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Swarms of Autonomous Microbots & Nanobots in the Human Body

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Abstract

Microbots and nanobots—tiny mechanical systems—can navigate through small spaces inside the human body (e.g., veins) in an automated manner to complete assigned missions such as biosensing, diagnosis, clinical therapy, minimally invasive surgery (e.g. clearing clogged arteries, removing plaques, repairing tissues), and drug delivery (e.g. cancer treatment). Biomedical applications of micro/nanoswarms have immense potential to replace traditional methods and change the game in clinical translation by minimising the need for painful and risky invasive treatments. With the use of these micro/nanorobots, the side effects of drugs or therapy can be minimised where drug delivery (e.g. chemotherapy agents, antibiotics) or therapy (e.g. repair with hyperthermia to destroy cancer cells) is localised in the human body (e.g. tumour sites). The therapy efficiency can be increased with local micro-incision of lesions and the required number of repetitions using integrated outer sensing systems such as ultrasound, tomography/X-ray, MRI or bespoke wearable biomedical devices. Those micro/nanoswarm agents developed for specific tissues, cells, or pathogens, can revolutionise medicine by leveraging cybernetics, materials science, swarm intelligence, and biomedicine.

The main challenges that need to be addressed urgently are i) the establishment of robust communication channels to automate the behaviours of micro/nano robotics swarms, ii) real-time high-quality sensed data transmission and process of it properly for effective decision-making, iii) their external control (e.g. electromagnetic actuation) for realignment, iv) their adaptation to the human body considering the varying characteristics of tissues (e.g. lumen structures), v) real-time state and situation awareness (SSA) (e.g. position through the digital twins (DTs) of human tissues, trajectory/navigational direction, task performance, energy (powered by internal or external energy sources, bio-harvesting) level), vi) real-time morphological control with navigational abilities through the tough and dynamic physiological ecosystem with biofluids (e.g. varying non-linear flow velocity, viscosity, and ion strength), vii) excretion of them from the body safely, and vii) ethical concerns.

Microbots and nanobots need to be understood in various aspects such as their interior mechanisms, modulations, inter/intra communication, behaviours in biofluids, and possible medical applications. This report presents the fundamental features of these tiny mechanical organisms, considering their potential medical applications with micro-scale precision tasks in the dynamic human body.

Index Terms— Nanorobotics, microbots, nanobots, microswarms, nanoswarms, micro biomedical systems, micro-scale precision, cybernetics

REFERENCES

[1] K. Kuru et al., “Autonomous low power monitoring sensors,” Sensors, vol. 21, 2021.
[2] N. Caswell et al., “Patient engagement in medical device design: refining the essential attributes of a wearable, pre-void, ultrasound alarm for nocturnal enuresis.” Pharmaceutical Medicine, 34, 39-48, 2020.
[3] K. Kuru et al., “Transformation to advanced mechatronics systems within new industrial revolution: A novel framework in automation of everything (AoE),” IEEE Access, vol. 7, pp. 41 395–41 415, 2019.
[4] K. Kuru, “Management of geo-distributed intelligence: Deep insight as a service (DINSaaS) on forged cloud platforms (FCP),” Journal of Parallel and Distributed Computing, vol. 149, pp. 103–118, Mar. 2021.
[5] K. Kuru, “Sensors and sensor fusion for decision making in autonomous driving and vehicles,” 2023.
[6] K. Kuru and W. Khan, “Novel hybrid object-based non-parametric clustering approach for grouping similar objects in specific visual domains,” Applied Soft Computing, vol. 62. Elsevier BV, pp. 667–701, Jan-2018.
[7] K. Kuru, “A Novel Hybrid Clustering Approach for Unsupervised Grouping of Similar Objects,” Lecture Notes in Computer Science (pp. 642–653), 2014.
[8] K. Kuru et al., "Treatment of Nocturnal Enuresis Using Miniaturised Smart Mechatronics With Artificial Intelligence," in IEEE Journal of Translational Engineering in Health and Medicine, vol. 12, pp. 204-214, 2024.
[9] K. Kuru, “Technical report: Big data-concepts, infrastructure, analytics, challenges and solutions,” 2024.
[10] K. Kuru et al., "Biomedical visual data analysis to build an intelligent diagnostic decision support system in medical genetics," Artificial intelligence in medicine 62, no. 2 (2014): 105-118.
[11] K. Kuru, "Optimization and enhancement of H&E stained microscopical images by applying bilinear interpolation method on lab color mode;" Theoretical Biology and Medical Modelling 11 (2014): 1-22.
[12] K. Kuru et al., "Feasibility study of intelligent autonomous determination of the bladder voiding need to treat bedwetting using ultrasound and smartphone ML techniques: Intelligent autonomous treatment of bedwetting," Medical & biological engineering & computing 57 (2019): 1079-1097.
[13] K. Kuru et al., "Intelligent autonomous treatment of bedwetting using non-invasive wearable advanced mechatronics systems and MEMS sensors: Intelligent autonomous bladder monitoring to treat NE," Medical & biological engineering & computing 58 (2020): 943-965.
[14] K. Kuru et al., "A novel report generation approach for medical applications: the SISDS methodology and its applications," *International journal of medical informatics* 82, no. 5 (2013): 435-447.
[15] K. Kuru et al., "A bilinear interpolation based approach for optimizing hematoxylin and eosin stained microscopical images," In Pattern Recognition in Bioinformatics: 6th IAPR International Conference, PRIB 2011, Delft, The Netherlands, November 2-4, 2011. Proceedings 6, pp. 168-178. Springer Berlin Heidelberg, 2011.
[16] G. Gürsel et al., "Determining the weak sides of Healthcare Information Systems: An Emprical e-Health Evaluation Study," AJIT-e: Online Academic Journal of Information Technology 7, no. 23 (2016): 17-30.
[17] K. Kuru et al., "Establishment of a diagnostic decision support system in genetic dysmorphology," In 2012 11th International Conference on Machine Learning and Applications, vol. 2, pp. 164-169. IEEE, 2012.
[18] K. Kuru, "Use of wearable miniaturised medical devices with artificial intelligence (ai) in enhancing physical medicine," (2024): 69.
[19] C. Combi, Carlo, Yuval Shahar, and Ameen Abu-Hanna, eds. Artificial Intelligence in Medicine: 12th Conference on Artificial Intelligence in Medicine in Europe, AIME 2009, Verona, Italy, July 18-22, 2009, Proceedings. Vol. 5651. Springer Science & Business Media, 2009.
[20] Jin, Dimitris Karagiannis Zhi, Yuncheng Jiang, Robert Andrei Buchmann, Yaxin Bi, Ana-Maria Ghiran, and Wenjun Ma. "Knowledge Science, Engineering and Management," (2009).
[21] K. Kuru et al., "Smart Wearable Device for Nocturnal Enuresis," In 2023 IEEE EMBS Special Topic Conference on Data Science and Engineering in Healthcare, Medicine and Biology, pp. 95-96. IEEE, 2023.
[22] D. Ansell et al., "Methods and apparatuses for estimating bladder status," European Patent EP 3328279B1, issued Nov 18, 2020.
[23] K. Kuru, "Joint cognition of remote autonomous robotics agent swarms in collaborative decision-making & remote human-robot teaming," (2024).
[24] K. Kuru et al., "Developing diagnostic dsss based on a novel data collection methodology," In Knowledge Science, Engineering and Management: Third International Conference, KSEM 2009, Vienna, Austria, November 25-27, 2009. Proceedings 3, pp. 110-121. Springer Berlin Heidelberg, 2009.
[25] K. Kuru et al., "A novel multilingual report generation system for medical applications," In Artificial Intelligence in Medicine: 12th Conference on Artificial Intelligence in Medicine, AIME 2009, Verona, Italy, July 18-22, 2009. Proceedings 12, pp. 201-205. Springer Berlin Heidelberg, 2009.
[26] H. Gul et al., "The Advantages of Electronic Prescription, the Problems and Tackling Them," (2005): 134-139.
[27] K. Kuru et al., "Analysis of Resources in Healthcare by Computer Simulation Studies in Healthcare: An Outpatient Clinic Study," (2005): 14-20.
[28] K. Kuru et al., "The Use of Lab Color Model for Sharpening and Optimization of Digital Images of Hematoxylin & Eosin Stained Microscopical Materials," (2005): 210-218.
[29] Kuru et al., "Artificial Intelligence and Machine Learning in Pediatrics," (2023).
[30] D. Ansell et al., "Mypad: A pre-void alarm device for the treatment of nocturnal enuresis (ne)." (2019).
[31] Kuru et al., “Transformation to advanced mechatronics systems within new industrial revolution: a novel framework in automation of everything (aoe),” IEEE Access 7, 41395–41415. 2019.
[32] Kuru et al., "Establishment of diagnostic decision support system (DDSS) in clinical diagnosis of genetic diseases: the facegp DDSS methodology and its applications," European Journal of Human Genetics 20, no. 1 (2012): 70-70.
[33] Loog, Marco, Lodewyk Wessels, Marcel JT Reinders, and Dick de Ridder, eds. Pattern Recognition in Bioinformatics: 6th IAPR International Conference, PRIB 2011, Delft, The Netherlands, November 2-4, 2011, Proceedings. Vol. 7036. Springer Science & Business Media, 2011.
[34] K. Kuru, "Human-in-the-Loop Telemanipulation Schemes for Autonomous Unmanned Aerial Systems," 2024 4th Interdisciplinary Conference on Electrics and Computer (INTCEC), Chicago, IL, USA, 2024, pp. 1-6.
[35] Kuru et al., "Medical Report Generation in a Structured and Interactive Way Using Speech Driven Approach," (2007).
[36] H. Gul et al., "A Versatile, User Driven, Flexible And Scalable Decision Making Tool In Toxicology," (2006): 134-139.
[37] Kuru et al., "MyPAD: An Intelligent Wearable Medical Device to Treat Incontinence," In IEEE EMBS International Conference on Data Science and Engineering in Healthcare, Medicine & Biology, 7th–9th December. 2023.
[38] Kuru et al., "Diagnostic Decision Support System in Dysmorphology," In Decision Support Systems. IntechOpen, 2012.
[39] Kuru et al., "A Novel Report Generation Approach for Medical Applications: The SISDS Methodology (METU-MIN-TR-2009-001-KK)," International Journal of Medical Informatics 82, no. 5 (2012).
[40] Karagiannis, Dimitris, and Zhi Jin, eds. Knowledge Science, Engineering and Management: Third International Conference, KSEM 2009, Vienna, Austria, November 25-27, 2009, Proceedings. Vol. 5914. Springer Science & Business Media, 2009.
[41] K. Kuru, "A Novel Report Generation System for Medical Applications." (2009).
[42] Kuru, K. "IoTFaUAV: Intelligent remote monitoring of livestock in large farms using Autonomous uninhabited aerial vehicles." Computers and Electronics in Agriculture (2023).
[43] Shahar, Carlo Combi Yuval, Silvia Miksch, and Peter Johnson. "Artificial Intelligence in Medicine," vol 1211 (1997): 51-61.
[44] D. Ansell et al., "Methods and Apparatuses for Estimating Bladder Status." U.S. Patent Application 17/875,004, filed May 25, 2023.
[45] D. Ansell et al., "Method and apparatus for estimating bladder status," JP2018528041A, 2018.
[46] D. Ansell et al., "Method and apparatus for estimating bladder condition," CN201680053526.3A, 2018.

[47] K. Kuru, "Technical Report: Use of A-mode Ultrasound in Medicine," (2022).
[48] C. De Goede et al., "MyPad–Intelligent Bladder Pre-void Alerting System: A project collaborated with NHS to treat Nocturnal Enureses (NE)," (2018).
[49] Hettinga, Marike, and Åsa Smedberg. "eTELEMED 2015," (2015).
[50] Kuru et al., "Urban Metaverse Cyberthreats and Countermeasures to Mitigate Them," (2024).
[51] G. Gürsel et al., "An E-health Evaluation Case study: Evaluating The New Laboratory Information System," eTELEMED 2015: 58.
[52] J. Lowe et al., "Development of Machine Intelligence for Self-Driving Vehicles Through Video Capturing," 2024 20th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA), Genova, Italy, 2024, pp. 1-8,
[53] Kuru et al., "Machine Learning Based Genetic Decision Making Methodology Using Genotype-Phenotype Mapping," (2013).
[54] Kuru et al., "A Novel Approach to Improve the Diagnostic Success of Computers in Dysmorphology: The DSESPC methodology and its Applications;" (2013).
[55] Kuru et al., "Diagnostic Decision Support System in Genetic Diseases: The FaceGP DDSS," (2012).
[56] Kuru et al., "Establishment of Diagnostic Decision Support Systems (DDSS) to Prediagnose the Dysmorphic Diseases (Congenital Malformation) Efficiently Caused by Genetic Syndromes," (2011): 122-132.
[57] K. Kuru, "A novel report generation approach for medical applications: The SISDS methodology and its applications (Tıbbi uygulamalar için yeni bir rapor üretim yaklaşımı: SISDS metodu ve uygulamaları)," PhD diss., Middle East Technical University, Turkey, 2010.
[58] Loog M, Wessels L, Reinders MJT et al. eds. 2011. Pattern Recognition in Bioinformatics, 6th IAPR International Conference, PRIB 2011, Delft, The Netherlands, November 2-4, 2011