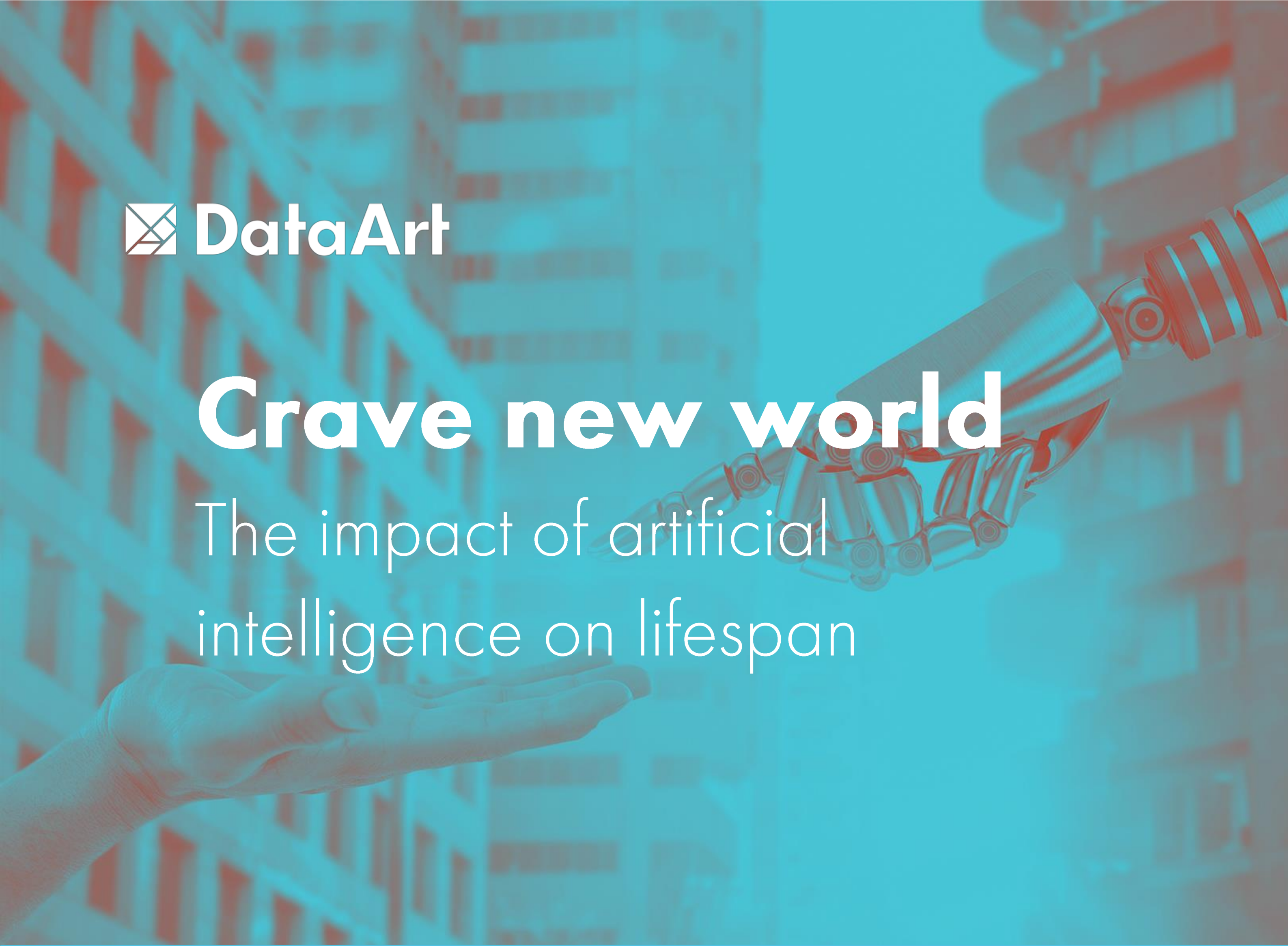

DataArt

Crave new world

The impact of artificial intelligence on lifespan

White Paper

Anton Dolgikh, Head of AI, Europe, DataArt

Dmitry Bubelnik, AI Research Scientist, Europe, DataArt

October 2019

www.dataart.com

Contents

Contents 1
1. Summary 2
2. Background 2
3. How age is determined 3
4. AI brings a new perspective 4
5. Getting rid of disease 5
6. The ageing dilemma 6
7. Is living longer actually desirable? Who will benefit? 6
8. Caveat Emptor – what we must be wary of? 8
9. Another path? 9
10. Conclusion 9
11. The Authors 10
12. References 11

1. Summary

For thousands of years human beings have been looking for ways to ward off the ravages of age, extend lifespan and improve later years. The arrival of artificial intelligence (AI) brings new hope for the future. What can AI do to stimulate ageing research? What will its limitations be, and is it even desirable to increase lifespan? We must be cautious when seeking to change the norms of human lifespan.

2. Background

A healthy diet, physical activity, a good night's sleep, no smoking – these are well known though tedious guidelines for longer life. Statistics show that those factors can prolong life up to 80-90 years on average, which is higher than the old standard "threescore years and ten" by a good ten to twenty years.

Unfortunately, a healthy diet alone is not a panacea against age-related diseases. The severity and ubiquity of these diseases drastically increase mortality among those above middle age. The famous Gompertz Law[1] expresses the relationship between mortality and age, which, upon an interpretation, leads us to the conclusion that the probability of dying during a given year doubles every eight years.

Analysis of current research activity in the field of biogerontology reveals two directions going through the most intense evolution, namely the increasing of lifespan and the increasing of healthspan. They've gone from solely employing classical biological approaches to supporting and reinforcing them with artificial intelligence to extract meaning from the deposits of ambiguous data produced by a cornucopia of disparate experimental sources.

Since the dawn of time, humans have sought to live longer. Now, we live longer (see *Figure 1*) than ever before, and AI is likely to steepen the trend of life expectancy even more, but what will we do with this "progress"?

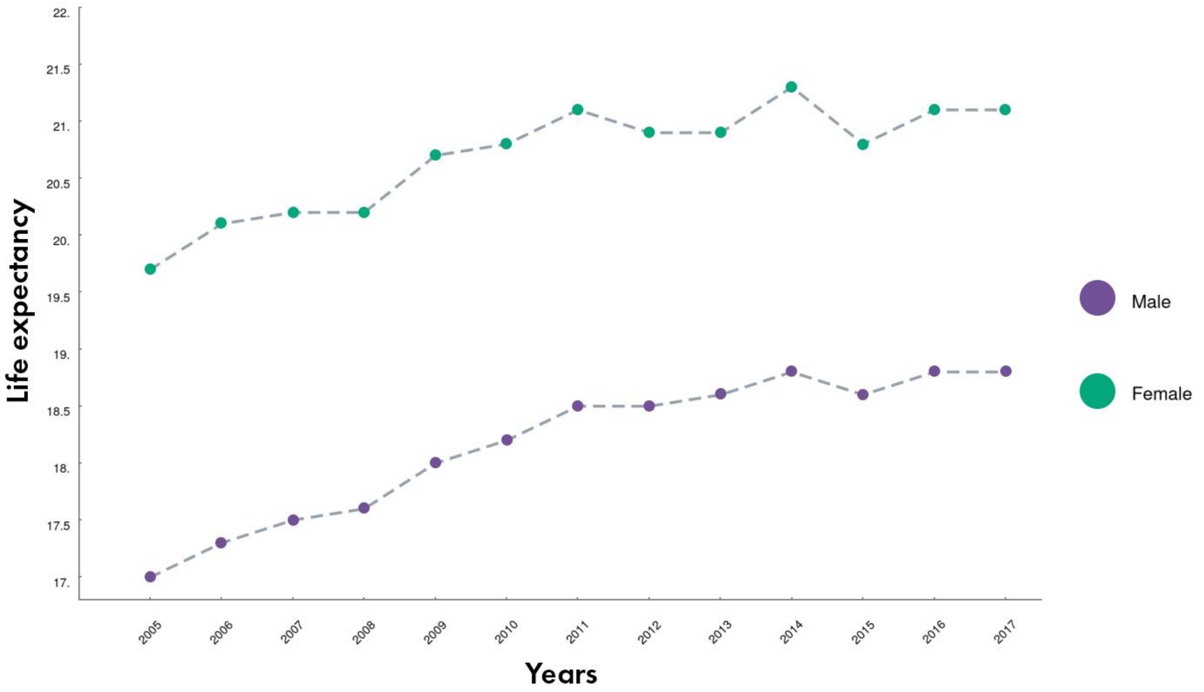

Figure 1: Life expectancy at age 65 by sex. Subset of data corresponding to United Kingdom is taken from https://ec.europa.eu/eurostat/web/health/data/main-tables.

3. How age is determined

To understand "lifespan", we must comprehend "age" in the first place.

There are two types of age — biological and chronological — and the difference is better understood with an example. We can say that a typical lifespan of a human being is 70 years, thus defining chronological expectancy of life, but the fact of import is that different people of the same age have different death odds because of various health statuses, the totality of which can be understood as biological age of a person. It means that chronological seventy-year-olds might be twenty years younger or older in terms of biological age.

The currently accepted approach to estimate a biological age is to use biomarkers. The biomarkers for biological age change over time and inform health status. Nowadays the most reliable and established biomarkers are telomere length, circulating proteins, DNA methylation, carbamylation, glycosylation, circulating proteins and markers of cellular senescence[2].

Biomarkers are equivocal when it comes to age estimation: judging by one biomarker, a person could be younger whereas according to another, older than their actual age. It means that to use a single marker for biological age is to get an estimation which may be way off. It is, nevertheless, possible to obtain a more precise estimate by constructing models incorporating all biomarkers. The well-developed multivariate statistical analysis works surprisingly well given meaningful observations[3] — the approach based on linear regression[4] has proved biological age to be a more reliable predictor of mortality than the chronological one.

However, science is evolving, and now AI is here to support natural intelligence in advancing medicine a step further towards a better understanding of age.

4. AI brings a new perspective

Lionized and portrayed by many mass-media as a game-changer AI appeared on a field of healthcare almost five decades ago. Presently the term is somewhat overused which leads to overblown expectations among decision-makers, but in this article, we speak about AI in a more traditional sense as a discipline that encompasses several knowledge areas with machine learning (ML) being among them. ML puts mathematical statistics, optimization theory and other good old mathematical disciplines into practice to detect hidden patterns in data. This combination of established disciplines is exactly the toolbox needed for age-related biological research because the data are so complex, diverse, and heterogeneous that the task of modelling seems almost intractable. AI promises to become a vital clue to the maze of biological data that stores within itself the precious secret of biological age.

In applied research, AI is thought of operationally and is oft identified with a specific machine learning method. Inspired by biological neural networks, artificial neural network (ANN) as of now, is the most prevalent of the models as they are the key component of what is called deep artificial neural networks. Deep neural networks form a frame of deep learning which supposedly is the most AI-like contemporary instrument[5,6] indisputably powerful, yet lacking the interpretability of time-honoured methods like linear regression. In 2016 Putin *et al.*[7] achieved impressive accuracy in predicting chronological age by a single blood test using an ensemble of 21 deep neural networks of varying depth. The best mean absolute error they observed was 5.5 years.

Blood biochemistry and genomic data are not the only predictors of chronological age. In 2018 Bobrov et al.[8] proposed to use high-resolution photos of eye corners area as an age predicting marker because a corner of an eye has the wrinkles imprinted by the weight of the years passed. The authors fed photos to neural networks which are known to have extraordinary performance in image analysis tasks. The method demonstrated an impressive performance: the mean absolute error is 2.3 year (though depends on image quality) that is an algorithm predicts the age which belongs to interval “true chronological age plus-minus 2.3 years.” In all the cases mentioned above, deep neural networks (the most AI-like approach) demonstrated the best predictive power.

5. Getting rid of disease

With Gems' statement[9] about ageing being a pathological process in mind, we begin to understand why it justifies the researchers' goal of slowing ageing down, or even preventing it altogether. Although no geroprotective therapy to remedy ageing exists, it is possible to develop effective geroprotective interventions. For example, one of the ways of interpreting biological systems called "network medicine"[10] formulates the problem in terms of factors involved in the process of ageing and interactions between them — the whole ageing process can be represented as a graph by letting the factors be nodes, and the directed edges represent causal relationships between them.

Network models are a natural fit when it comes to representing biological interplays and relationships in living organisms – for example interactome (which is a multitude of protein-protein interactions[11]) or transcriptome (which is the set of all RNA molecules[12]).

Ageing is accompanied by some phenotypical changes that can be explained by alterations in gene expressions, but phenotypical variability cannot be fully explained by a change in expression of a single gene. To get a realistic picture of genetic changes, Xue *et a*l proposed a network model of ageing based on the transcriptome[13]. Within this model, the authors considered the simultaneous evolution of interactome and transcriptome during ageing. The model showed the genes "whose changes correlate or inversely correlate with chronological age". Analysis of biological network models enables the detection of the key regulating nodes affected by ageing, which can be further treated as targets for geroprotective drug therapy.

Gerontology is being developed at an impressive pace, and the results obtained (with and without AI's support) make us believe that Director of the Biogerontology Research Foundation and CEO of Insilico Medicine Dr Alex Zhavoronkov's claim about increasing lifespan to 150 years does not sound too fantastical.

Today AI is helping to the search for a solution to the old problem of increasing human lifespan. However, it does not make us wiser in terms of understanding athe possible ramifications of this step, and we need to solve the whole problem by ourselves, as human beings. To avoid a misleading interpretation of what it is, AI should be viewed as a tool put to the use in the search for longer life — a machine looking at the numbers and strings generated by humans and trying to detect hidden knowledge gems amidst the mess of biological data.

6. The ageing dilemma

Working on slowing down the ageing process, we enter the territory of ethics and economics. Economists have thoroughly studied the question of ageing influence on economic growth — contribution to the growth of the economy deteriorates very quickly within the group of the population older than 60 years. As far as economics is concerned, it seems evident that extending the health span of a population can reduce the deterioration speed.

However, the question is, how can economists be sure that making the older population healthier will alleviate the burden from countries' economies? Healthier people need less medical care, which could reduce healthcare expenses but extending health span does not necessarily imply an extended work span. Sure, one of the reasons for pension is the inability of older people to maintain efficiency at work due to the age-related diseases but making ageing healthier does not mean pension age would be increased. Closely related to this problem is the question of living in anticipation of death among the healthy elderly. As philosopher Leon Kass[14] said: "Death would always be untimely, unprepared for, shocking."

7. Is living longer actually desirable? Who will benefit?

The prospect of having longer lives possess new questions such as how to live them and how governments should regulate them? What are the philosophical and socio-economic consequences? Are we prepared to solve them?

Although most of us are not keen to get ill and die, the actual question posed differently — David Gems noted that scientists are trying to answer the question of how "to add life to years, not years to life." The quote in the context of our discourse should be interpreted not in the sense of "living shorter but better" but rather "not only longer but better". We have already said that age-related diseases complicate the lives of ageing. The progress of two of them with age is illustrated below. First is sarcopenia, which is loss of muscle strength with ageing — a natural and dreadful process of weakening which affects the strongest (see figure 2).

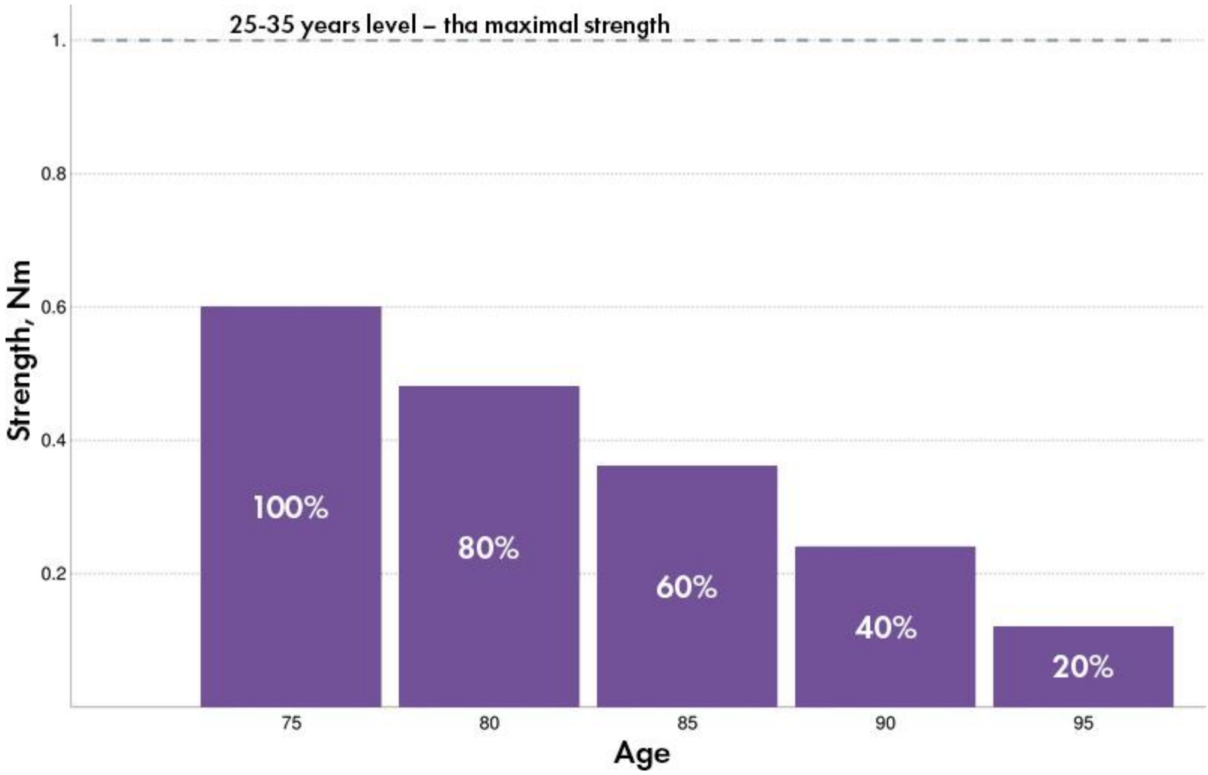

Figure 2: Strength degradation over age. According to Francis et al.[15] *strength in the arms and legs reach peak values between 25 and 35 years which is marked with a dashed line at the plot. It was established in a longitudinal study (see Metter et al.*[16] *and Table 1 therein) that the drop of leg strength from 25 to 75 years is about 40%. The first bar corresponds to this value – 40% of a peak strength. Next, in the Health ABC study (see Goodpaster et al.*[17] *and Table 4 therein) the authors estimated linear law of between leg strength and baseline strength change over the age. The dependency says that strength decreases linearly by 4% per year with respect to the baseline of 100%. It means that every five years the strength drops down by 20%. Therefore, starting from 75 years (which we consider to be 100%) we end up at mere 20% of the 75-years' strength.*

---

[1] *Cohort consisted of a volunteer sample of 3075 men (48.4%) and women (51.6%) aged 70–79 years. We took the midst of the interval.*

[1] *The difference between values for men and women is negligible for our purposes.*

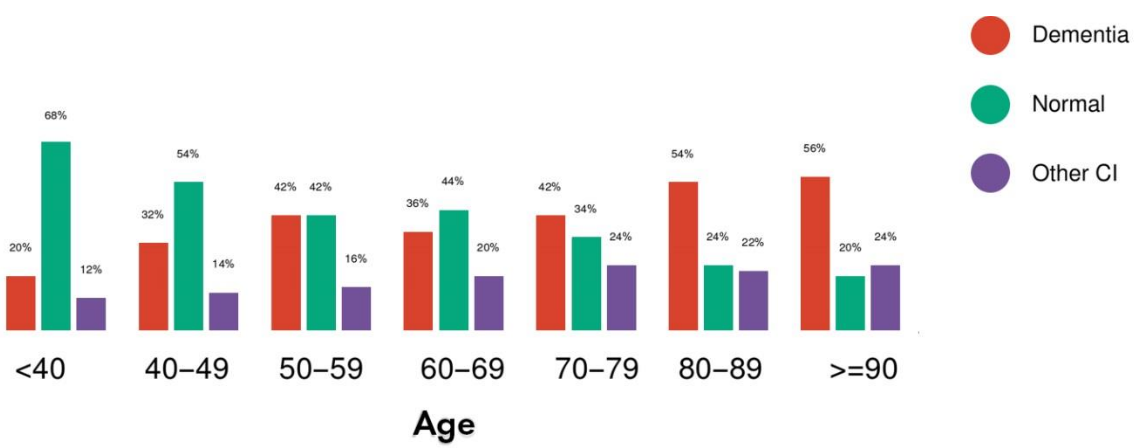

Figure 3: Distribution of Alzheimer associated dementia over age. Data is collected from the National institute of aging-funded Alzheimer's Disease Centers across the United States, https://www.alz.washington.edu/WEB/naccquery.html

Dementia is another grave illustration of Gem's words (see Figure 3) demonstrating a mismatch between physical and mental wellness – one that could be problematic if AI gets it wrong. It is only natural that we as humans want to live longer lives, but most of us do not want to live for 50 extra years afflicted by an illness making us forget who our nearest and dearest are and impacting our senses of independence and dignity.

8. Caveat Emptor – what we must be wary of?

The purely mechanical nature of a tool called AI leaves all responsibility to ones using it; thus, one must evaluate all the eventualities of non-negligible verisimilitude. While AI gives us new insights, does it ultimately make us wiser?

It is important to consider the possible consequences of actions taken with the help of AI. For example, will AI increase the gap between the poor and the rich because poor people won't have access to the power of AI?

Treating ageing as a disease — we have to fight it — but the whole picture is more complex, the process of ageing is vastly different from the common illnesses and current state of our knowledge leaves much to be desired. It is not only the medical problem that is hard but moreover, the societal and economic aspects of solving it — however bright the light of even facing them wouldn't be — are intertwined and require scrutiny. Nonetheless, in practice, researchers work with more straightforward matters, and while we know how to deal with the side effects of the diseases even so special as ageing, socio-economic aspects are much harder to foresee. The only thing we can do is to repeat "be careful" every time before using AI.

9. Another path?

We have outlined two primary directions in which contemporary biogerontology is evolving. However, it is important to mention the third and an entirely different approach that might ultimately free humanity of the burden of ageing — mind uploading. It is not surprising that such an idea appeared first in the books of sci-fi authors, e.g., Egan's "Permutation City"[18]. The progress of Cognitive Science achieved with the development of AI[19] makes it possible to discuss mind uploading as a scientific possibility. Moreover, Ray Kurzweil, computer scientist, and futurist speculates that the "digital immortality" can become real by 2045[20].

10. Conclusion

The idea of artificial intelligence — born in an attempt to replicate the power of the human brain in silico — made us realize the complexity of the endeavour and significantly advanced our understanding of principles underlying the brain functioning. Having been diluted by the vague descriptions in mass media, the very term became misleading which lead to the creation of a new label — now we speak of AI only in the limited sense of applied ML models and distinguish it from what was dubbed Artificial General Intelligence (AGI).

Amongst many different applications of AI, we use it to push the limits of the natural lifespan, but it is hard to predict whether the puzzle is solvable or not and there is no telling about the potential problems the solution might entail. The benefits are known — live longer and be healthier — but could and should we ever expect a much-prolonged lifespan and AI to solve our problems or would that path lead simply to life-long discontent? With AI being applied to every minute problem – where are we going? Just because something can be done, it doesn't necessarily mean it should. And while the benefits are obvious — the downsides are to be empirically discovered.

Without a doubt, extended lifespan and elder life bereft of severe diseases will change the socio-economic landscape of future society. Whether these changes are ultimately positive or negative depends on how wise and cautious we will be in making decisions along the way, when applying such a powerful toolset to tackling the sacral question of human life. Whether we are to achieve the borderline of 150 years or become immortal "in a digital sense" – the journey has only just begun, and we are moving to new horizons that are still blurred by the fog of ignorance.

11. The Authors

Anton Dolgikh,
Head of AI, Healthcare and Life Sciences,
DataArt

Anton Dolgikh leads AI and ML-oriented projects in the Healthcare and Life Sciences practice at DataArt and runs educational and training developers focussed on solving business problems with ML methods.

Prior to working at DataArt, Dolgikh worked in the Department of Complex Systems at the Université Libre de Bruxelles, a leading Belgian private research university. Previous to this, Anton taught Physics and Mathematics and conducted scientific research in the Voronezh State University, and has published 11 articles on Condensed Matter Physics, Quantum Mechanics, and Statistical Physics.

Dolgikh holds Bachelor's and master's Degrees in Theoretical Physics and a PhD in Condensed Matter Physics from Voronezh State University.

Dmitry Bubelnik,
AI Research Scientist,
DataArt

Dmitry Bubelnik is a developer, ML engineer and AI research scientist, focussing on ML-driven solutions for the Healthcare and Life Sciences practice at DataArt. He is passionate about the recent developments in the type theory, software verification and functional programming, in AI & ML technologies, as applied to life sciences in particular.

Bubelnik holds a master's degree in Computer Science from Voronezh State University.

12. References

1. Kirkwood, T. B. L. Deciphering death: a commentary on Gompertz (1825) ‘On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies’. *Philos. Trans. R. Soc. B Biol. Sci.* **370**, 20140379–20140379 (2015).
2. Mitnitski, A. B. *Epigenetic Biomarkers for Biological Age*. *Epigenetics of Aging and Longevity* (Elsevier Inc., 2018). doi:10.1016/B978-0-12-811060-7.00007-3
3. Klemera, P. & Doubal, S. A new approach to the concept and computation of biological age. *Mech. Ageing Dev.* **127**, 240–248 (2006).
4. Levine, M. E. Modeling the rate of senescence: Can estimated biological age predict mortality more accurately than chronological age? *Journals Gerontol. - Ser. A Biol. Sci. Med. Sci.* **68**, 667–674 (2013).
5. Lecun, Y., Bengio, Y. & Hinton, G. Deep learning. *Nature* **521**, 436–444 (2015).
6. Min, S., Lee, B. & Yoon, S. Deep learning in bioinformatics. *Brief. Bioinform.* bbw068 (2016). doi:10.1093/bib/bbw068
7. Putin, E. *et al.* Deep biomarkers of human aging: Application of deep neural networks to biomarker development. *Aging (Albany. NY).* **8**, 1021–1033 (2017).
8. Bobrov, E. *et al.* PhotoAgeClock: Deep learning algorithms for development of noninvasive visual biomarkers of aging. *Aging (Albany. NY).* **10**, 3249–3259 (2018).
9. Gems, D. The aging-disease false dichotomy: Understanding senescence as pathology. *Front. Genet.* **6**, 1–7 (2015).
10. Barabási, A. L., Gulbahce, N. & Loscalzo, J. Network medicine: a network-based approach to human disease. *Nat. Rev.* **12**, 56–68 (2011).
11. Vidal, M., Cusick, M. & Barabási, A.-L. Interactome networks and human disease. *Cell* **144**, 986–998 (2011).
12. Wang, Z., Gerstein, M. & Snyder, M. RNA-Seq: a revolutionary tool for transcriptomics. *Nat. Rev. Genet.* **10**, 57–63 (2009).
13. Xue, H. *et al.* A modular network model of aging. *Mol. Syst. Biol.* **3**, (2007).
14. Kass, L. R. *Toward a More Natural Science*. (Free Press, 1988).
15. Francis, P. *et al.* Measurement of muscle health in aging. *Biogerontology* **18**, 901–911 (2017).

16. Conwit, R. *et al.* Muscle Quality and Age: Cross-Sectional and Longitudinal Comparisons. *Journals Gerontol. Ser. A Biol. Sci. Med. Sci.* **54**, B207–B218 (2011).
17. Goodpaster, B. H. *et al.* The Loss of Skeletal Muscle Strength, Mass, and Quality in Older Adults: The Health, Aging and Body Composition Study. *Journals Gerontol. Ser. A Biol. Sci. Med. Sci.* **61**, 1059–1064 (2006).
18. Egan, G. *Permutation City: A Novel*. (Night Shade, 2014).
19. Forbus, K. D. AI and cognitive science: The past and next 30 years. *Top. Cogn. Sci.* **2**, 345–356 (2010).
20. Kurzweil, R. Mind uploading & digital immortality may be reality by 2045, futurists say. *Huffingt. Post* (2013).

About DataArt

DataArt is a global technology consultancy that designs, develops and supports unique software solutions, helping clients take their businesses forward. Recognized for their deep domain expertise and superior technical talent, DataArt teams create new products and modernize complex legacy systems that affect technology transformation in select industries.

DataArt has earned the trust of some of the world's leading brands and most discerning clients, including Nasdaq, Travelport, Ocado, Centrica/Hive, Paddy Power Betfair, IWG, Univision, Meetup and Apple Leisure Group among others. DataArt brings together expertise of over 3000+ professionals in 20 locations in the US, Europe, and Latin America.

www.dataart.com

@dataart

Contact

Anton Dolgikh

anton.dolgikh@dataart.com

+7 (473) 2334425 x 2430

Sales:

Julie Pelta

julie.pelta@dataart.com

+44 (207) 0999464

Media:

Lief Anya Schneider

lief@sbc.london

+44 7971 950 899