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Unveiling the vision: exploring the potential of image analysis in Africa

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Here we discuss the prospects of bioimage analysis in the context of the African research landscape as well as challenges faced in the development of bioimage analysis in countries on the continent. We also speculate about potential approaches and areas of focus to overcome these challenges and thus build the communities, infrastructure and initiatives that are required to grow image analysis in African research.

The simple statement 'the Africa we want' exemplifies the driving force for the continent's strategic framework, which is to transform Africa into a global leader of and contributor to global development and progress. Bioimaging in African biomedical research — although in its infancy — is steadily expanding following concerted efforts to grow and connect community networks (for example, the African BioImaging Consortium), establish skills development opportunities[1], and to provide open-access infrastructure[2] and tools[3], as well as various funding programs that facilitate bioimaging research. Researchers on the continent are priming themselves to take full advantage of the wide array of bioimaging technologies and approaches that have been developed over recent decades and apply them to locally relevant research topics. Many of the African researchers with whom we have engaged are cognizant of the potential for further development of the imaging community and are committed to joining scientists globally in advancing life science and microscopy by solving locally and globally relevant challenges. As a group of researchers working in African countries across the continent, we believe the continent's bioimaging community — as well as the broader scientific community — must focus on strategic gaps in knowledge and infrastructure to develop bioimaging over the next several years. One aspect of this is arguably the most challenging and is often overlooked: data science and image analysis.

As there is a general scarcity of image analysts within the continent, image data scientists and bioimage analysts currently comprise a very small fraction of existing bioimaging networks. This is despite the relative strength of data science and computational biology in many countries within Africa[4]. We believe that this provides an opportunity for the development of new and contextually relevant image analysis capacity. To do this, the existing pool of talented data scientists must be exposed to and impactfully engaged with questions of bioimaging research and, importantly, skilled data scientists must be attracted (and retained) in regional research settings to apply their expertise to bioimage analysis. A clear requirement moving forward is the need

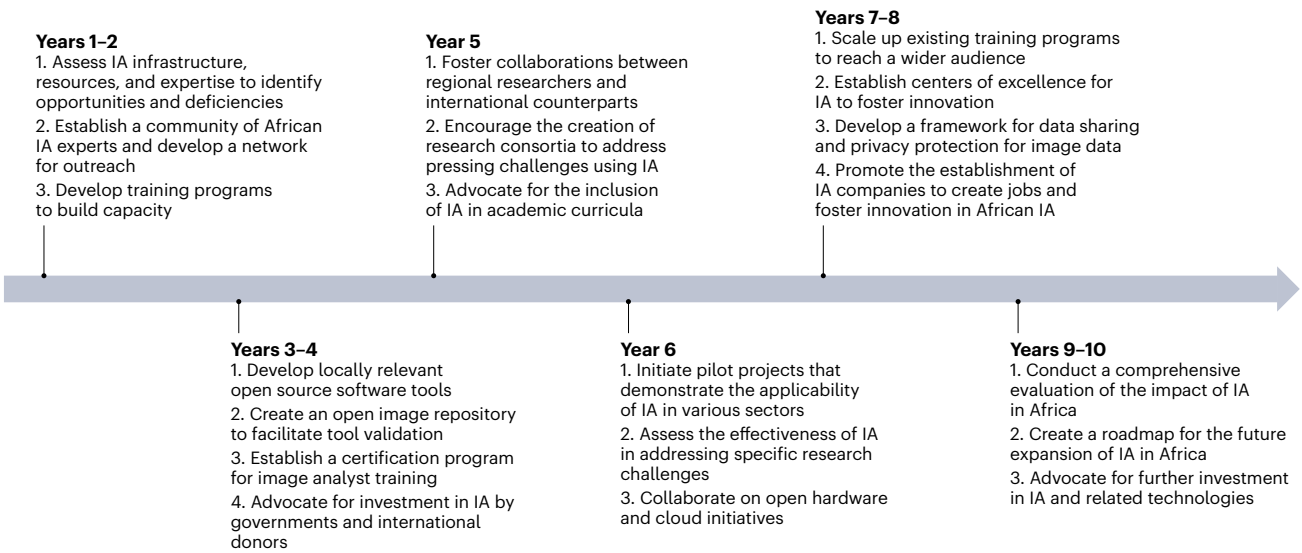


Fig. 1 | A 10-year outline to develop image analysis in Africa. To facilitate the development of image analysis (IA), a concerted effort is required by various stakeholders (including governments, universities, consortia and individual researchers). By following a systematic approach in which African image analysists can learn new skills and apply them in real-world situations, a considerable growth of IA in Africa could be achieved in 10 years. Development and support at a number of levels and in several sectors will be needed to have a sustainable impact.

to seed and develop new knowledge and expertise regionally and locally. Investment in tertiary-level training programs and capacity development should be prioritized to supply the current demand for image analysts to complement microscopy work in understanding and developing novel approaches to Afrocentric bioimaging research. This could include the development of post-graduate degrees at local universities that focus specifically on bioimage analysis techniques to seed and establish the careers of future image analysts.

We are of the opinion that increasing the number of image analysts alone will not be enough to drive quantitative microscopy forward in Africa. It is imperative that the continent's image data scientists are connected with other data scientists — both at a regional and global level — to support the dissemination of knowledge and the development of new analytical approaches. Through this kind of network development, data scientists within the continent could establish formal networks and begin to complement similar communities globally (such as the Network of European BioImage Analysts). Such networks will help to foster innovation and collaboration to facilitate the rapid evolution of microscopy applications. With strategic support from existing research communities, we believe that within the next decade researchers working in countries in Africa will become key players in imaging and image analysis globally.

Although access to imaging technologies is becoming somewhat more commonplace on the continent, we note that this is not currently accompanied by an increase in the establishment and use of computational resources. As machine learning and artificial intelligence become more prevalent in bioimaging, not having access to high-performance computation will put researchers in low-income regions at a severe disadvantage. One key solution is the development of shared data repositories and computational resources that can be accessed remotely to reduce the need for local computational power and data storage facilities. Shared resources will undoubtedly lead to improved collaboration and maximized resource utilization — two factors that are important for growth in Africa. Coupled with the continued development of open-access software (such as napari)[5], there is the potential to make image processing and analysis more routine for researchers who are working with ever larger and more complex datasets. Cloud-computing developments will similarly lessen the local hardware burden required for data storage and computation as analysis pipelines become more integrated with open platforms (for example, ZeroCostDL4Mic[6]). Solutions such as these are important as they truly begin to democratize imaging knowledge and its application in life science research and are likely to drive increased collaboration among researchers working in different countries in Africa. Moreover, although far from being fully realized, machine learning will rapidly come into prime focus for computational image analysis; for this to be realistically implementable, many researchers are going to be reliant on open-access platforms. This will be equally relevant for the sharing of suitably annotated training sets as well as fully trained models.

Once open and shared platforms have come to fruition, bioimaging in African research groups will face its own share of computational challenges. Applying deep learning models is challenging as algorithm accuracy is inherently affected by the magnitude and quality of available training datasets, and these would need to be curated to ensure the rapid and effective development and use of machine learning techniques. Other notable difficulties in applying deep learning in microscopy analysis that all data scientists will need to tackle include data imbalances and the limited availability of high-quality ground-truth data. Data augmentation, transfer learning and ensemble learning are likely to be developed to address these challenges over the coming years. However, future trends also necessitate the development of more robust algorithms, integrations with other technologies and the development of advanced hardware systems to support the needs of researchers. Ultimately, hardware and software strategies to increase the accuracy and fidelity of deep learning models trained on low signal-to-noise images are going to be another crucial avenue that needs to be addressed to ensure microscopy technologies and image analysis approaches can be implemented in more settings globally. These challenges are not unique to research scientists working in Africa; however, regional researchers should remain cognizant of these issues while developing image analysis capacity.

Assuming substantial investments are made, it is reasonable to expect that progress will be made over the next 5–10 years. However, developing a strong pipeline of skilled scientists and researchers will require sustained investments in education, training, mentorship programs and computational hardware. With the expectation that open repository initiatives could begin to be developed within the next 4–5 years, it could take at least 10–20 years for research hubs in Africa to develop expertise that facilitates frontier scientific advancement in microscopy and bioimage analysis. This timeline will probably vary depending on the level of investment, the pace of technological innovation and the effectiveness of capacity-building programs. Regardless, to meet these goals, funding needs to be allocated strategically to support computational infrastructure (including open-access and cloud facilities), training and capacity building at multiple levels, data collection and management, and collaborations, as well as research and innovation (Fig. 1). Investing in these areas would help to build a strong foundation for the field of image analysis on the continent and will enable researchers to make important contributions to bioimaging and to benefit from its applications in Afrocentric biomedical research. Overcoming the digital divide faced by many countries in Africa is crucial to develop knowledge and skills as well as to foster innovation and entrepreneurship — which will eventually be an important catalyst of scientific and economic growth.

The future of microscopic image processing and analysis is promising. Advancements in artificial intelligence approaches globally are enabling the development of ever more accurate and efficient image-analysis algorithms, which further drives new discoveries in the life sciences. As the amount of data continues to grow, however, there will be an increasing need for scalable and automated analysis methods. This means that the use of cloud computing and distributed infrastructure is likely to become more prevalent — particularly in Africa. Furthermore, the integration of multiple imaging modalities and data sources is expected to provide even greater insights into complex biological systems, which further supports the need for researchers in countries in Africa to have reliable access to analyses powered by artificial intelligence. With continued investment by governments and funding agencies, as well as further local and international collaboration, we believe scientists working on the African continent will make substantial gains in applying image processing and analysis in understanding a wide range of research challenges on a global level.

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Competing interests

The authors declare no competing interests.