Paper AD04

Advancing Kidney Assessments for Transplants with AI-driven Applications

Federica Citterio, SAS Institute, EMEA

ABSTRACT

Adopting AI-driven decision making in the clinic depends on multiple factors: accuracy, transparency, safety and more The goal is to create a system that optimizes the interaction between humans and AI, striking a balance between the automated capabilities of AI models and the discernment of highly trained professionals.

In this presentation we will show an AI-driven app, developed in partnership by SAS and the School of Medicine at University of Cambridge, to assess kidney's pre-implantation quality. The application focuses on the critical time window when histopathologists can review kidney biopsies to determine transplant viability and supports them by automating routine tasks thanks to computer vision models.

The user-friendly nature of the application ensures that human professionals remain involved in the process, eliminating technological concerns and allowing doctors to concentrate on patient care.

INTRODUCTION

Renal transplantation is widely regarded as the best treatment for patients with end-stage kidney disease, but the demand for kidney transplants is increasing and it's hard to find enough organs.

More elderly deceased donors are being considered, but the problem is that kidney function deteriorates with age, so kidney transplants from elderly donors are associated with higher risks of early failure. Early failure of a kidney transplant is a disastrous outcome for the recipient, because they undergo a major operation with no lasting benefit. For this reason, many organs from elderly donors are either declined or discarded as unsuitable.

One way to potentially offset these risks is to perform a biopsy of the donor kidney that assesses the degree of chronic injury or age-related damage of the organ, and then use this information to guide the decision to implant or not.

However, this is not current practice because of staffing bottleneck: in the UK there are about 30 individuals that can make a call on the kidney biopsy, and they might not be available in the critical and short time window when the analysis must be performed (usually less than 4 hours).

SAS and the University of Cambridge have worked together to develop a tool that uses AI to perform a similar interpretation of a biopsy that is currently carried out by a specialist histopathologist. In this way we can increase the number and quality of kidneys transplanted.

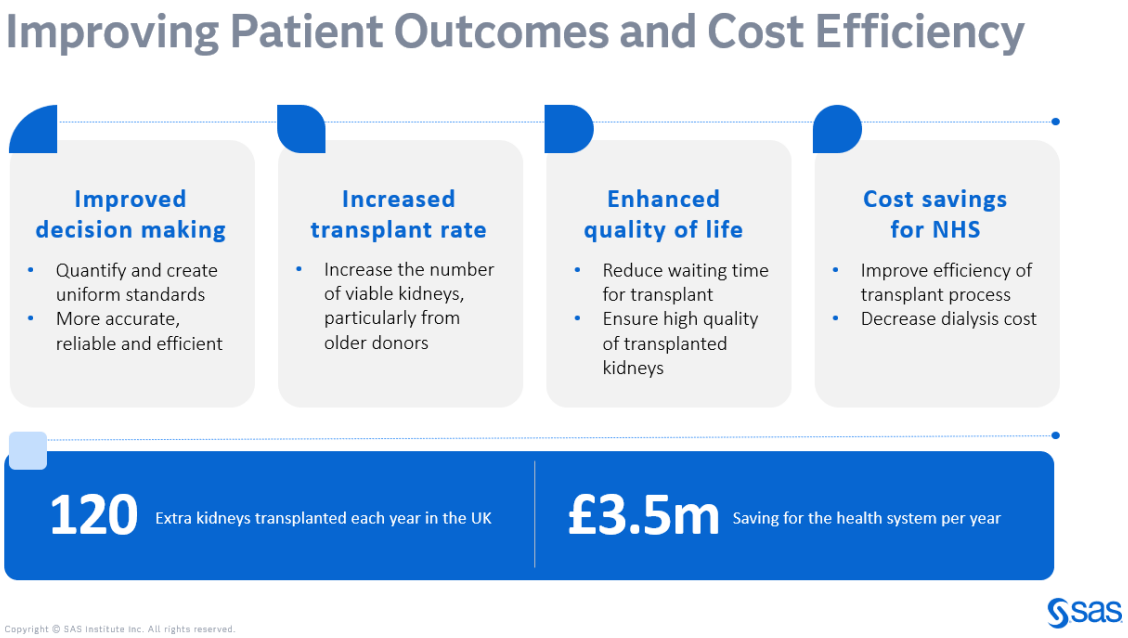
You can learn more about this work here: University of Cambridge | Advancing Kidney Assessments for Transplants with AI | SAS Customers

AUGMENTING HUMAN POTENTIAL WITH AI

By leveraging AI to automate the most time-consuming tasks, we can improve patient outcomes and cost efficiency. In particular, we could achieve:

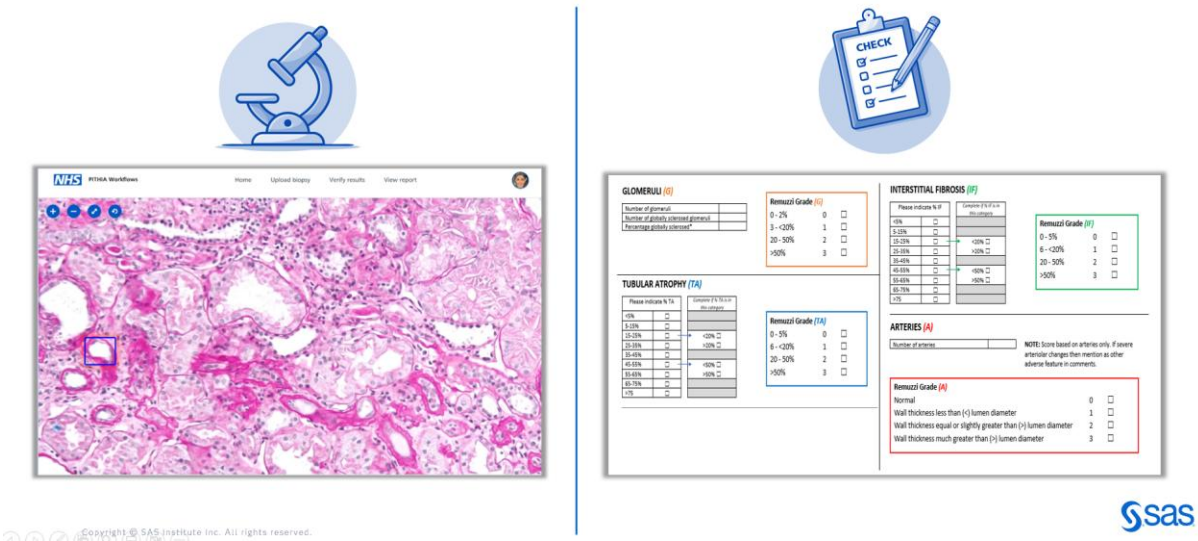
- **Improved Decision Making:** using computer vision to quantify specific metrics, can create uniform standards and lead to less subjective and more efficient decisions. A trained AI model can access the collective experience of multiple clinicians, rather than relying on the intuition and judgement of an individual or small group.
- **Increased Transplant Rates:** the AI-powered biopsy assessment can increase the number of viable kidneys, particularly from older donors, leading to more transplants.
- **Enhanced Quality of Life for Patients:** faster and more accurate assessments can reduce waiting times. Successful transplant transforms the life of a recipient, by offering a very real survival advantage to the recipient and substantial improvements in quality of life, reducing the need for dialysis.
- **Cost Savings for NHS:** the AI solution can reduce the burden on the NHS by decreasing dialysis costs and improving the efficiency of the transplant process.

The University of Cambridge estimated that if this experience is replicated nationally, this new service could allow for 120 extra kidney transplants to be performed each year, saving up to £3,500,000 for the health service.



TRUSTWORTHY AI IN DECISION MAKING

The assessment currently performed by renal histopathologists follows a clinical scoring system designed to estimate the extension of kidney damage. They analyze the biopsy and report specific metrics, that adds up to a suitability score.
We used AI to replicate this process, by breaking down the components and replicating the scoring system using computer vision models. This would inform transplant clinicians on the suitability of a particular kidney for transplantat



The AI solution relies on two requirements:

- Developing accurate, reliable and scalable AI models.
- Developing a well-designed and easy to use application for the histopathologist to review the results. They should be able to easily visualize the results, understand how they were calculated and override any decision they don't agree with.

In the rest of the presentation we will show how we achieved these steps.

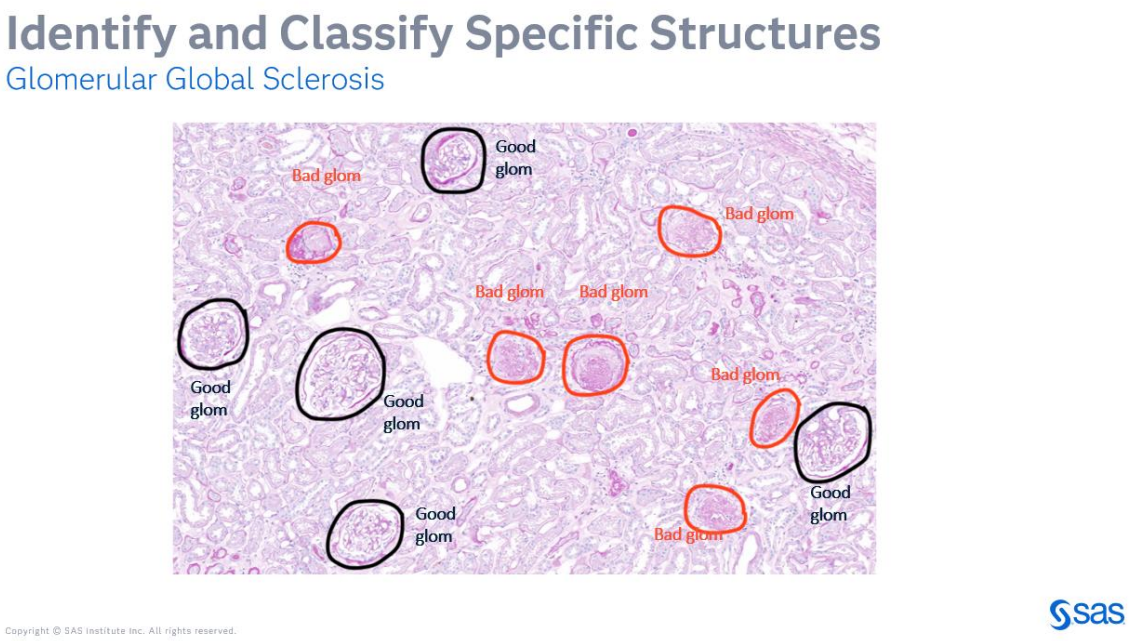
DEVELOPING COMPUTER VISION MODELS

Computer vision is the branch of AI that aims to interpret and understand the visual world. It relies upon training systems to emulate human tasks through learning and automation.
All the computer vision models mentioned below have been trained on SAS Viya, with the help of SAS DLPy (https://github.com/sassoftware/python-dlpy). DLPy is high-level Python library for the SAS Deep learning features available in SAS Viya, designed to provide an efficient way to apply deep learning methods to image, text, and audio data.

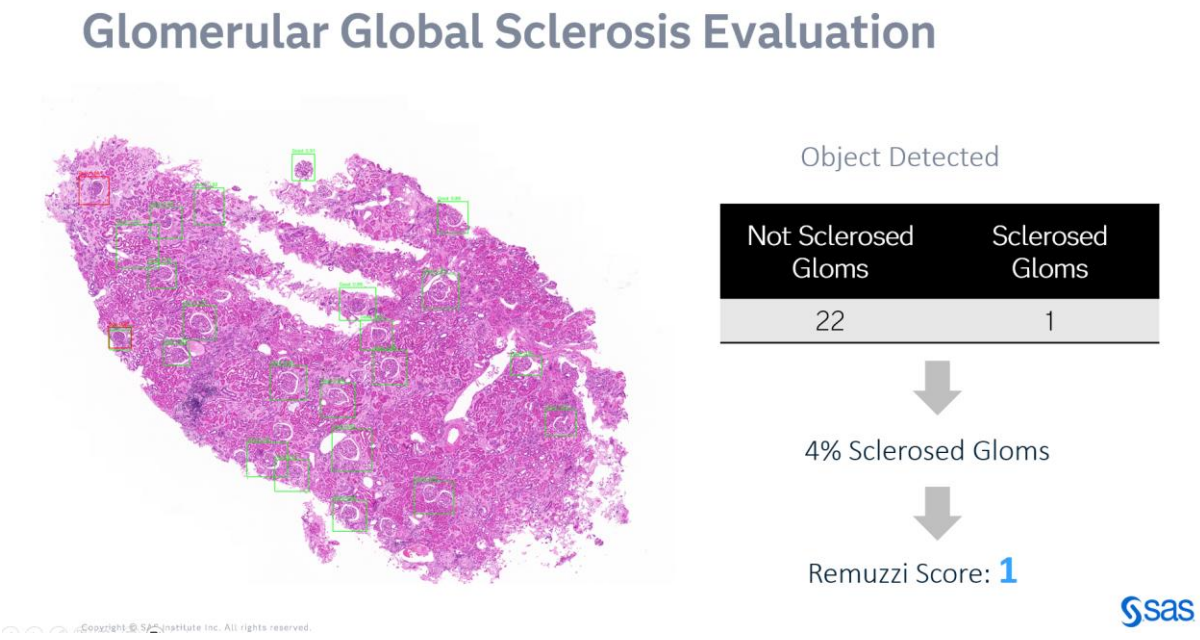
In this project, we had to deal with three different assessments, namely:

- Glomerular Global Sclerosis
- Interstitial Fibrosis and Tubular Atrophy
- Arterial Narrowing

GLOMERULAR GLOBAL SCLEROSIS

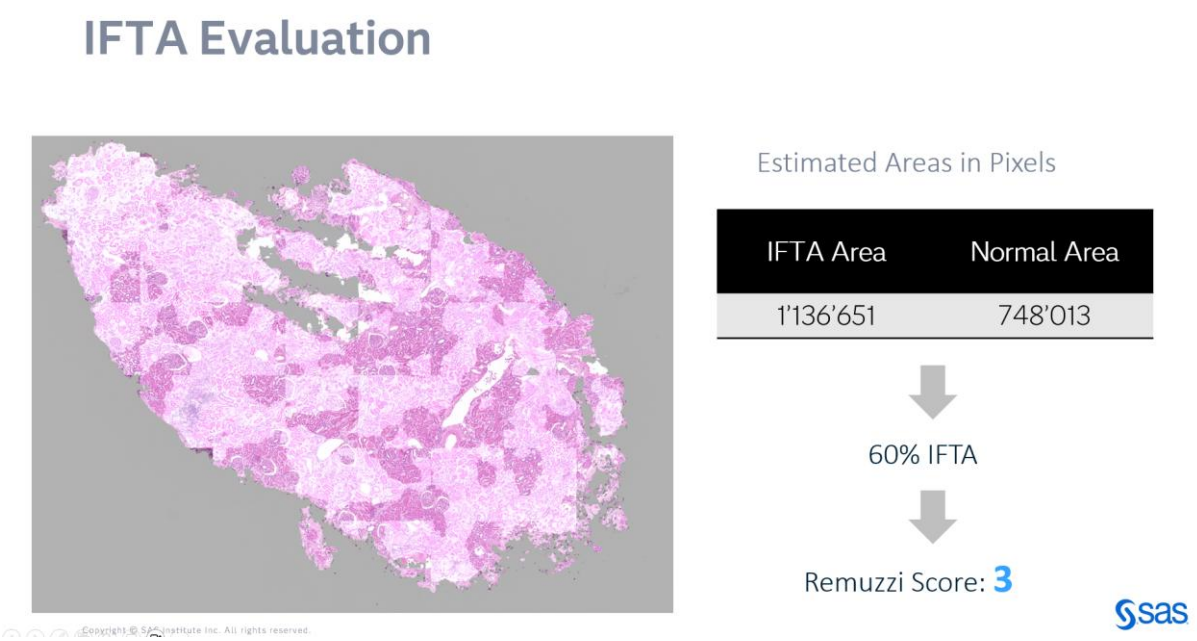


Glomerular global sclerosis is a kidney disease characterized by the scarring and hardening of the glomeruli, the tiny filtering units within the kidneys. The histopathologist needs to analyze a portion of the kidney biopsy and calculate the percentage of sclerosed glomeruli, against the number of total glomeruli.
We used an object detection model, from the YOLO family, to detect glomeruli from the image and classify them in two classes: sclerosed and not sclerosed.



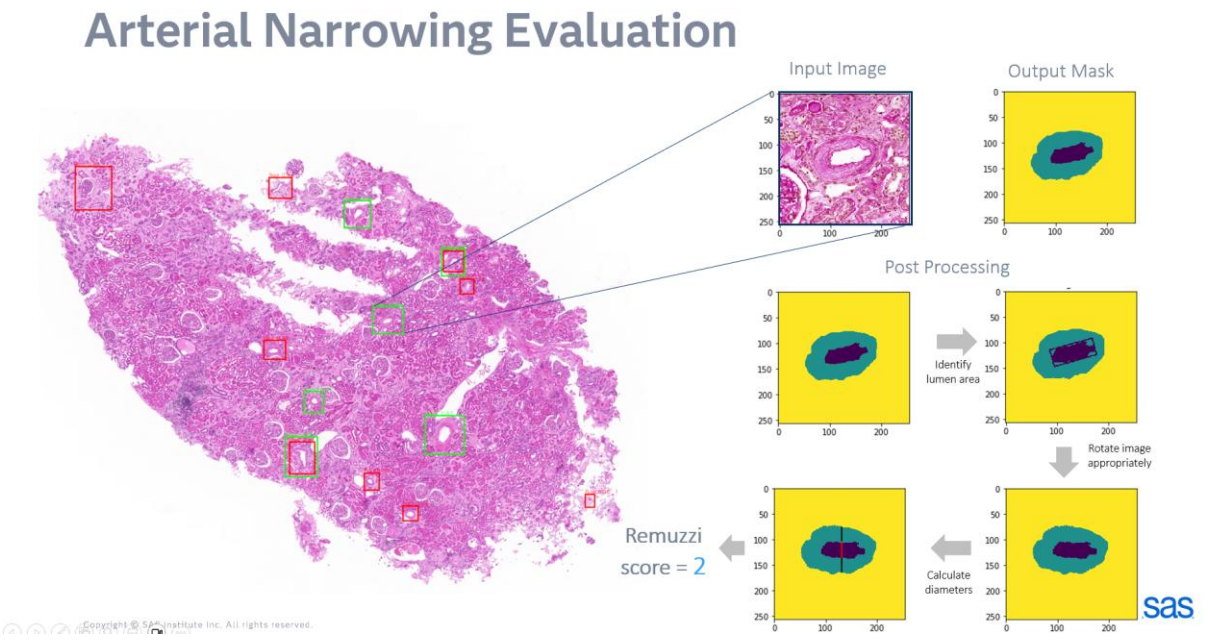
INTERSTITIAL FIBROSIS AND TUBULAR ATROPHY

Interstitial fibrosis and tubular atrophy are two common pathological changes often seen in chronic kidney disease (in short we will refer to both as IFTA). They represent the progressive scarring and degeneration of the kidney's structural components. The histopathologist looks for areas with too much connective tissue at the expense of more active tissue, or areas where the tubules waste away. They annotate those areas and estimate their size in percentage of the entire area of the kidney biopsy.
We used a semantic segmentation model, namely a UNet model, to assign a label to each pixel in the image out of one of these classes: IFTA, non-IFTA, background. In this way the model can identify the IFTA area in the image, by accurately determining borders and the extension of it.



ARTERIAL NARROWING

Arterial narrowing in the kidney occurs when the arteries that supply blood to the kidneys become narrowed. This narrowing can reduce blood flow to the kidneys, leading to a decline in kidney function.
The histopathologist needs to find at least one artery in the biopsy that is sectioned in a transverse plane, and compare the size of the lumen with the size of the wall.
We trained first an object detection model to detect all the arteries in the biopsy and rank them, to prioritize the ones that are best suited to the arterial narrowing evaluation. The ranking is based upon a computer-based classification and a set of deterministic rules, defined with the help of experts histopathologists.
The arteries that are suitable for the assessment, are then scored with an images segmentation model that detects the lumen, the wall and the background. Subsequently, it applies some image processing technique to rotate the image appropriately and calculate diameters of the wall and the lumen and their relative size.
Out of all the tasks, this is the one that is most subjective, where it's crucial to provide an interface that allows flexibility for the histopathologist to complement his own judgement.

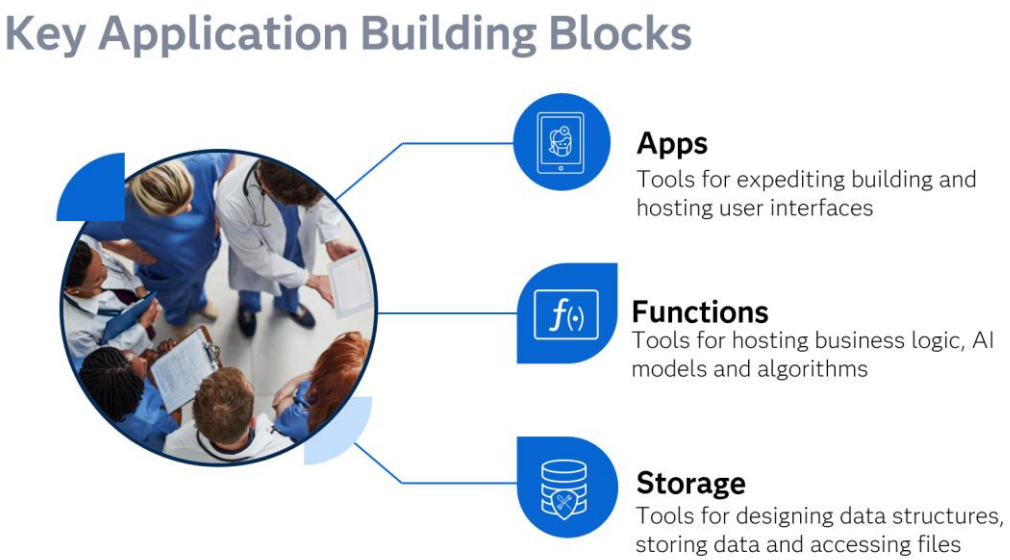


DEVELOPING APPLICATIONS

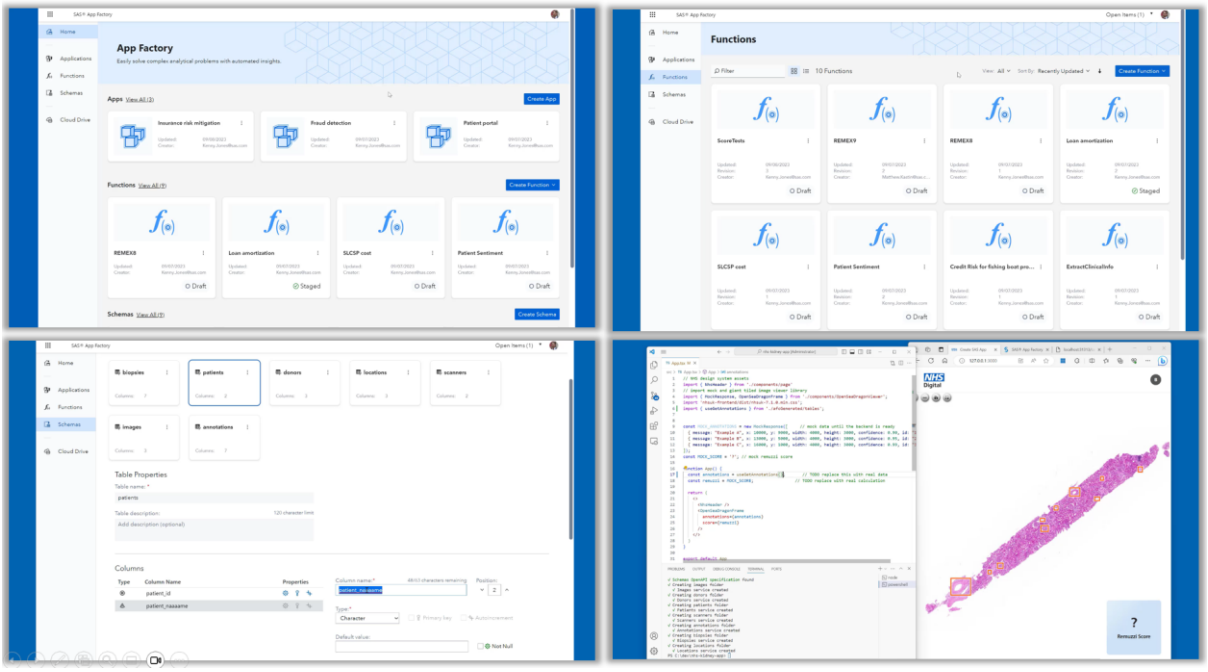
For the system to really provide value, we need to optimize the interaction between humans and AI, striking a balance between the automated capabilities of AI models and the discernment of highly trained professionals. It means that the computer vision models mentioned before need to be served in a easy-to-use application, where the histopathologist can review and interact with the results.

Three components must be considered:

- **Storage**: design data structures, store data and access files
- **Functions**: host business logic, AI models and algorithms
- **Apps**: build and host the user interface



We used SAS App Factory, that is a rapid application development environment for creating fit-for-purpose, AI-driven applications. The offering automates the setup and integration of a cloud-native tech stack built on React, TypeScript and Postgres. It allows developers to focus on getting models and AI-driven applications into production. SAS App Factory has planned general availability for 2024.



CONCLUSION

AI can revolutionize healthcare by automating repetitive and error-prone tasks, freeing up clinicians to focus on complex patient care. Our application, powered by advanced computer vision models, aims to replicate human judgment in a specific protocol that assess kidney chronic damage before transplantation. This approach empowers clinicians to "trust, but verify," accessing the results in an easy-to-use application that ensures the reliability of AI-generated insights.

CONTACT INFORMATION

Your comments and questions are valued and encouraged.
Contact the author at:
Author Name: Federica Citterio
Company:SAS Institute
Address: Via Carlo Darwin, 20/22, 20143 Milano, Italy
Email: Federica.Citterio@sas.com
Website: https://www.linkedin.com/in/federica-citterio/