BIOGRAPHICAL SKETCH

Provide the following information for the key personnel and other significant contributors in the order listed on Form Page 2.
Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME Anthony P. Reeves	POSITION TITLE Professor of Electrical and Computer Engineering
eRA COMMONS USER NAME (credential, e.g., agency login) APREEVES	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(s)	FIELD OF STUDY
University of Kent, Canterbury, UK	B.Sc.	1970	Electronics
University of Kent, Canterbury, UK	Ph.D.	1973	Electronics

A. Personal Statement

My research career has a focus on advancing the science of quantitative measurements from images with a particular focus on medical applications. Over the last 17 years year our Vision and Image Analysis research group has established a unique fully automated image analysis system that makes a large number of quantitative image measurements and radiomic evaluations on low-dose CT images of the chest. This system will be used in the proposed project to computer the quantitative image biomarkers associated with every low-dose CT image available in the cohort.

Recent papers demonstrate our fully automated methods for the analysis of large datasets (1-2) and our experience in using radomic methods for image analysis of pulmonary nodules (3,4).

1. Reeves, A. P., Xie, Y. and Liu, S. (2018), Automated image quality assessment for chest CT scans. Med. Phys., 45: 561–578. doi:10.1002/mp.12729
2. Reeves, A. P., Xie, Y., and Liu, S. Large-scale image region documentation for fully automated image biomarker algorithm development and evaluation. *Journal of Medical Imaging 4*, 2 (2017), 024505.
3. Liu, S., Xie, Y.,A. Jirapatnakul, A, and Reeves, A. P. "Pulmonary nodule classification in lung cancer screening with three-dimensional convolutional neural networks," Journal of Medical Imaging,4(4): 041308, Nov. 2017
4. Reeves, A. P., Xie, Y., and Jirapatnakul, A. Automated pulmonary nodule CT image characterization in lung cancer screening. *Int J CARS 11*, 1 (2016), 73-88.

B. Positions and Honors.

Positions and Employment

1973 - 1974 Research Assistant, Department of Physics and Astronomy, University College London, UK
1974 - 1975 Visiting Assistant Professor, Department of Electrical and Computer Engineering, University of Wisconsin-Madison
1975 - 1976 Visiting Assistant Professor, Department of Electrical Engineering, McGill University, Canada.
1976 - 1982 Assistant Professor, School of Electrical Engineering, Purdue University.
1982 (Summer) Visiting Professor, Pavia University, Italy.
1982 - 2006 Associate Professor, School of Electrical Engineering, Cornell University.
1987 - 1988 (On leave from Cornell) Associate Professor, Department of Computer Science, University of Illinois at Urbana-Champaign
2000 - present Associate Professor of Electrical Engineering in Radiology, Weill Medical College of Cornell University.
2010 - present Adjunct Professor, Department of Radiology, Mount Sinai School of Medicine
2006 - present Professor, School of Electrical and Computer Engineering, Cornell University.

Other Experience and Professional Memberships

1977 – present Senior member of the Institute of Electrical and Electronics Engineers
1977 – present Member the Association for Computing Machinery
1982 – present Senior Member of SPIE (formerly the Society of Photo-Optical Instrumentation Engineers)
2007 – present Member of the Radiological Society of North America
2003 – 2011 Member of the Lung Image Database Consortium (LIDC) steering committee
2009 – present Member of the RSNA Quantitative Imaging Biomarkers Alliance (QIBA)

C. Contribution to Science

The main contributions to science from my research program are to bring precise image measurement to clinical practice. Radiology traditionally has not made good use of measurement science preferring, in general, the inaccurate measurements made my human observation and interactive measuring tools. This is in sharp contrast to the precision control that is in place in many other areas of medicine; for example, laboratory blood analysis tests.

Pulmonary Nodule Volumetrics

The most significant scientific contribution occurred when I became acquainted with medical imaging analysis in 1997 when I met Caludia Henschke and David Yankelevitz. The work they were doing in pulmonary nodules size measurement was a natural fit to the work we had done on 3D image analysis. The major advance was to consider that the pulmonary nodule was a three-dimensional entity spanning several images slices rather than a representation in a single 2D image slice. This started the interest in measurement using volumetrics which is today is supported by all major CT manufacturers. The first publication below outlined the clinical benefit, subsequent papers provide details on the novel techniques that were used.

D. F. Yankelevitz, A. P. Reeves, W. J. Kostis, B. Zhao, and C. I. Henschke. CT small pulmonary nodules: Volumetrically determined growth rates based on CT evaluation. Radiology, 217(1):251-256,2000

W. J. Kostis, A. P. Reeves, D. F. Yankelevitz, and C. I. Henschke. "Three-dimensional segmentation and growth-rate estimation of small pulmonary nodules in helical CT images." *IEEE Transactions on Medical Imaging*, 22:1259-1274, October 2003

A. P. Reeves, A. B. Chan, D. F. Yankelevitz, C. I. Henschke, B. Kressler, and W. J. Kostis. "On measuring the change in size of pulmonary nodules." *IEEE Transactions on Medical Imaging*, 25:435-450, April 2006

Emphysema

Our research has also provided review and developments of currently used emphysema measures from CT images. We have improved the precision of these measures by compensating for CT scanner settings especially in the context of low-dose CT scans.

D. A. McAllister, F. S. Ahmed, J. H. M. Austin, C. I. Henschke, B. M. Keller, A. Lemeshow, A. P. Reeves, S. Mesia-Vela, G. D. N. Pearson, M. C. Shiau, J. E. Schwartz, D. F. Yankelevitz, and R. G. Barr, "Emphysema predicts hospitalization and incident airflow obstruction among older smokers: A prospective cohort study," *PLOS ONE*, 9(4):e93221, 2014.

B. M. Keller, A. P. Reeves, C. I. Henschke, and D. F. Yankelevitz. "Multivariate Compensation of Quantitative Pulmonary Emphysema Metric Variation From Low-Dose, Whole-Lung CT Scans," *AJR*, 197(3):W495-W502, 2011.

R. G. Barr, S. Mesia-Vela, J. H. M. Austin, R. C. Basner, B. M. Keller, A. P. Reeves, D. Shimbo, and L. Stevenson. "Impaired flow-mediated dilation is associated with low pulmonary function and emphysema in ex-

smokers: The emphysema and cancer action project (EMCAP) study." *Am. J. Respir. Crit. Care Med.*, 176(12):1200-1207, 2007.

Quantitative image biomarkers

Recent interest in quantitative image biomarkers has resulted in the creation of the RSNA sponsor quantitative image biomarkers alliance (QIBA). We have been active in moving forward the statistical issue in this important initiative.

D. C. Sullivan, N. A. Obuchowski, L. G. Kessler, D. L. Raunig, C. Gatsonis, E. P. Huang, M. Kondratovich, L. M. McShane, A. P. Reeves, D. P. Barboriak, A. R. Guimaraes, R. L. Wahl For the RSNA-QIBA Metrology Working Group, "Metrology standards for quantitative imaging biomarkers," *Radiology*, 2015. DOI: http://dx.doi.org/10.1148/radiol.2015142202.

N. A. Obuchowski, A. P. Reeves, E. P. Huang, X. Wang, A. J. Buckler, H. J. Kim, H. X. Barnhart, E. F. Jackson, M. L. Giger, G. Pennello, A. Y. Toledano, J. Kalpathy-Cramer, T. V. Apanasovich, P. E. Kinahan, K. J. Myers, D. B. Goldgof, D. P. Barboriak, R. J. Gillies, L. H. Schwartz, D. C. Sullivan for the Algorithm Comparison Working Group, "Quantitative imaging biomarkers: A review of statistical methods for computer algorithm comparisons," *Stat Methods Med Res*, 24(1): 68-106, 2015.

A. P. Reeves, Y. Xie, and A. Jirapatnakul, "Automated pulmonary nodule CT image characterization in lung cancer screening," *Int J CARS*, 2015. DOI: http://dx.doi.org/10.1007/s11548-015-1245-7.

E. P. Huang, X. Wang, K. R. Choudhury, L. M. McShane, M. Gönen, J. Ye, A. J. Buckler, P. E. Kinahan, A. P. Reeves, E. F. Jackson, A. R. Guimaraes, G. Zahlmann, and Meta-Analysis Working Group. Meta-analysis of the technical performance of an imaging procedure: Guidelines and statistical methodology. Stat Methods Med Res, 24(1):141-174, 2015.

3D OCR

The 3D optical tomography microscope is a unique instrument capable of 3D sub-micron imaging of single cells. With support from NSF, we have explored how the 3D algorithms that we have developed for CT medical imaging may be redirected towards the diagnosis of cancer in the 3D OCR images.

Q. Miao, A.P. Reeves, Patten F.W., and Seibel E.J. "Multimodal 3d imaging of cells and tissue, bridging the gap between clinical and research microscopy," *Annals of Biomedical Engineering*, 40(2):263-276, 2011.

N. Agarwal, A. M. Biancardi, F. W. Patten, A. P. Reeves, and E. J. Seibel. Three-dimensional dna image cytometry by optical projection tomographic microscopy for early cancer diagnosis. *Journal of Medical Imaging*, 1(1):017501, June 2014.

Image segmentation of low-dose CT scans

We have designed a number of robust image processing methods that have facilitated the solution of a range of applications involving precision automated image analysis. That is, high-precision segmentations are achieved often in situations where the CT imaging is at a lower dose and hence exhibits higher noise and distortion than traditional clinical CT image scans. Several examples of the range of these applications are listed below. Our current fully automated system for the analysis of low-dose chest CT images segments a scan into over 100 individual anatomical components and has been evaluated on over 7000 whole-chest CT scans. This unique system provides the foundation for exploring and validating both existing and new quantitative image biomarkers.

M. Li, A. Jirapatnakul, A. Biancardi, M. L Riccio, R. S Weiss, and A. P Reeves. Growth pattern analysis of murine lung neoplasms by advanced semi-automated quantification of micro-CT images. *PloS one*, 8(12):e83806, 2013.

J. Padgett, A. M. Biancardi, C. I. Henschke, D. F. Yankelevitz, and A. P. Reeves, "Local noise estimation in low-dose chest CT images," *Int J CARS*, 9(2):221-229, 2014.

A. C. Jirapatnakul, Y. D. Mulman, A. P. Reeves, D. F. Yankelevitz, and Henschke H.I. Segmentation of juxtapleural pulmonary nodules using a robust surface estimate. International Journal of Biomedical Imaging, 2011(632195):1–14, 2011.

W. S. Vanden Berg-Foels, S. J. Schwager, R. J. Todhunter, and A. P. Reeves. "Femoral head bone mineral density patterns may identify hips at risk of degeneration," *Annals of Biomedical Engineering*, 39(1):75-84, 2011.

D. Research Support

Ongoing Research Support

National Aeronautics & Space Administration NASA (Co-PI Reeves) 1/15/2018 to 1/14/2020 *Use pf FLEX data to enhance video image processing for studying combustion of soot-producing jet fuel droplets and their blends with bio-derived fuels.* The purpose of this project is to retrospective analyze FLEX video images recorded on the space station and to prospectively analyze drop tower videos of fuel combustion in zero gravity conditions. Improved precision image measurements will be made possible through the development of advanced computer analysis methods.

Completed Research Support:

Flight Attendants Medical Research Institute (Henschke) 01/07-12/17 *FAMRI-IELCAP Collaborative Network*. *Screening for Respiratory and Cardiac Diseases in Never-smokers Exposed to Secondhand Smoke*. The goal of this project is to determine the probability of specific respiratory diseases (emphysema, chronic bronchitis, bronchiectases, focal pneumonia, lung and mediastinal cancer), cardiovascular diseases, and other diseases among study participants who have never smoked, including the way in which this probability relates to the indicators of risk, CT findings and quantitative lung health indices (e.g., age, second-hand smoke exposure, nodules) in order to develop appropriate clinical (screening and treatment) programs.

National Science Foundation NSF: 1014813 (Reeves) 15/9/2010-31/8/2013 *Interdisciplinary Research: Quantitative 3D Optical Topographic Microscopy for Lung Cancer Diagnosis* This project is to identify lung cancer from modifications to the 3D images of single cells.