmentally friendly, and improve the citizen's quality of life, all of which aligns with SDG 11.2. In fact, in a study of traffic management in the City of Valencia, ICT's smart city was utilized garner sensors, smart devices, and real-time data in order to de-clog the traffic that inhabits a certain area. The findings of this study saw that by gathering data and developing a benchmark of certain patterns of traffic, then tracing that back to where the traffic was coming from could prove beneficial. The study notes that, "Technologies such as sensor networks, ubiquity, connectivity infrastructure-vehicles and others, become essential elements to achieve this goal" (Castellas).

Not only that, the idea of a smart city took over an actual city in Japan called Shio-jiri City, which has a fully implemented, artificial intelligence backed data gatherer that conducts a million different tests in different sectors of the city in the blink of an eye. A Case Study notes, "platform on these networks can provide ICT services within the city, such as healthcare, social welfare, disaster mitigation, tracking of children and elderly people using wireless tags, weather observation, etc." (ITU). This aligns with the SDG 11.1 and 11.4 in that wireless tags could help locate missing people, disabled people, young children who are lost, etc. and would vastly improve the safety and wellbeing of the citizens within the city. Furthermore, it would be much easier to send help and cater to victims during any sort of crisis or disaster utilizing this "smart city" technology. Drawbacks of course include a lack of privacy due to all of the monitoring and data gathering associated with artificial intelligence modeling, and also increasing dependency on technology we don't fully know all the capabilities to. Another potential issue, according to an article on Greenbiz.com, is that "One sustainability-related risk that AI poses is automated bias. Bias can happen when the machine learns to identify patterns in data and make recommendations based on, for example, race, gender or age. As AI algorithms do more analysis, companies must be diligent in ensuring that their algorithms analyze data and make predictions in a fair way" and this is something that we must navigate through in order to get the idea of a smart city function able in multiple places throughout the globe.

Sources:

Castellas, Maria. "Use of ICT in Smart Cities. A Practical Case Applied to Traffic Management in the City of Valencia." IEEE Conference Publication, 25 June 2015, ieeexplore.ieee.org/document/7181559/

March 27, 2017 · by itu4u · in Artificial Intelligence, SDGs. "Accelerating the UN's Sustainable Development Goals through AI." The ITU Blog, 15 May 2017, itu4u.wordpress.com/2017/03/27/accelerating-the-uns-sustainable-development-goals-through-ai/

Riffle, Conor. "What Artificial Intelligence Means for Sustainability." GreenBiz, GreenBiz Group Inc., 19 July 2017, www.greenbiz.com/article/what-artificial-intelligence-means-sustainability.

Suzuki, Hikofumi. "Realization of a Safe and Secure Society Using ICT in Shiojiri-City, Nagano Prefecture, Japan." IEEE Conference Publication, 30 Nov. 2015, ieeexplore.ieee.org/abstract/document/7402051/.

7. Case Study: Smarter Cities

Addresses SDG 17
SDG 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development
SDG 17.17: Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.

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In a public-private sector collaboration, the Rio de Janeiro city government and IBM have created an instrumented system across many sectors to achieve real time city and smart urbanism. More than thirty public sectors contributed data streams, including traffic and public transport data, municipal and utility services, emergency services, weather information, and call details records. Citizens interact on social media platforms, contributing real time data, such as tweets about traffic jams. As a result, decentralized data and information goes into one centralized command center, consisting of both private sectors and public sectors. With data from different sources, policy makers and administrators have a better understand of city dynamics and find hidden correlations. Combined with advanced algorithms predictive models are created to create scenarios for natural disasters and crimes in a real time. Due to this big data project, it is reported that the city of Rio de Janeiro emergency response is 30 percent faster than before. Rio Operations Center is one of the seven pilot projects (other pilots include 3 US, 1 Polish, 1 Vietnamese, and 1 Chinese cities) that are part of IBM's Smarter Cities Challenge. Since its 2010 launch, IBM has advised (and in some cases awarded grants) over 100 cities in how they can address some of their more challenging issues while also doing this in a way that is more sustainable through the usage of these smarter technologies. Sources:

Reference:
IBM. (2011). IBM Helps Rio Become a Smarter City. Retrieved from https://www.youtube.com/watch?v=vuBBGYFonXM

Smart City Strategy: Rio de Janeiro (Brazil). (2015, March 23). Retrieved July 19, 2016, from http://www.urenio.org/2015/03/23/smart-city-strategy-rio-de-janeiro-brazil/

VialPereira, G. (n.d.). Delivering public value through open government data initiatives in a Smart City context. Retrieved July 19, 2016, from http://link.springer.com/article/10.1007/s10796-016-9673-7
Extra Information:
http://www.telecomstechnews.com/news/2014/may/28/big-data-the-road-to-smart-cities/

8. Case Study: HiBot, optimizing water resources.

Addresses SDG 12:
12.2: By 2030, achieve the sustainable management and efficient use of natural resources

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Researchers across the globe are searching for answers to one of conversations great questions: what do we do about water? Research groups like those at HiBot USA and JEA (the water, sewer, and electric provider for Jacksonville, Florida), have turned to big data and artificial intelligence to help conserve. HiBot employs a "databotics system" designed to algorithmically locate where pipes are more at risk of failure employing inspection of pipes that have already been replaced and evaluating soil dynamics, electromagnetic forces coming from power lines, etc. in those areas. As there are approximately 240,000 water main breaks recorded a year across the country, HiBot technology allows for conservation of water through prevention of leaky pipes. They plan to send tiny, three-segmented HiBot robots through old, worn pipes to determine what kind of deterioration has come about since it's installation. The robots are designed to expand to the size of the pipe so that wheels touch the insides. They are equipped with a camera in the front, and tow RFT magnetic sensors that allows the HiBot USA team to measure material loss in the pipe.

At JEA, management was challenged to reduce withdrawal of water from the area aquifer and turned to artificial intelligence to meet the challenge. They created a new system, Optimized System Controls of Aquifer Resources (OSCAR) controls the water system in real time creating what JEA terms "Operations Optimization", meaning the water system is monitored, regulated and adjusted every minute of every day, creating a "just in time" water supply. OSCAR regulates the pumping of water from the aquifer by evaluating data from a variety of sources and JEA operators use the data to switch from reactive to proactive based on the consumption forecast. Energy consumption is then minimized while water generation is maximized. This process allows savings in several areas: the value of the energy used for the system is maximized because water use is predicted ahead of time and pumping is scheduled for times of day when energy costs are lower, groundwater supplies are better managed, ensuring supplies for future generation,and salt intrusion into wells has been reduced (which in turn increases water quality). Through systems like these, we can finetune systems to keep water safe and accessible for generations to come.

Sources

1. https://www.fastcompany.com/3068423/how-robots-and-ai-could-save-american-water-utilities-half-a-trillion-dolla
2. http://www.waterworld.com/articles/print/volume-22/issue-6/automation-technology/artificial-intelligence-helps-jea-optimize-water-resources.html
3. https://techcrunch.com/2017/04/04/pluto-ai-raises-2-1-million-to-bring-intelligence-to-water-treatment/
4. https://www.infrastructurereportcard.org/cat-item/drinking-water/
5. http://www.waterrf.org/Pages/Projects.aspx?PID=3001

9. Case Study: Intelligence irrigation systems.

Addresses SDG 12:
12.2: By 2030, achieve the sustainable management and efficient use of natural resources

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Agricultural irrigation systems often do not use water efficiently, causing overconsumption of water resources. AI irrigation systems can be implemented in farms to provide long-term positive effects in both farm economy and environmental sustainability. At Chile's Universidad Catolica de Santisima Concepcion (UCSC), researchers created an AI drip irrigation system that aims to increase water efficiency. The system works by inserting a network of ground sensors into the soil to discover plants' irrigation needs, monitor demand, and optimize water use remotely. Artificial Neural Networks (ANN) based intelligent control systems are then used to effectively schedule irrigation, controlling irrigation time and water flow to provide plants the optimal amount of water at the best time. The ANN controller is programmed with MATLAB, which models the input parameters of air temperature, soil moisture, radiations, humidity, etc. The ANN works with the ground sensors to simulate the amount of water needed for irrigation based on ecological conditions, evapotranspiration, and type of crop.
The UCSC researchers pilot-tested the system on blueberries, which require large volumes of water to grow, but this mechanism is expected to save 70% more water than other irrigation methods. This system is particularly helpful to Chile, where blueberries were the third largest export in 2011. Additionally, the Chilean Government's Agricultural Innovation Foundation (FIA) executive Rodolfo Cortes stated that efficient water use is crucial to the agricultural industry, especially because the country is suffering an agricultural emergency due to a drought affecting 106 municipalities. Besides helping Chile, this AI drip irrigation system can be helpful to developing nations that lack water and must use it sparingly; this technology can help provide more food at lower prices for the poor.

Sources:
"Chile: wireless sensor irrigation cuts water use in blueberry production." Fresh Fruit Portal. 30 March 2012. https://www.freshfruitportal.com/news/2012/03/30/chile-wireless-sensor-irrigation-cuts-water-use-in-blueberry-production/
Moncrief, Haley. "Researchers develop artificial intelligence irrigation system to reduce water use." BN Americas. 28 March 2012. www.bnamericas.com/en/news/waterandwaste/researchers-develop-artificial-intelligence-irrigation-management-system
"Toward autonomous irrigation. Can artificial intelligence irrigation system reduce water use?." *AI*, AI Business. 23 January 2017, http://ai.business/2017/01/23/towards-autonomous-irrigation-can-artificial-intelligence-irrigation-system-reduce-water-use/
Umair, S. Muhammad. "Automation of Irrigation System Using ANN based Controller." International Journal of Electrical & Computer Sciences IJECS-IJENS. Vol. 10, 02. ijens.org/104602-5757%20IJECS-IJENS.pdf

10. Case Study: Timber conservation

Addresses SDG 15:
SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG Goal 15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

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Bolsa Verde do Rio de Janeiro, known as BVRio, is a non-profit organization in Rio de Janeiro, Brazil. The organization collaborates with Rio De Janeiro State Government, the Municipality of Rio de Janeiro, and the Brazilian Amazonian states to prevent illegal timber trades in Brazil. BVRio adopts a computational system that includes analytical tools for due diligence and risk assessment system. The system consists of four components, including document analysis, remote sensing (i.e: satellite imagery), field audits, and external databases. Through machine learning, BVRio's analysis found that more than 40 percent of the forest management operations in the Brazilian states of Pará and Mato Grosso between 2007 and 2015 likely involved severe breaches of the law. Those areas are responsible for more than 70 percent of Brazil's timber production. Different from conventional databases, which usually only include logging permits and sawmill operating licenses to detect illegality of timber, the system collects more diverse data sources from legal records of forest owners, loggers, and forest engineers. Algorithms allow to scan data in real time and find hidden correlations in datasets to make modeling and predictive analysis more accurate and efficient. As a result, administrators and policy makers can identify inconsistencies and illegal behavior and respond them quickly. At the same time, buyers can inform themselves about their timber sources and protect themselves from purchasing illegal ones.

Sources:
1 About iBVRio | BVRio Institute. (n.d.). Retrieved from http://www.bvrio.org/sobre-bvrio/
2 BVRio Timber Exchange | BVRio. (n.d.). Retrieved from http://timber.bvrio.org/
3 Five technologies help thwart illegal logging by tracing wood's origin. (2016, May 23). Retrieved August 14, 2016, from https://wildtech.mongabay.com/2016/05/five-technologies-help-thwart-illegal-logging-tracing-woods-origin/
4 Using Big Data to combat the illegal timber trade in Brazil. (2016, August 10). Retrieved August 14, 2016, from https://news.mongabay.com/2016/08/using-big-data-to-combat-the-illegal-timber-trade-in-brazil/

11. Case Study: Using AI to assist medical tasks.

Addresses SDG 3
SDG 3: Good Health and Well-being - Ensuring healthy lives and promoting the well-being for all at all ages is essential to sustainable development.

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Artificial Intelligence is being utilized around multiple different industries and sectors and one very important use-case is in the healthcare industry. A lot of routines and tasks are conducted manually and individually by hundreds of nurses and doctors on the daily, detracting valuable time that could be spent with patients or studying cases of patients. IBM Watson is taking the lead on compartmentalizing doctors, nurses, medical assistants, and practitioner's times to make sure it is being used efficiently. For example, the World Health Organization estimated that "in 2015 there were only 1.5 physicians for every 1,000 people in China, compared with 2.5 in the US and 2.8 in Britain" (World Health Statistics, 2015). Furthermore, compounded aging population and new population contributes to a rise in demand for healthcare that cannot be backed by the existing supply. Here is where AI comes in. AI's "virtual doctors" can read CT scans, identify early indications of chronic diseases, and can even make diagnoses in seconds compared to a human doctor. Furthermore, doctors are under increased pressure to see as many patients as possible, whether it be in China or the United States; and this leads to less personalized care and explanations of individualized targeted treatments. A published study in the Annals' of Internal Medicine in 2016 detailed that for every hour physicians were seeing patients, they were spending nearly two hours on paperwork. Additionally, some medical staff spend almost 10% of their working hours answering basic patient questions about physician credentials, lunch, and visiting hours. IBM Watson and its AI capabilities aim to eliminate these menial and rudimentary tasks to free up time for what really matters—patient care and wellbeing. By alleviating the burden of paperwork and basic questions, and attending to needs that do not require medical expertise, these works can utilize time effectively. This promotes healthy lives and well-being for individuals of all ages, and can be expanded to third world countries where medical care is scarce. Third world countries also suffer from medical issues that can easily be solved with more resources and better distribution of care—by installing Watson in these countries, Doctors can hone in on more emergency, complex medical situations.

Sources:
Cecchi, Guillermo . "How AI and Machine Learning are Aiding Schizophrenia Research." IBM Watson Research, 21 July 2017, www.ibm.com/blogs/think/2017/07/ai-schizophrenia-research/.
Fix, Oren. "Faculty of 1000 evaluation for Allocation of physician time in ambulatory practice: A time and motion study in 4 specialties." F1000 - Post-Publication peer review of the biomedical literature, 2017, doi:10.3410/f.726713892.793530006.
"World Health Statistics 2015." World Health Organization, 2015, www.who.int/gho/publications/world_health_statistics/2015/en/.
https://www.cnet.com/news/ai-enters-the-hospital-room/

12. Case Study: Economic Growth Potential Across Industries

Addresses SDG 8
SDG 8: Decent Work and Economic Growth - promote inclusive and sustainable economic growth, employment and decent work for all
SDG 8.1: Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors
SDG 8.2: Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services

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Business across industries and sectors today face steady decline—causing erosion in job development, career prospects, investment, innovation, and economic potential. Artificial Intelligence is a booming new factor of production that aims to disrupt this decline. According to Accenture Research, “AI has the potential to lead to an economic boost of $14 trillion across 16 industries in 12 economies by 2035.” By bridging the gap between humans and technology, AI will decrease the need for manpower and in turn increase productivity. Labor productivity is set to increase by 40% in developed economies according to a research report from Accenture Research. Countries like the United States, Japan, Finland, and France are significantly boosted through the integration of artificial intelligence. Communication, Manufacturing, and Financial sectors will face the most growth rates after integrating artificial intelligence into their business process. Manufacturing will integrate AI to streamline supply chain operations and utilize AI to automate assembly lines, Financial services will relieve workers of mundane repetitive tasks, and even labor-intensive sectors like Education and Social Services see growth rates of 2% and billions of dollars in economic output.

The AI revolution can be compared to the industrial revolution in terms of how fundamentally it progressed industries and boosted the economy. The biggest fear surrounding the potential of AI is that it disrupts our current economy and displaces many jobs. According to a paper on Artificial Intelligence and Economic Progress from Stanford University, however, firms that implement artificial intelligence automatically have higher R&D costs, and firms with higher R&D costs obviously hire more highly paid, highly skilled, specialized workers. The study notes that what is interesting about these companies is that they also set a higher wage standard for their lower skilled workers and they end up getting paid more relative to low skilled workers that work at a firm without AI implementation. This is because “more innovative firms display more complementarity between low-skill workers and the other production factors (capital and high-skill labor) within the firm” (Agion and Jones, page 38). This theory goes hand in hand with SDG goal 8.1, and experiments with the idea that AI can benefit workers of all different skill types, and increase the wage level fundamentally across the employed sector of individuals.

In addition to adding money to individual wages and specific firms in different sectors, AI is posed to add money to the global economy as a whole. According to an article from Bloomberg, AI will add a monumental $15.7 Trillion dollars to the global economy, boosting global GDP by 14% in 2030. "What we see as the future is man and machine together can be better than the human" (Rao), $6.6 trillion dollars will be from increased productivity as "businesses automate processes and augment their labor forces with new AI technology, and $9.1 trillion from consumption side-effects as shoppers snap up personalized and higher-quality goods" (PWC). Factoring in AI into our economic sector has a real chance of impacting real wages and changing the way we do business—but it will take some serious rebuilding and research on privacy, growth, regulation and oversight.

Sources:
Agion, Phillipe, et al. "Artificial Intelligence and Economic Growth." 10 Oct. 2017, web.stanford.edu/~chadj/AI.pdf. https://web.stanford.edu/~chadj/AI.pdf
"AI Will Add $15.7 Trillion to the Global Economy." Bloomberg.com, Bloomberg, 28 June 2017, www.bloomberg.com/news/articles/2017-06-28/ai-seen-adding-15-7-trillion-as-game-changer-for-global-economy.
"Artificial Intelligence Is the Future of Growth." Future of Artificial Intelligence Economic Growth | Accenture, www.accenture.com/us-en/insight-artificial-intelligence-future-growth.
Columbus, Louis. "Artificial Intelligence Will Enable 38% Profit Gains By 2035." Forbes, Forbes Magazine, 22 June 2017, www.forbes.com/sites/louiscolumbus/2017/06/22/artificial-intelligence-will-enable-38-profit-gains-by-2035/#1bdc74ad1969.

13. Case Study: Mobile phone malaria diagnosis.

Addresses SDG 3
SDG 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases
SDG 3.13: Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks

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Accurate malaria diagnosis is vital -- false negatives can be fatal, and false positives lead to increased drug resistance, economic burden, and can even lead to the failure to treat diseases with similar early symptoms (such as meningitis or typhoid). There are 300-500 million cases of acute malaria illness annually, of which 1.1-2.7 million are fatal. Of those fatal cases, a vast portion are children. In developing countries, the lack of access to accurate diagnosis is largely due to a shortage of expertise coupled with a shortage of equipment. Findings of a recent survey carried out in Uganda show that only half of rural health centers have microscopes, and of that half, only 17% had staff with the training necessary to use them for malaria diagnosis. Even where a microscopist is available, they are often in such high demand that they cannot spend long enough examining each sample to give a confident diagnosis. As stated in Scientific Reports, it can be difficult to determine the presence of the pigment from background and other artifacts, even for skilled microscopy technicians. This situation has prompted increasing focus on finding a solution via using technology to diagnose. In particular, in taking advantage of existing equipment and compensating for the shortage of human expertise. Image processing and computer vision techniques can be used to identify parasites in blood smear images captured through a standard microscope and given sufficient training data, the algorithms used in other medical imaging problems or computer vision tasks such as face detection can be applied to recognize the malaria plasmodia. Through a mobile phone application based on the morphological image processing algorithms, a complete malaria diagnostic unit using the mobile phones attached to a portable microscope is set up. The goal behind this system is to achieve performance equal to or better than the manual microscopy, which has been the gold standard in malaria diagnosis, in order to produce a reliable automated diagnostic platform without expert intervention, for the effective treatment and eradication of the deadly disease. To help mitigate the impact of malaria, with its associated increasing drug resistance, implementation of prompt and accurate diagnosis is needed
.

Sources:

1. https://www.nature.com/articles/srep13368
2. http://westminsterresearch.wmin.ac.uk/14711/1/Saumya_KAREEM_RENI_2014.pdf
3. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3521230/
4. https://www.researchgate.net/publication/266146329_Automated_Blood_Smear_Analysis_for_Mobile_Malaria_Diagnosis
5. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2223842/

14. Case Study: Medical imaging and intelligent healthcare

Addresses SDG 3:
3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services

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AI has the ability to revolutionize the healthcare industry by providing greater accessibility and efficiency. Both accessibility and efficiency are highlighted in Google's DeepMind Health project which can be used to interpret test results and learn which types of treatments are most effective for different patients (DeepMind, 2017). While DeepMind was founded in London with the immediate goal of streamlining the United Kingdom's NHS system, the technology that is being developed may impact communities worldwide as it seeks to support an existing healthcare system and become a self-sustaining initiative (DeepMind, 2017). One of the greatest potential benefits of DeepMind is its ability to offer improved equality of access to care as it is able to provide diagnostic support (DeepMind, 2017).

The diagnostic ability of AI is perhaps one of its most globally beneficial traits as access to medical professionals is often lacking in remote regions. Enlitic is a medical start-up which couples deep learning with medical data to advance diagnostics and thereby improve patient outcomes (Enlitic, 2016). Enlitic's deep learning networks examine millions of images to automatically learn to identify disease. This can provide important insights regarding early detection, treatment planning, and disease monitoring (Enlitic, 2016).

IBM researchers are using global data to track the spread of diseases (IBM, 2016). IBM's World Community Grid is a virtual, crowdsourced supercomputer that is saving researchers millions of dollars in equivalent computing resources and running projects such as OpenZika which allows scientists to screen millions of chemical compounds to identify candidates for Zika virus treatment (IBM, 2016). IBM has also developed Watson for Oncology which possesses the advanced ability to analyze the meaning and context of data in clinical reports to select a treatment plan for a particular patient based on the patient's attributes and external research (Medical Futurist, 2017).

Zebra Medical makes a deep learning image analytics platform which may revolutionize the healthcare industry by catching misdiagnosed diseases, early-stage cancers and other life-threatening ailments through algorithms. By collecting data from millions of scans, it uses a deep learning engine that can detect a number of medical issues and is able to predict diseases with accuracy that surpasses human ability. In 2017, Zebra announced that it was making all of its algorithmic scans available for $1 each and would put them in Google cloud for greater accessibility.

NVIDIA's AI tech will be integrated into GE Healthcare's 500,000 imaging devices. The Revolution Frontier CT system utilizes NVIDIA's computing platform to process images twice as fast as current technology and is expected to deliver better clinical outcomes in detection and identification of certain lesions in the liver and kidney. For patients, this partnership aims to lower radiation doses, promote faster exam times, and result in higher quality medical imagine.

GE healthcare is utilizing the Intel Xeon Scalable platform which aims to lower the total cost of ownership for imaging devices by 25% by reducing imaging display time and load times to increase performance by improving radiologists' reading productivity.

References:

Sources:

Artificial Intelligence Will Redesign Healthcare. (2016, August 4). http://medicalfuturist.com/artificial-intelligence-will-redesign-healthcare/
Chisling, A. (2017, September 11). 8 ways AI is helping industries today. https://blog.rossintelligence.com/8-ways-ai-is-helping-industries-today-1ff22619433a?wpnd_cid=6cea5b9736793ff8
Enlitic. (2016). https://www.enlitic.com/
IBM Intensifies Fight Against Zika. (2016, July 27). [CTB10]. https://www-03.ibm.com/press/us/en/pressrelease/50244.wss
DeepMind, Researching for tomorrow. (2017). https://deepmind.com/applied/deepmind-health/working-nhs/health-research-tomorrow/
DeNisco Rayome, A. (2017) GE, NVIDIA build AI-powered CT scanner that processes images 2x faster. Tech Republic. https://www.techrepublic.com/article/ge-nvidia-build-ai-powered-ct-scanner-that-processes-images-2x-faster/

Fast Company, "Most Innovative Companies: Zebra Medical Vision." https://www.fastcompany.com/company/zebra-medical
Business Wire (2017) GE healthcare partners with Intel to accelerate digital imaging from Edge to Cloud. https://www.businesswire.com/news/home/20171126005053/en/GE-Healthcare-Partners-Intel-Accelerate-Digital-Imaging
NVIDIA News, (2017) GE and NVIDIA join forces to accelerate artificial intelligence adoption in healthcare. https://nvidianews.nvidia.com/news/ge-and-nvidia-join-forces-to-accelerate-artificial-intelligence-adoption-in-healthcare
Rogers, S. (2018) Zebra medical gains FDA approval for AI-powered heart disease detection. Venture Beat. https://venturebeat.com/2018/07/12/zebra-medical-gains-fda-approval-for-ai-powered-heart-disease-detection/
Zebra-med.com

15. Case Study: Diagnosing tuberculosis.

Addresses SDG 3
SDG 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.

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Tuberculosis (TB) has been a top ten cause of death worldwide, with over 10 million patients in 2016, almost 2 million of which passed away. TB can normally be easily recognized on chest x-ray scans by radiology interpretation experts, but TB-prevalent areas are typically in developing nations that lack the expertise required to diagnose the illness. Researchers have sought help from deep learning artificial intelligence, specifically deep convolutional neural networks (DCNN), which use many layers and patterns to classify images. In Dr. Paras Lakhani's study, two DCNN models, AlexNet and GoogLeNet, learned from 1,007 collected x-rays of patients with and without TB. The combination of the two deep learning models resulted in a net accuracy of 96%. Where there were disagreements, human researchers stepped in and interpreted the images to accurately diagnose 100 percent of the cases. These diagnoses are especially helpful in terms of TB because it is a treatable condition, and being able to determine who the patients are will undoubtedly aid treatment and save many lives.
Given thousands of images of a disease, these deep learning algorithms will teach themselves to discover the similar characteristics between provided images automatically. Other similar potential applications of these AI systems are to help radiologists identify brain hemorrhages and malignant lung nodules, and even perform triage, which is determining which cases are the most critical and should be prioritized for the radiologists.

Sources:
Brook, Oak. "Artificial intelligence could help diagnose tuberculosis in remote areas." *RSNA Press Release*, Radiological Society of North America. 24 April, 2017, http://press.rsna.org/timssnet/media/pressreleases/14_pr_target.cfm?ID=1943
Huber, Jennifer. "Enlisting artificial intelligence to assist radiologists." *Scope Blog*, Stanford Medicine, 22 June 2016, http://scopeblog.stanford.edu/2016/06/22/enlisting-artificial-intelligence-to-assist-radiologists/

16. Case Study: Babylon medical consultations

Addresses SDG 3
SDG 3.D Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks

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Babylon is a British medical consultation and healthcare service which offers medical AI consultation based on personal medical history and common medical knowledge. The smartphone application that allows patrons to access doctors, schedule appointments, and order prescriptions remotely. Users report their symptoms to the app, which then checks them against a database of illnesses using speech recognition technology. It then offers an appropriate course of action based on symptoms, the patient's medical history, and circumstances. As well as allowing for remote healthcare, Babylon can remind patients to take their medications and follow up with how they are feeling. Through this, the app's efficiency of diagnosing patients will increase and can help to provide healthcare in remote locations, even going as far as potentially bringing down costs of healthcare in developed countries.

Sources:
Dickson, Ben. "Feeling Sick? Consult Your AI Chatbot." *PC Magazine*. Uk.pcmag.com, 13 Oct. 2017. Web.
"Artificial Intelligence Will Redesign Healthcare." *The Medical Futurist*. 17 July 2017. Web.
"How Our Online Doctor Consultations Work". *Babylon Health*. Web.
Burnip, Laura. "What Is the NHS Medical Advice Smartphone Helpline?" *The Sun*. 11 Sept., 2017. Web.

17. Case Study: Congenital cataracts, a treatable disease.

Addresses SDG 3
SDG Goal 3.4: By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being

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Congenital cataracts is a type of cataract that impacts children and needs to be diagnosed early on for treatment to be effective. While the disease is often curable in developed nation, it is a leading cause of irreversible blindness in developing countries as well as countries like China, where the large population makes it hard for experts to examine all children. Researchers in China created CC-Cruiser, an AI program that mines their clinical database of childhood cataracts to diagnose the congenital cataracts, predict the severity of the individual case, and suggest treatment decisions. CC-Cruiser was tested in five ways, first in which the AI program was able to distinguish patients from healthy individuals with 98.87 percent accuracy. CC-Cruiser also performed well a clinical trial, distinguishing patients with a 98.25 percent accuracy, only by using real images of children's eyes. In another test, CC-Cruiser handled low-quality cases from the Internet with a high level of accuracy. The program also successfully identified the only three cataract cases out of 300 normal cases. CC-Cruiser has been recorded to show comparable levels of accuracy to expert ophthalmologists, which is promising because the machine is intended to help hospitals that do not have experts on site. The machine is intended to receive images of children's eyes and respond with a diagnosis, severity evaluation, and possible treatments. After further clinical trials, the researchers hope that doctors in non-specialized hospitals may use CC-Cruiser to identify congenital cataracts and send patients to specialized centers, where they may be treated. The research into identifying and diagnosing congenital cataracts could potentially be used to develop more efficient methods of identifying other diseases via medical imaging.

Sources:
Long, Erping. Nature Biomedical Engineering 30 Jan 2017. https://nbmecommunity.nature.com/users/24989-erping-long/posts/14653-translating-artificial-intelligence-into-a-rare-eye-disease
Lobo, Joe. Inbenta. 27 Mar 2017. https://www.inbenta.com/en/blog/artificial-intelligence-five-ways-it-can-change-our-lives-for-the-better/
Scudellari, Megan. IEEE Spectrum. 01 Feb 2017. https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/ophthalmologists-vs-ai-its-a-tie
Panko, Benl. Smithsonian.com 01 Feb 2017. "Can Eagle-Eyed Artificial Intelligence Help Prevent Children From Going Blind?" https://www.smithsonianmag.com/science-nature/eagle-eyed-ai-doctor-could-nip-cataracts-bud-180961993/
Raina, Amit. "Journal of Opthalmology & Visual Neurosciences." 01 Feb 2016. scientonline.org/open-access/a-clinical-study-of-congenital-cataract.pdf
Yirka, Bob. Tech Xplore. 31 Jan 2017. https://techxplore.com/news/2017-01-convolutional-neural-network-rare-eye.html
Zhu, J.F. PubMed. Oct 2012. https://www.ncbi.nlm.nih.gov/pubmed/23075719/

18. Case Study: From Virtual to Real Gender Equality

Addresses SDG 4:
SDG 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities.

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The goal of the "Half the Sky Movement" is to develop mobile phone simulation games to raise awareness of the general audience regarding issues that women and girls are facing. In addition, the game helps women in developing countries empower themselves. In 2012, Game developer Mudlark was supported by USAID to develop three small games, called 9 minutes, Worm Attack!, and Family Values. In 9 Minutes women and girls play out the adventure of pregnancy in a game that rewards them for keeping both mother-to-be and the baby inside her healthy and happy. Players learn the principles of managing a healthy and successful pregnancy, compressing the nine-month process into a short game experience. Worm Attack! is aimed at children 7 and older. Players are tasked with keeping a growing number of boys and girls healthy by defeating the worms inside their tummies. They will gain awareness of the dangers of intestinal worms and learn about the simple de-worming solution that has had an incredible impact on children's health and education. The game Family Values is an interactive "soap opera" with dramatic elements. The interaction aims at enhancing the perception of a girl's value to a family, with an emphasis on extending girls' education, as opposed to child labor or early marriage. Initially, the mobile phone simulation game was distributed to India, Kenya, and Tanzania in late 2012, but in an alliance among Frima Studio, the Ford Foundation, Zynga.org, and Intel Corporation it was brought and spread to a wider audience through Facebook. With the high diffusion rate of cell phones in developing countries, women can access the simulation game on their phones. On the other hand, embedding the simulation game on Facebook is an ideal way to spread ideas and raise awareness of gender equality. Different from traditional "problem and solution" type of editorials, the computer simulation provides a platform to help people interact with real-world causes and challenges, expand players' horizon, and explore different possibilities.

Sources:
Half the Sky: Turning Oppression Into Opportunity for Women Worldwide. (n.d.). Retrieved September 2, 2016, from http://www.halftheskymovement.org/pages/mobile-games
Play | Half the Sky Movement: The Game | Games for Change. (n.d.). Retrieved from http://www.gamesforchange.org/play/half-the-sky-movement-the-game/
Half The Sky: Games For Change In The Developing World. (2011, December 28). Retrieved September 2, 2016, from https://www.fastcoexist.com/1679056/half-the-sky-games-for-change-in-the-developing-world
Mobile games teach women and children vital survival skills. (2013, August 11). Retrieved September 2, 2016, from http://designtoimprovelife.dk/half-the-sky-mobile-games/

19. Case Study: Giuseppe, plant-based replacements of animal-based food products.

Addresses SDG 2 and 12
SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG 12.2: By 2030, achieve the sustainable management and efficient use of natural resources

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NotCo is a technology-based company that uses artificial intelligence (AI) to develop plant-based foods for human consumption. Their company intends to use plants to create the same taste of animal-based food products, such as milk, cheese, yogurt, mousse, and their flagship mayonnaise product. Minimizing the meat industry allow us to waste less land, water, and other resources on the plants that we grow to feed the animals; we can also combat other negative effects of animal agriculture, such as global warming, greenhouse gas emissions, deforestation, and desertification.
NotCo developed an artificial intelligence program called Giuseppe, which uses and replicates the molecular composition of animal-based foods to determine which vegetables would create a food with similar taste, texture, and even smell. Not Mayo is made mostly from basil, peas, potatoes, and canola oil, instead of eggs and canola oil, but has a taste and texture almost exactly like normal mayonnaise. Additionally, according to Al Jazeera's report, NotCo's Not Milk, created from mushrooms and seeds, is sweeter and creamier than milk, while having the same nutrients, but with fewer calories and at a lower cost than alternative milks.
Besides creating food products, Giuseppe's AI technology is also being used to determine the optimal balance between resource availability, energy use, land use, and nutrition. One of the NotCo team's goals is to use AI to eradicate the animal livestock industry and switch to plant-based foods that can be locally grown. NotCo's low-price food products could be the solution to feeding the millions of malnourished people around the world, as well as providing jobs for local farmers, who would grow the plants needed for NotCo recipes.

Sources:
"Beyond meat: The end of food as we know it?" Youtube. 03 June 2017. http://www.aljazeera.com/programmes/talktojazeera/2016/02/meat-artificial-food-160205152233913.html
Brodwin, Erin. "An eggless mayostartup is out to beat Hampton Creek - here's the verdict." Business Insider. 16 September 2017. www.businessinsider.com/eggless-mayo-startup-out-to-beat-hampton-creek-taste-test-2017-9
Mok, Kimberley. "Scientists using artificial intelligence to develop tastier vegan foods." *Narrative Content Group*, Treehugger. 27 April 2016, https://www.treehugger.com/gadgets/giuseppe-ai-creating-vegan-vegetarian-food-not-company.html
O'Brien, Rosalba. "Chilean start-up that uses AI to reinvent food eyes U.S. deals." Reuters. 05 December 2016. https://www.reuters.com/article/us-chile-tech/chilean-start-up-that-uses-ai-to-reinvent-food-eyes-u-s-deals-idUSKBN13U2SV

20. Case Study: Sustainable roadwork

Addresses SDG 11:
11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

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AI can be used to help improve road safety in a number of ways. In an article about AI and the road construction industry, The Mercury News cited three ways Contra Costa County has worked to improve the road construction and maintenance industry (Baldassari, 2017). Drones are being used for a number of tasks that are traditionally time consuming, expensive, and even potentially dangerous (Baldassari, 2017). Such tasks may include surveying construction sites and performing inspections on poles or bridges. While increasing efficiency these companies are also improving road safety, both for their workers and also for the general public, as drones are often able to capture images of potential problems far sooner than individuals (Baldassari, 2017). This addresses SDG 11, which aims to improve road safety, while also providing greater safety for those tasked with improving roads.

SDG 11 is further supported by RoadBotics, a program that uses car-mounted cellphone cameras to snap photos of street conditions to create color-coded maps showing which roads are in good condition, which need monitoring, and which are in need of immediate repair (Baldassari, 2017). The company's goal is to make it easier to manage and monitor road conditions thereby maintaining safety standards.

AI can be used to not only maintain existing safety standards, but also to implement new standards. Brisk Synergies is using cameras and AI software to see how the design of a road influences the way drivers behave (Baldassari, 2017). Cameras installed monitor how cars, cyclists, and pedestrians move through intersections and identify why drivers might be speeding at particular places (Baldassari, 2017). Having a better understanding of driver behavior can help establish important safety standards.

Sources:
Baldassari, E. (2017, July 26). Roadwork gets techie: Drones, artificial intelligence creep into the road construction industry. http://www.mercurynews.com/2017/07/26/roadwork-gets-techie-drones-artificial-intelligence-creep-into-the-road-construction-industry/
Chisling, A. (2017, September 11). 8 ways AI is helping industries today. https://blog.rossintelligence.com/8-ways-ai-is-helping-industries-today-1ff22619433a?wpnd_cid=6cea5b9736793ff8

21. Case Study: Sustainability for oceans, seas and marine resources.

Addresses SDG 14:
14.1 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
14.2 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
14.3 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

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Pollution and over-development has caused much of our ocean, seas, and marine resources to dwindle and in some cases, cease to exist. Extrapolating the capabilities of AI can be useful in gathering data to implement "science-based management plans" that cities, towns, states, and eventually national and global governments can utilize and roll out on a large scale basis. This is in line with the SDG goal 14.1. A lot of the ocean's wildlife exists on a precious and extremely fragile food chain that can easily be disrupted and cause havoc throughout the entire ecosystem.

Intel is looking to combat the fragility of the marine ecosystem by collaborating with Marine Biologist Iain Kerr and his company Ocean Alliance. This collaboration will "leverage the power of hi-end drones capable of gathering data from whales" (Inquisitr). The team will utilize a drone called "SnotBot", that will then capture images of whales and collect the actual snot of whales that exits their blowholes when they surface to breathe. While this may seem peculiar, "that blow is rich with biological data stemming from DNA, stress hormones, pregnancy hormones, viruses, bacteria, and toxins. The SnotBot then relays collected samples to researchers on boats that are a comfortable distance away from the whales" (Griffin, Intel Corporation). The "SnotBot" serves as a solid technological innovation that can help humans understand a lot more about one of the ocean's most mysterious creatures. Whales on an average travel 3200 miles in a year, which is one of the longest migratory patterns of any mammal on earth, according to whale migration research conducted by the NSW National Parks. This means that they are unknowingly collecting a lot of data from oceans all across the globe. The data gathered by these whales could provide much insight on the current situation and the current mysteries of the oceans around us. They can also give insight on the environmental and pollution damage that has occurred thus far. This is in line with SDG 14.1 in that this data will be fundamental in deciding what areas of the oceans and coastal areas need priority conservation efforts and " Furthermore, the SnotBot eliminates any need for killing of whales in the name of "research"; a ploy that has been instituted everywhere by the country of Japan. Japan maintains to this day that "although the Scientific Committee (SC) of the IWC attempted to provides expert assessment of national research plans, the nations carrying out scientific whaling, especially Japan, still use scientific whaling as an alibi for their excess in whaling" (Gales, pgs. 883–884). The SnotBot can assist and eliminate the alibi for "whaling for research" as it provides an alternative platform to gather data and implement solutions. This aligns with SDG Goal 14.2, specifically the "destructive fishing practices" inititice within the goal. By protecting these mysterious marine creatures, we can take one huge step to demystifying the oceanic ecosystem and revert some of the damage that was done.

Another integration of AI and Ocean sustainability can be seen in the work Boeing's Liquid Robotics Company, which proposes a sort of "Digital Ocean". Gary Gysin writes, "The ocean covers more than 70% of the Earth’s surface, but only a tiny fraction of it has been explored. Imagine a networked ocean connecting billions of sensors, manned and unmanned systems, and satellites above. A place where data is available on demand, around the clock" (Gysin, Digital Ocean). He points out many different oceanic problems today, such as "One in five fish brought to market is caught illegally, costing the global economy up to $23.5B annually worldwide--In the Digital Ocean, we can crack down on illegal fishing and recoup those losses" (Gysin, Digital Ocean). Another example is the work of Dr. Amanda Hodgson from Murdoch University in Western Australia, who aims to use drones to track an endangered sea animal called the Dugong. Both of these projects align with the SDG goals of 14.3, in that restoring coastal and marine areas are benefited by saving endangered animals, especially when we do not know the catastrophic effect of an animal leaving the oceanic food chain.

Computational science, modeling, and artificial intelligence are vastly being utilized in order to beat the clock against oceanic destruction. The Artificial Intelligence for Ecosystem Services, or ARIES, is a consortium of individuals solely interested in leveraging complex technology to solve our Earth's ever-present problems. The study notes, "ARIES provides an intelligent modeling platform capable of composing complex ecosystem services models from a collection of models specified by the user". The report and the model implemented findings across the global ecosystem, including data on Carbon, floods, water supply, sediments and coastal floods. "Societal dependence on subsistence fisheries, combined with the recognition that the world’s oceans are in crisis due to overfishing, pollution, and climate change (Diaz and Rosenberg 2008, Cooley and Doney 2009, Worm et al. 2009, Hoegh-Guldberg and Bruno 2010) strongly argues the case for more sustainable management of aquatic and marine resources" (ARIES, pg. 59). This issue coincides with the SDG goal 14.2, to effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing. The ARIES model can be utilized "by mapping societal dependence on subsistence fisheries, we can demonstrate direct linkages between ecosystems and human well-being. In addition, by linking flows of sediment, nutrients, and fresh water from land into the coastal zone, the complex tradeoffs between land management choices and provision of coastal and marine ecosystem services can be illuminated, (ARIES, pg. 59).

Sources:
Gales, Nicholas; Toshio, Kasuya; Robert, Brownell (16 June 2005). "Japan's Whaling Plan under Scrutiny". *Nature*. 435: 883–884.
Eade and Moran 1996, Chan et al. 2006, RaudseppHearne et al. 2010

Whales, Wild About. “Whale Migration.” *Wild About Whales | NSW National Parks*, www.wildaboutwhales.com.au/whale-facts/about-whales/whale-migration.
Nippon Foundation-Nereus Program. “Restored Ocean Will Alleviate Poverty, Provide Jobs, and Improve Health, Finds Report.” *ScienceDaily*, ScienceDaily, 31 May 2017, www.sciencedaily.com/releases/2017/05/170531133326.htm
Bagstad, K.J., Villa, F., Johnson, G.W., and Voigt, B. 2011. ARIES – Artificial Intelligence for Ecosystem Services: A guide to models and data, version 1.0. ARIES report series n.1.

22. Case Study: Climate Action

Addresses SDG 15:
15.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
15.2 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
15.3 Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

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Climate change is affecting every country on every continent. It uproots wildlife, vegetation, entire ecosystems, atmospheric layers, and of course human beings and national economics. Today the impact of climate change can be seen in every corner of the world—what began as polar ice caps melting can now be added on the list to forest fires, lack of rain, lack of a winter despite it being January, animals dying off, and much worse. Climate change is manifesting itself in front of our very own eyes and a scalable solution has yet to be put into motion.

Implementing the large-scale spread of artificial intelligence could be one potential hack to learning more about the disastrous effects of global warming and climate change, which could then give a view on how to combat and reverse it, and what policies need to be set on a global and national scale in order to further educate the masses and prevent further damage for the future. Erin Biba from GreenBiz notes, “One place machine learning is turning out to be the most beneficial is in the environmental sciences, which have generated huge amounts of information from monitoring Earth’s various systems” (Biba, Greenbiz). The National Science Foundation has found a way to integrate big data and the health of the Earth as a whole, in a product they like to call “EarthCube”. EarthCube is a 3-D living model of the entire planet that depicts every layer of the earth, every solid, gas and liquid that forms to create atmospheric levels, bodies of water, tectonic plates beneath the surface, and a whole mixing pot of other interactions that take place above, below, and on the Earth. This 3D model has “whole slew of disciplines — measurements of the atmosphere and hydrosphere or the geochemistry of the oceans, for example — to mimic conditions on, above and below the surface”, and will prove very valuable to monitor the conditions of the Earth as a whole as climate change begins to increase and its effects begin to externalize. How does the EarthCube plan to do this? Sky Bristol, the branch chief of biogeographic characterization at USGS and USGS team lead for the EarthCube Digital Crust project, notes, “Machine learning also comes in to play when two models from different parts of the cube (such as the crust and the atmosphere) have to interact with each other, for example, what does it look like when there’s an increase in groundwater extraction and an increase in the warming climate at the same time?” Artificial intelligence and machine learning can be used in this geosciences context to fulfill SDG goal 15.1, by providing a firm, data backed mechanism to fuel UN Policy, Government and State Legislations. Much of the backlash from climate change skeptics stem from the fact that there is conflicting theory and data out there that do not match what we can actively see and feel. By creating a physical model that can depict these potential changes and outline where we need to improve, we are more likely to create a stronger case for better policy.

Furthermore, EarthCube's functionality spreads to disaster prevention and relief. This satisfies the SDG 15.1, adaptive capacity to climate-related hazards and natural disasters in all countries. EarthCube will be able to "model different conditions and predict how the planet's systems will respond. With that information, scientists will be able to suggest ways to avoid catastrophic events or simply plan for those that can't be avoided (such as flooding or rough weather) before they happen" (GreenBiz). With so many different data feeds of tectonic plates, wind movements, forest fires, and floods all in one model, disasters can be prevented or at least individuals in an affected area can be warned ahead of time to facilitate evacuation and minimize damage. At the very least, this technology will provide us with more information about the carbon footprint we've left on the Earth and how we can go about fixing it, rather than inflicting more harm.

Sources:
Berg-Cross, G., Cruz, I. F., Dean, M., Finin, T., Gahegan, M., Hitzler, P., Hau, H., Janowicz, K., Li, N., Murphy, P., Nordgren, B., Obrst, L., Schildhauer, M., Sheth, A. P., Sinha, K., Thessen, A., Wiegand, N., & Zaslavasky, I. (2012). Semantics and Ontologies for EarthCube. https://corescholar.libraries.wright.edu/knoesis/179
https://earthcube.org/
Biba, Erin. "3 Ways Artificial Intelligence Will Save the Day." GreenBiz, GreenBiz Group Inc., 27 June 2016, www.greenbiz.com/article/artificial-intelligence-knight-shining-armor.
Richard, S. M., G. Pearthree, A. K. Aufdenkampe, J. Cutcher-Gershenfeld, M. Daniels, B. Gomez, D. Kinkade and G. Percivall (2014), Community-Developed Geoscience Cyberinfrastructure, Eos Trans. AGU, 95(20), 165.
Yang, Chaowei. "Redefining the Possibility of Digital Earth and Geosciences with Spatial Cloud Computing." International Journal of Digital Earth, www.tandfonline.com/doi/citedby/10.1080/17538947.2013.769783?scroll=top&needAccess=true.

23. Case Study: Cardiovascular Health

Addresses SDG 3
SDG 3.D Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks.

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A prospective cohort of 378,256 patients from UK family practices (derived from the Clinical Patient Data Link) have been studied by Stephen Wang, an epidemiologist at University of Nottingham, U.K. and his colleagues over the course of 10 years. All patients were free from cardiovascular disease at outset of the study. Their data was tested again four new machine-learning algorithms: random forest, logistic regression, gradient boosting machines, and neural networks. The data was then compared to an algorithm established by the American College of Cardiology guidelines to predict first cardiovascular event over 10 years. 24,970 incident cardiovascular events (6.6%) occurred over the period of the study. Compared to the established risk prediction algorithm, machine-learning algorithms improved prediction. The best/most accurate algorithm of the four (neural networks) predicted 4,998/7,404 cases and 53,458/75,585 non-cases , correctly predicting 7.6% more patients who developed cardiovascular disease compared to the previously established algorithm.

Sources:
Hutson, Matthew, “Self-Taught Artificial Intelligence Beats...”Science Magazine, 26 July 2017, www.sciencemag.org/news/2017/04/self-taught-artificial-intelligence-beats-doctors-predicting-heart-attacks.
Rayner, Emma. “Artificial Intelligence Can Accurately Predict Future Heart Disease and Strokes, Study Finds.” News and Articles on Science and Technology, Phys.org, 26 Apr. 2017, phys.org/news/2017-04-artificial-intelligence-accurately-future-heart.html.
Weng, Stephen F., et al. “Can Machine-Learning Improve Cardiovascular Risk Prediction Using Routine Clinical Data?” PLoS ONE, Public Library of Science, 4 Apr. 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5380334/.

24. Case Study: Predicting breast cancer and reduce surgical procedures.

Addresses SDG 3
SDG 3.D Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks.

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Every year 40,000 women die from breast cancer in the U.S. alone. Mammograms are the best test available to catch it early (with the greatest chance of being cured), but despite this, they often result in false positive results that can lead to unnecessary biopsies and surgeries. False positives are often caused by "high-risk" lesions -- those which appear suspicious on mammograms and have abnormal cells when tested by needle biopsy. With this variety of false positive, the patient typically undergoes surgery to have the lesion removed; however, the lesions turn out to be benign at surgery 90 percent of the time. To eliminate unnecessary invasive surgeries while still maintaining the role of the mammogram in cancer detection, researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL), Massachusetts General Hospital, and Harvard Medical School have applied artificial intelligence. The teams collaborated to develop an AI system that uses machine learning to predict if a high-risk lesion identified on needle biopsy after a mammogram will upgrade to cancer at surgery.

The technology is trained on information about over 600 existing high-risk lesions, and looks for patterns among many different data elements, including but not limited to demographics, family history, past biopsies, and pathology reports. Using a method known as a "random-forest classifier," the model resulted in fewer unnecessary surgeries and was able to diagnose more cancerous lesions as compared to the typical practice of only doing surgery on traditional "high-risk lesions." When tested on 335 high-risk lesions, the model correctly diagnosed 97 percent of the breast cancers as malignant and reduced the number of benign surgeries by more than 30 percent compared to existing approaches.

Sources
http://news.mit.edu/2017/artificial-intelligence-early-breast-cancer-detection-1017
http://pubs.rsna.org/doi/abs/10.1148/radiol.2017170549
https://www.rdmag.com/article/2017/10/machine-learning-used-improve-breast-cancer-detection
http://www.bbc.com/news/technology-41651839