RADBOUD UNIVERSITY NIJMEGEN

THE FUTURE OF HEALTH

Applications of Artificial Intelligence for the HIV Epidemic in Developing Countries

Luka Čupić

Nijmegen, October 2019.

1. Introduction

Human immunodeficiency virus (HIV) is a retrovirus that attacks and progressively damages the human immune system. It is transmitted through several bodily fluids, namely: blood, semen, vaginal fluids, and breast milk. If left untreated, HIV-infected individuals develop a very serious condition called acquired immune deficiency syndrome (AIDS). This usually happens within a decade, with an estimated net survival time of 9 to 11 years after the initial infection [12].

Currently, there is no cure for HIV. This simple yet bitter fact tells us that anytime somebody contracts the virus, it stays with them for life.[1] To a person living in the first-world countries, this doesn't pose a life-threatening problem because of the highly active antiretroviral therapy (HAART), which is both greatly available to HIV patients and highly effective in reducing plasma levels of HIV RNA [5]. To a person living in developing countries, however, the reality could not be more different. It is an estimation of the The World Health Organization (WHO) that by the end of 1997, out of 30.6 million people living with HIV over 90% of them were living in developing countries [4]. Due to high poverty and low socio-economic status of such countries, a great majority of HIV patients living there have no practical means of being treated. All of this show us not only the miserable circumstances in which these people live, but also reflects much deeper problems with our society that stem from centuries-old geopolitical issues.

Another problem with HIV is that its high genetic variability makes it extremely difficult to "keep up" with the virus and develop antibody-based drugs. In other words, it evolves and mutates too fast. In the next chapter, we will also explore some ways in which such problems can be tackled.

One promising area that has the potential to provide major insights and potentially solve previously described problems is artificial intelligence. Advancements of AI (as

[1] Except in exceptionally rare cases where (so far two) individuals have in fact been cured of HIV (`https://www.nytimes.com/2019/03/04/health/aids-cure-london-patient.html`)

well as technology in general) in the last several decades have been astonishing. We have now reached a point where we are able to solve problems and perform tasks that could have seemed impossible just one or two generations ago. Let us briefly consider the example of IBM Watson – a system that contains a large knowledge base and works on the principle on question-answering by understanding natural language. Even though still not perfectly capable of giving very accurate medical diagnosis, Watson is a giant leap forward in the domains of medicine and artificial intelligence.

However, it is not a secret that artificial intelligence is currently being used mostly for commercial purposes in the private sector. Applications in areas such as recommender systems, media marketing, advertisements, and so on, are the main focus point of today's commercially-fueled world because in those areas, (proper) use of technology increases profit. Therefore, the applications in public sector, and especially in non-profit domain, remain considerably lower. Despite this, there are currently many non-governmental organizations fully dedicated to solving the HIV problem. One such organization is Aidsfonds – Soa Aids Nederland, a Dutch organization that aims to end AIDS before 2030.

Considering the global implications of HIV and the potential of artificial intelligence, the rest of this research plan will provide some examples on how AI could be used in dealing with HIV.

2. Potential Applications of Artificial Intelligence

In this chapter, we will focus on several subsets of artificial intelligence that are among the most promising ones to see what kind of implications they could have in dealing with the HIV problematic. There could be several potential applications, greatly differing in terms of complexity (i.e. how difficult would it be to solve a certain kind of problem) and usability (i.e. how simple would it be to actually start applying a solution on real-world problems).

2.1. Machine Learning

Arguably, the first thing that comes to mind in the context of artificial intelligence is machine learning. In recent years it has gotten so much attention because of its ubiquitous use in everything from electric vehicles to producing a motion picture trailer[1] that it became sort of a synonym for AI [10]; however, there is a major difference. Machine learning is a subset of artificial intelligence which aims to automate data analysis by using algorithms that identify patterns in data and subsequently learn from them [11].

There are several ways in which machine learning can be used when dealing with HIV. One potential use would be constructing a model capable of predicting the spread of the virus, which is exactly what Marcus et. al. did in July of 2019 when they showed that their prediction models can identify patients at high risk of acquiring HIV and initiate them to start with prevention medications, i.e. pre-exposure prophylaxis (PrEP) [5]. Such a system could have tremendous implications since PrEP has been shown to reduce the risk of contracting HIV by 99% when used properly [2]. This means that such a system could be used to (i) target those individuals with a high risk of contracting the illness, and (ii) put them on prevention medications, greatly

[1] This was actually done by IBM Watson in 2016. (ref needed)

decreasing the number of new infections.

The problem is that such a system would only be beneficial to people living in those countries which have both approved the treatment and are able to provide access to it for their citizens. Another problem is pricing: data from 2012 shows that PrEP medication costs between $8,000 and $12,000 per year [7]. Such a price is unimaginable for certain developing countries which have trouble providing people with even the simplest human needs, such as food or shelter.

However, this kind of research seems very promising and hopefully it will have larger implications in the future.

2.2. Deep Learning

As mentioned in the previous chapter, HIV's mutability is one of the reasons why developing vaccinations has proved to be so difficult. Currently, we have no means of constructing a system capable of tracking the virus and its constant evolution. However, it is possible that in the not-so-distant future, we will have computer systems powerful enough to be able to track the virus in real-time and evolve with the virus itself. This could make vaccinations much more probable because we would have new insights and knowledge about the virus. Deep learning is one promising area that could be a part of the puzzle because it has hitherto been able to provide solutions for difficult problems and discover complex patterns, due to its unique structure. It is natural to assume, therefore, that by combining deep learning and virology, we could be able to gain deeper knowledge of the HIV virus and its evolution.

2.3. Expert Systems

Mentioned briefly in the previous chapter, expert systems are programs with expert knowledge built into them. This is typically done with a collaboration of the developer team and an expert or a team of experts in the domain for which the system is being built. In our case, the expert would be a medical professional specializing in treatment, diagnosis, or research on the topic of the HIV virus.

In fact one such system has started with the development in early 2010; authors Masizana et. al. have proposed building an expert system to provide information on HIV and AIDS to the public of Botswana, one of the leading countries in the HIV/AIDS pandemic [6]. They conclude that the system was "found to be a good system to sup-

port the public with timely information on HIV and AIDS." What exactly is meant by this remains unclear, but the very fact that such a system already exists and has reached some (even marginal) levels of success shows not only that such applications are currently possible, but also effective in the real world.

2.4. Natural Language Processing

Natural language processing (NLP) is a specific subset of artificial intelligence that focuses on extracting information from human-readable text and providing computers with means of understanding it. It is closely related to linguistics because some approaches use various analysis, such as syntax or semantic, to determine formal features of a text.

With an explosion of (textual) data being collected in the recent years, it is only a matter of creativity in using this data for various (research) purposes. Applications of NLP may range anywhere from personality prediction on social networks to ranking tweets by their humorousness [3] [14].

In the context of HIV, however, one interesting research question was tackled by Young et. al. in 2018 [13]. They wanted to see if NLP could be used to extract information from communicated sexual behaviours on social media in real-time. Doing this could enable better prevention by targeting those geographical regions in which an increase in sexual- or HIV-related conversations has recently been observed.

This kind of research still has the largest implications in developed countries in which the smartphone penetration has been the highest. However, as mobile phones (and especially smartphones) are becoming cheaper and cheaper every year, there is a global trend in which more and more people from developing countries are now owning a smartphone [8]. Considering this, such applications might still be of much relevance in the upcoming years and decades.

3. Conclusion

This internship proposal has so far explained the ongoing problem of both new and existing HIV infections in developing countries. Several areas of artificial intelligence have the potential to offer major insights and ideally assist in solving these problems, so further research in the context of the internship would be to deeper explore these areas. For instance, with recent advancements of computing power machine learning, deep learning, and big data have become ubiquitous in the world of technology. Collecting large amounts of data from people's phones, social media profiles, etc. could be beneficial to developing systems aimed at (geolocational) prevention of HIV. Furthermore, using technologies such as mobile phones, social media, etc. can be very useful in providing people with accurate HIV-related information, otherwise unavailable to them in their own countries for political, infrastructural, or economic reasons.

In terms of potential host organizations, further research in this domain would best be done in a non-governmental/non-profit organization focused on contributing to global health and stopping the spread of HIV, among other infections. One such organization is already mentioned Dutch-based Aidsfonds, intending to end AIDS by 2030. Thus, a collaboration with such an organization in the domain of artificial intelligence could be a great way of doing this type of research because of their devotion and global contribution of saving lives.

Further work on this topic will be done in the research project by (i) analyzing the evolution of HIV in developing countries and the subsequent response by health organizations (both regionally and globally); (ii) looking into how the poor conditions in such countries contributed to our inability to provide their citizens with adequate medical; and (iii) addressing these problems from the perspective of artificial intelligence in an attempt to find potential solutions for better handling of the HIV situation in developing countries.

4. Bibliography

[1] J. C. et. al. Effectiveness of highly active antiretroviral therapy in reducing heterosexual transmission of HIV. https://www.ncbi.nlm.nih.gov/m/pubmed/16123689/, 2005.

[2] C. for Disease Control and Prevention. Effectiveness of Prevention Strategies to Reduce the Risk of Acquiring or Transmitting HIV . https://www.cdc.gov/hiv/risk/estimates/preventionstrategies.html, 2019.

[3] M. Gjurković and J. Šnajder. Reddit: A Gold Mine for Personality Prediction. https://www.aclweb.org/anthology/W18-1112/, February 2014.

[4] A. D. Grant and K. M. D. Cock. The growing challenge of HIV/AIDS in developing countries. https://pdfs.semanticscholar.org/c116/71917719ef4c66d22a270fd42dfc344d5a25.pdf, 1998.

[5] J. L. Marcus, L. B. Hurley, D. S. Krakower, S. Alexeeff, M. J. Silverberg, and J. E. Volk. Use of electronic health record data and machine learning to identify candidates for HIV pre-exposure prophylaxis: a modelling study. https://www.thelancet.com/journals/lanhiv/article/PIIS2352-3018(19)30137-7/fulltext, 2010.

[6] A. Masizana-Katongo, L. T, and M. D. Building an Expert System for HIV and Aids Information. https://link.springer.com/chapter/10.1007/978-90-481-8776-8_28, 2010.

[7] N. Y. H. D. of Health. Pre-Exposure Prophylaxis (PrEP) to Prevent HIV Infection: Questions and Answers. https://www.health.ny.gov/publications/0265/, December 2012.

[8] J. Poushter, C. Bishop, and H. Chwe. Smartphone ownership on the rise in emerging economies. https:

//www.pewresearch.org/global/2018/06/19/2-smartphone-ownership-on-the-rise-in-emerging-economies/, June 2018.

[9] A. Sharon. Thailand govt to use AI to help lower HIV infection rate. https://www.opengovasia.com/thailand-govt-to-use-ai-to-help-lower-hiv-infection-rate/, February 2019.

[10] J. R. Smith. IBM Research Takes Watson to Hollywood with the First "Cognitive Movie Trailer". https://www.ibm.com/blogs/think/2016/08/cognitive-movie-trailer/, 2010.

[11] B. Wahl, A. Cossy-Gantner, S. Germann, and N. R. Schwalbe. Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings? https://gh.bmj.com/content/3/4/e000798, 2018.

[12] U. . WHO. AIDS epidemic update. http://data.unaids.org/pub/epislides/2007/2007_epiupdate_en.pdf, December 2007.

[13] S. D. Young, C. Rivers, and B. Lewis. Methods of using real-time social media technologies for detection and remote monitoring of HIV outcomes. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4031268/, February 2014.

[14] L. Čupić, V. Kašljević, and I. Smoković. Comparison of Classification- and Regression-Based Approaches for Humor Ranking on a #HashtagWars Twitter Dataset. https://www.fer.unizg.hr/_download/repository/TAR-2019-ProjectReports.pdf, October 2019.