

# MULTI CHOICE CHAIR IN MACHINE LEARNING

**2018-2022  
PROGRESS  
AND SUCCESS**



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**Faculty of Engineering,  
Built Environment and  
Information Technology**

Fakulteit Ingenieurswese, Bou-omgewing en  
Inligtingtegnologie / Lefapha la Boetšenere,  
Tikologo ya Kago le Theknolotši ya Tshedimošo

A photograph of a server room with rows of server racks and a blue overlay. The text is centered on the left side of the image.

**The collaboration between MultiChoice and the University of Pretoria is aimed at developing and sustaining scarce artificial intelligence, and specifically machine learning technology skills in South Africa.**



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*As we approach the end of the initial five-year term of support of the MultiChoice Chair in Machine Learning in the Faculty of Engineering, Built Environment and Information Technology, it is with a sense of pride and accomplishment that both partners look back at the progress and success that has been achieved.*

## Message from the Acting Deputy Dean: Research and Postgraduate Studies

Having occupied the position of Head of the Department of Electrical, Electronic and Computer Engineering at the time of the signing of the original Memorandum of Agreement with MultiChoice on 28 May 2018, I have a personal involvement in the success stories that have emerged from this partnership.

I wish to express my sincere appreciation to MultiChoice for its contribution to the Faculty's innovation and progress, as well as the opportunities it offered students to pursue postgraduate studies, and its belief in the quality of the teaching and research presented at the University of Pretoria. Five years later, we are able to look back at the progress that has been made and the success that has been achieved in terms of capacity development, and research and development.

I also wish to take this opportunity to thank the two chairholders: Prof Nelishia Pillay, representing the Department of Computer Science, and Prof Pieter de Villiers, representing the Computer Engineering programme in the Department of Electrical, Electronic and Computer Engineering. With the support of MultiChoice, they have succeeded in combining the data-based programming component of computer science with the computer engineering application of intelligent systems related to audio, video and signal processing to achieve unique benefits.

The research emanating from this partnership is not only future-focused, but has contributed to the development of an unparalleled skills set that enables the Faculty to innovate our tomorrow.

*Prof Johan Joubert*



# Faculty of Engineering, Built Environment and Information Technology, University of Pretoria

**TOP 1%**

OF ENGINEERING  
SCHOOLS IN THE  
WORLD

**TOP 352**

IN THE  
WORLD FOR  
ENGINEERING  
AND  
TECHNOLOGY

**TOP 350**

IN THE WORLD  
FOR ELECTRICAL  
AND ELECTRONIC  
ENGINEERING

**TOP 550**

IN THE WORLD  
FOR COMPUTER  
SCIENCE AND  
INFORMATION  
SYSTEMS

**100**

NRF-RATED  
RESEARCHERS

**18**

RESEARCH  
CHAIRS

**13**

RESEARCH  
CENTRES AND  
INSTITUTES

**6**

TRANS-  
DISCIPLINARY  
RESEARCH FOCUS  
AREAS



*When the opportunity presented itself for MultiChoice to partner with the University of Pretoria five years ago, the company had no idea that the benefits would exceed its expectations to the degree that it has. The partnership entailed the development of scarce artificial intelligence (AI) skills – specifically as they relate to machine learning (ML) technology – in South Africa.*

## Message from the Group Chief Technology Officer: MultiChoice

In 2018, when the idea of a Research Chair in Machine Learning at the University of Pretoria was born, Koos Bekker, the Chairperson of MultiChoice's parent company at the time, the Naspers Group, had already experienced the cutting-edge research that was being conducted in the University's Faculty of Engineering, Built Environment and Information Technology.

As far back as the early 1980s, researchers in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the University's Department of Electrical, Electronic and Computer Engineering developed an application-specific integrated circuit (ASIC). It was already in use in the company's MNet decoders by the mid-1980s.

The management of MultiChoice was so impressed by what it had seen at the University of Pretoria's School of Engineering in terms of equity, research and human capital development, that discussions ensued with the Faculty's former Dean, Prof Sunil Maharaj (now Vice-Principal: Research, Innovation and Postgraduate Education). These discussions would lead to collaboration between the two entities to establish a mutually agreed roadmap that would result in the establishment of a Research Chair in Machine Learning.

At that stage, machine learning was just starting to gain traction as an emerging discipline in computer science and computer engineering. Companies in the information and communication technology (ICT) sector were recognising the benefits of investing in this disruptive technology.

The University's Faculty of Engineering, Built Environment and Information Technology is one of the foremost faculties of its kind in Africa. Its programmes in Computer Science and Information Systems are ranked in the top 550 in the world according to the latest QS World University Rankings by Subject in the field of engineering and technology.



MultiChoice therefore considered a partnership with the University to acquire and identify human resource capacity for the company, which would result in a win-win engagement.

According to the Memorandum of Agreement, the University would provide MultiChoice with human capital development, research and development, consultancy services, advisory, supervisory and managerial support, as well as resources that could contribute to the development of specific projects to the benefit of MultiChoice. The agreement included the awarding of bursaries to promising students in computer science and computer engineering.

MultiChoice would be granted access to the creative projects that were developed during the students' research. In addition, MultiChoice grants students the option of completing its vacation work programme, as well as the opportunity of employment upon conclusion of their studies.

Further to supporting students financially, MultiChoice also provides guidance in terms of potential research topics that could benefit the University in terms of research output, as well as MultiChoice in terms of maintaining its competitive edge in the industry.

Some current and future topics include the following:

- Technical failure analysis
- Real-time monitoring
- The extraction or creation of metadata
- Video-on-demand quality assurance
- Cloud resource allocation
- Machine learning on embedded systems
- Social media analytics
- Customer profiling for automated testing
- Computer network intrusion detection
- Piracy monitoring
- Forecasting weather-related impacts on service delivery

The outputs of the research emanating from the projects associated with the Chair in Machine Learning not only benefit the University and MultiChoice, but also have the advantage of creating more knowledge and competence in South Africa. The ability to harness machine learning has seen some excellent projects from both the computer science and computer engineering domains. A student project aimed at automatic thumbnail selection using machine learning, for example, has been accepted for deployment at MultiChoice. This is a very exciting outcome of the partnership.

Another project, which focused on the development of an ML-based recommender system, is also being implemented by MultiChoice. Following the conclusion of their studies, two graduates of the Computer Engineering programme have been appointed by MultiChoice, with a third graduate joining them before the end of the year. These graduates not only illustrate the success of the programme, but also the value of employing a graduate from the University of Pretoria. As employees, they are truly phenomenal – they are well-rounded individuals, who fit into the context and culture of the organisation right away. They are able to step into their role in the company with an immediate understanding of what is expected of them and how to work as a member of a team.

I have a great appreciation for the role played by the two chairholders at the University of Pretoria: Prof Nelishia Pillay (Computer Science) and Prof Pieter de Villiers (Computer Engineering). Their supervision and guidance of students at undergraduate and postgraduate level have definitely contributed to the success of the programme.

I look forward to partnering with the University of Pretoria for an additional five-year term, and to see the current projects reaching their anticipated conclusion to the benefit of the country at large.

*Gerdus van Eden*



## Message from the Chairholder: Computer Science



*The biggest advantage of the MultiChoice Chair in Machine Learning from the perspective of the Department of Computer Science is its ability to attract top postgraduate students who are involved in a very visual aspect of the discipline.*

Machine learning is making a major contribution to the advancement of information and communication technology at the moment. Students' involvement in projects of relevance to MultiChoice gives them good experience that they can use when they enter industry. Working in collaboration with this cutting-edge technology giant in sub-Saharan Africa gives them the feeling that what they are doing is of benefit to the people of Africa.

The projects that our postgraduate students are doing on topics related to the MultiChoice programme have generated a lot of internationally published research. This contributes to giving the University of Pretoria the competitive edge in computer science research. It also adds to the Department's research output in terms of both the number of graduates and the number of publications. This played a role in the University's improved international ranking in computer science and information systems.

While most research projects initiated in the Department of Computer Science have the potential of being largely academic and theoretical – especially at postgraduate level – the MultiChoice projects give students the benefit of being able to use what they have learnt in industry.

This meets one of the requirements of the MultiChoice Research Chair in terms of human capacity and skills development in artificial intelligence and machine learning, and encourages students to pursue further postgraduate studies. At master's level, students develop techniques that enhance MultiChoice's existing technology. MultiChoice assists by providing a list of potential topics from which students can choose to conduct research in an area that interests them or that is aligned to previous research they have conducted.

Students can make use of data that is available at MultiChoice for their research, and attend regular meetings with the company's AI team to discuss the application of their research. This gives the students additional experience in solving real-world problems, while improving their communication and problem-solving skills.

Through this support from MultiChoice, students are exposed to real-world applications. They also have the opportunity of employment by the company following the completion of their studies, where they can apply what they have learnt.

I look forward to the continued collaboration with MultiChoice.

*Prof Neliswa Pillay*





## Message from the Chairholder: Computer Engineering



*From the perspective of the Computer Engineering programme, the collaboration with MultiChoice has fostered a greater appreciation of the technological challenges and opportunities encountered in industry.*

The establishment of the MultiChoice Chair in Machine Learning opened novel research avenues to students in the Department of Electrical, Electronic and Computer Engineering that are problem specific, and for which ready-made solutions do not exist. This, in turn, led to research projects that were addressed by students supported by MultiChoice as part of their postgraduate studies.

This enabled skills to be developed in machine learning applications related to audio and video processing, the streamlining of business processes, recommender systems, automated translation and speech recognition, and other topics of interest to MultiChoice. For example, automated translation allows MultiChoice to develop local content that can be consumed by a wider audience. This has the added advantage of promoting multilingualism within the South African context.

Computer engineering students are benefitting from the partnership with MultiChoice in many ways. Postgraduate study fosters critical thinking and develops the skill to approach a problem using sound engineering and scientific principles. This enables them to correctly characterise a problem. This is a highly sought-after skill in business, not only locally, but internationally as well.

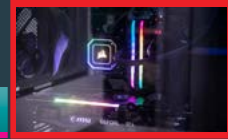
Students are also equipped with knowledge and skills in machine learning with a focus on audio, video and signal processing applications. These skills are in demand in South Africa and abroad, and could assist in making companies like MultiChoice more globally competitive. Through the opportunity of participating in MultiChoice's vacation work programme, students also get to meet their prospective employers and colleagues.

The most important benefit, of course, is the financial support the students receive from MultiChoice, which allows them to proceed with postgraduate study. For many students, this may otherwise not have been possible.

In the process, the research outputs developed in the form of papers presented at international peer-reviewed conferences and published in accredited journals contribute to expanding the Department's research profile.

With the extension of the partnership for a further five years, I am confident that an even closer working relationship will be established with MultiChoice.

*Prof Pieter de Villiers*



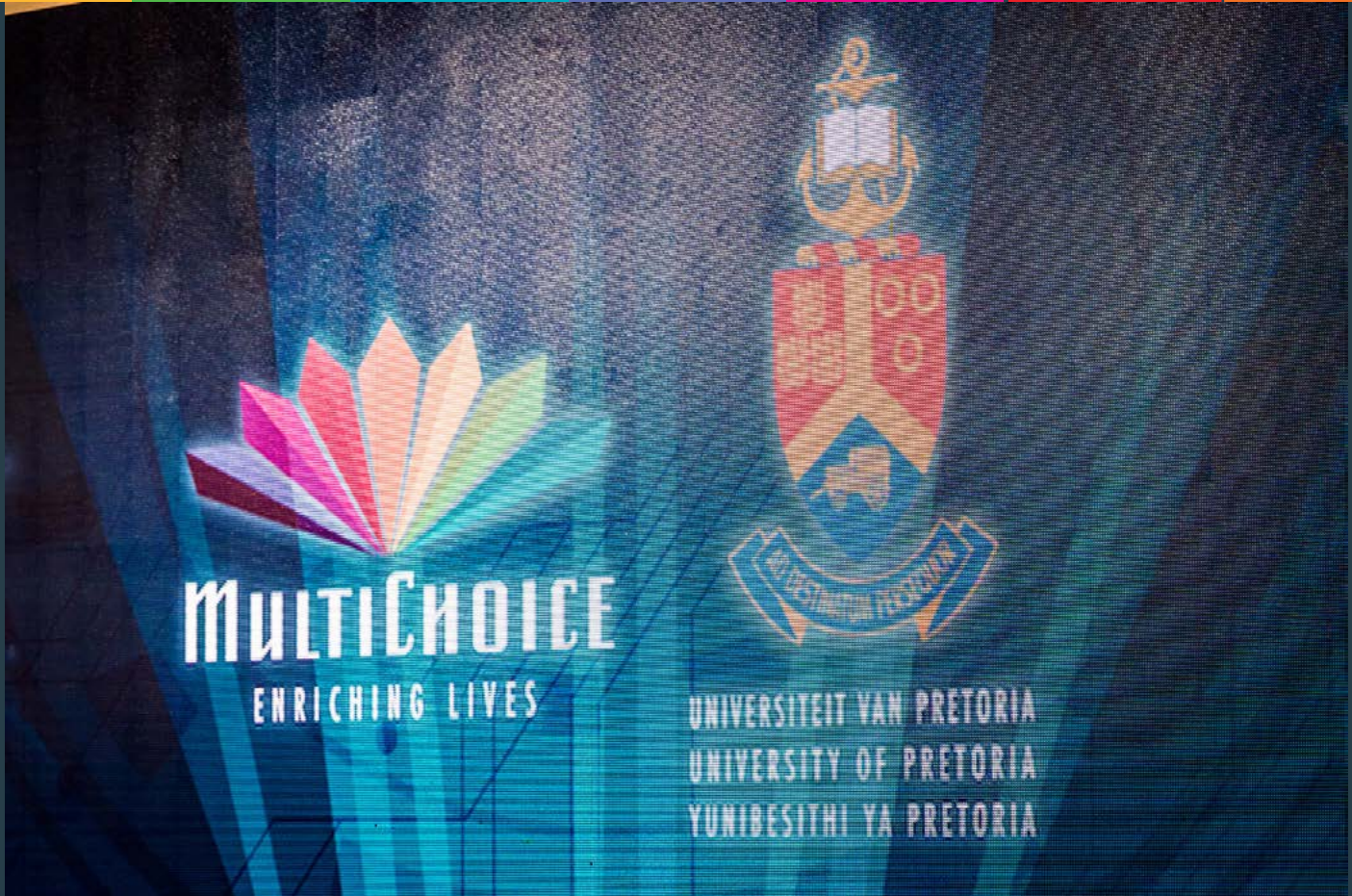
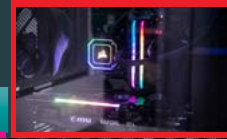
# Five years of mutually beneficial collaboration

*The recent pandemic and global uncertainties have highlighted the advantages of a digital society. Increased online activity has demonstrated how large volumes of data travels all over the world every second of the day. Machine learning (ML) and artificial intelligence (AI) are two elements of the digital future that assist humans to perform tasks where underlying patterns in and insights into large volumes of data are not obvious.*

In recognition of the key role that AI – and specifically machine and deep learning – will play in unlocking a truly digital future, MultiChoice South Africa partnered with the University of Pretoria (UP) to sponsor the MultiChoice Chair in Machine Learning in 2018. This research chair, located in the Faculty of Engineering, Built Environment and Information Technology, strives to address the global skills shortage in ML development, thereby helping to bridge the digital divide. This will enable Africa to excel, given its unique challenges and opportunities.

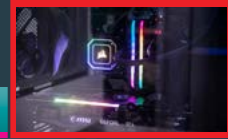
The Chair is jointly located in the School of Information Technology and the School of Engineering. Acting as co-chairholders, Prof Nelishia Pillay represents the Department of Computer Science, and Prof Pieter de Villiers represents the Department of Electrical, Electronic and Computer Engineering. Prof Pillay heads her Department's Nature-inspired Computation Optimisation Group, while Prof De Villiers heads his Department's Signal Processing and Telecommunications Research Group.

The initial five-year agreement entered into between UP and MultiChoice South Africa in 2018 was aimed at the pursuit of joint collaboration and research for their mutual benefit. Given its past success, the agreement has now been renewed for a second five-year term. The Chair undertakes academic and applied research, as well as human resource development in the field of ML, which is applied to several advanced topics of interest to MultiChoice. The company has identified several opportunities and projects to apply AI and ML at various points throughout its value chain. This includes content creation, understanding what content to offer customers (recommender systems), customer service and improving interactions with customers.



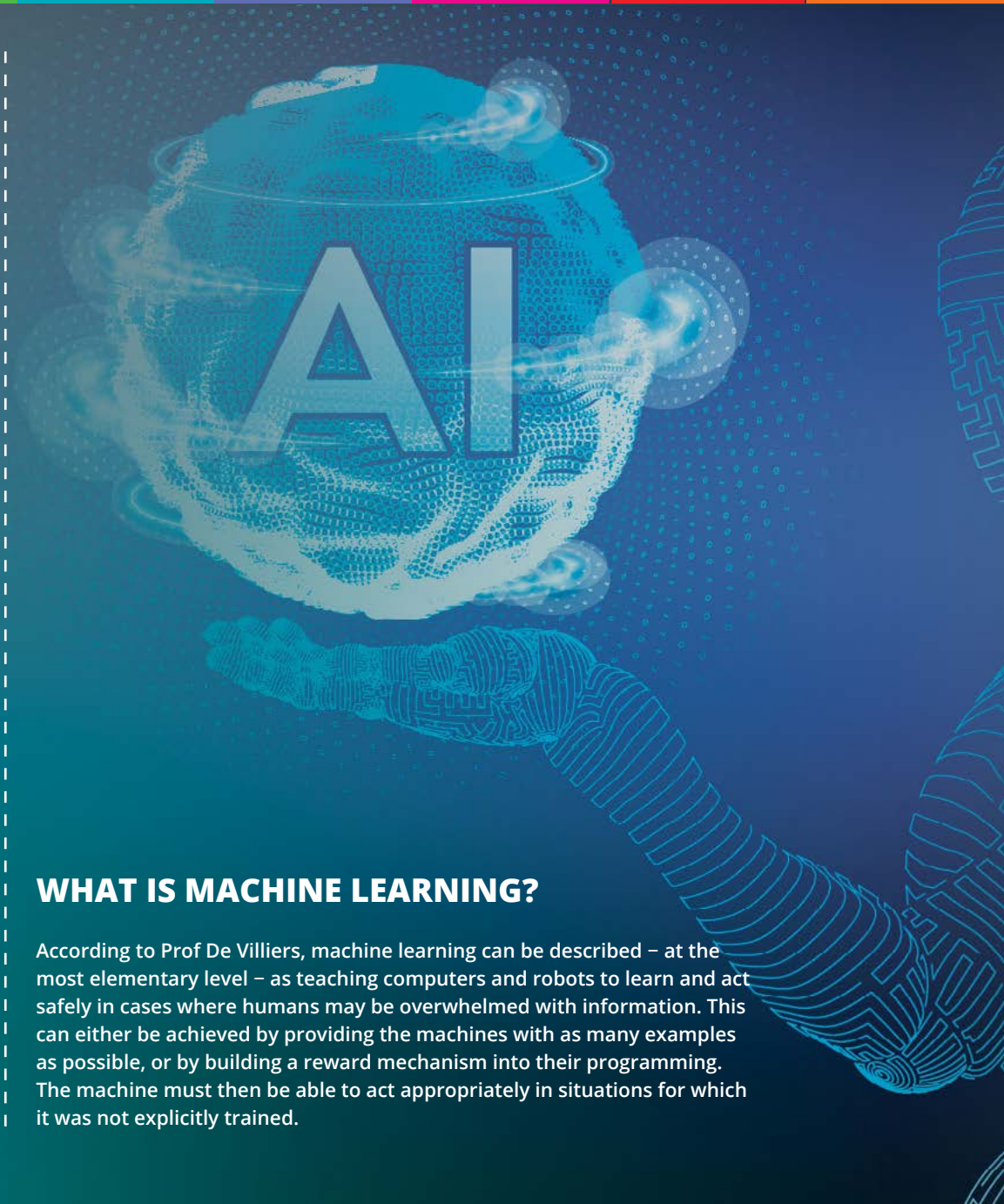
These challenges and opportunities are addressed through master's and PhD projects that propose novel and creative ML approaches to solve global problems, while providing students access to pressing real-world industry research and realistic data. Several exciting ML-related research projects are currently under way or have been completed within the Chair in the application domain of satellite broadcasting and internet video streaming.

Topics include, but are not limited to, the automated genre labelling of motion picture (movie) trailers, the automated analysis of audio and video content to extract meaningful and descriptive metadata, the automated generation of closed captions through automated audio processing, automated audio and video segmentation for scene skipping, automated movie trailer creation, and even the forecasting of weather-related impacts on DStv service delivery.



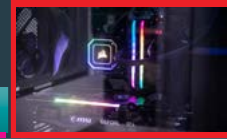
Some of these projects address Big Data challenges, where the volume, velocity, variety, veracity and value (the 5 Vs of Big Data) of video and audio content have become so overwhelming that it is impossible for humans to process. As ML is a very specialised field, the partnership between MultiChoice and UP is a forward-looking way to nurture and improve these skills in South Africa, while addressing problems of research and commercial interest through interesting collaborative projects.

The benefits of this collaboration have already been realised by students who have performed vacation work at MultiChoice, and three graduates of the Chair who have been offered employment at MultiChoice. Early in 2020, several MultiChoice staff members also attended a short course on ML that was presented under the auspices of the MultiChoice Chair in Machine Learning, further demonstrating the benefits of this collaboration.



## WHAT IS MACHINE LEARNING?

According to Prof De Villiers, machine learning can be described – at the most elementary level – as teaching computers and robots to learn and act safely in cases where humans may be overwhelmed with information. This can either be achieved by providing the machines with as many examples as possible, or by building a reward mechanism into their programming. The machine must then be able to act appropriately in situations for which it was not explicitly trained.



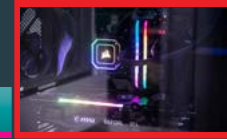
The objective of ML is not, as some people fear, to replace jobs, but rather to support and assist humans in economic and technological development. It is an enabling technology.

Students and practitioners must be prepared with the requisite knowledge and skills for the current Fourth Industrial Revolution and the subsequent Fifth Industrial Revolution, or Society 5.0. The MultiChoice Chair in Machine Learning represents a significant step towards preparing and developing human resources for this exciting era that awaits us.

According to Prof Pillay, ML has contributed to various facets of life in South Africa, including industry, education and society. It has made an impact in various areas of industry, such as reducing energy consumption, assisting in financial forecasting, and developing automated software, network optimisation and content management.

In education, ML has enabled academics to provide students with individualised tutoring by means of intelligent tutoring systems. ML has also enabled lecturers to study student performance and identify learning difficulties that may exist.

**Machine learning  
is an enabling  
technology**



## MACHINE LEARNING IN THE ENTERTAINMENT INDUSTRY

One of the first ML initiatives implemented by the broadcasting industry was the automated creation of the 2017 Wimbledon segment. Where highlights of a major sporting event such as this would only be available hours later if compiled manually, ML enabled the highlights to be available immediately as automated content. This contributed to the improved productivity of broadcasting companies.

## THE WIDER IMPACT OF MACHINE LEARNING

The impact of ML can be seen in several other elements of society as well, such as automated music composition, automated art, and enabling conversation in a natural language with computers.

In 2017, AlphaGo, a computerised Go player driven by ML, beat the world's top Go<sup>1</sup> player in the world, Ke Jie, at the Future of Go Summit.

As we move towards a digital future, ML will play a pivotal role in meeting the challenges of digital transformation. It is anticipated that the incorporation of AI and ML to find industry solutions will improve economic growth rates in South Africa by 2035.



*Prof Cheryl de la Rey, former Vice-Chancellor and Principal of the University of Pretoria (left), and Calvo Mawela, CEO of MultiChoice South Africa.*

## A PARTNERSHIP TO FOSTER TECHNOLOGICAL TALENT

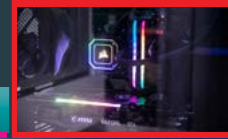
The University of Pretoria's collaboration with MultiChoice South Africa provides a platform to produce graduates capable of dealing with the challenges posed by the Fourth Industrial Revolution and to contribute to the country's economic growth.

The intention of the collaboration was to develop and sustain scarce AI, and specifically ML technology skills in South Africa.

The field of AI – and specifically machine and deep learning – is key to a truly digital future. There is a severe skills shortage worldwide, and even more so in Africa. MultiChoice has identified opportunities to apply AI and ML at various points throughout its value chain. This includes content creation, understanding what content to offer customers, customer service and improving its interactions with its customers. As this is a very specialised field, partnering with an academic institution such as the University of Pretoria was a very forward-looking way for MultiChoice to nurture these skills in South Africa.

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<sup>1</sup> Go is an abstract strategy board game for two players in which the aim is to surround more territory than the opponent. The game currently has over 20 million players, the majority of whom live in East Asia.

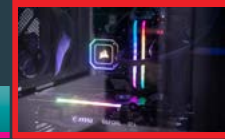


*Celebrating the launch of the MultiChoice Chair (from left) is Prof Sunil Maharaj, former Dean of the Faculty of Engineering, Built Environment and Information Technology, Buti Manamela, Deputy Minister of Higher Education and Training, Prof Cheryl de la Rey, former Vice-Chancellor and Principal of the University of Pretoria, and Calvo Mawela, CEO of MultiChoice South Africa.*

The Research Chair, which is fully funded by MultiChoice South Africa, acts as a bridge between the two partners to guide them on the projects and research topics to be chosen for sponsorship. It includes awarding bursaries and supporting students at all levels. These projects range from final-year and honours projects through to master's and PhD degrees in computer engineering and computer science.

At the launch of the Chair on 28 May 2018, Buti Manamela, Deputy Minister of Higher Education and Training, said:

“Our country is fully aboard the Fourth Industrial Revolution train, and this chapter, which illustrates the partnership between the private and public sector, is indicative of our commitment to place our country at the centre of development. Yes, there should be technological advancement and development, and as government, we believe in guiding this in a more people-centred fashion. We are pleased that this is taking shape in this manner, and hope to see many more collaborations between the public and the private sector.”



The CEO of MultiChoice South Africa, Calvo Mawela, said that the Chair will help MultiChoice grow its pool of talent in engineering to help the company build its digital future: “Technology and innovation are part of our DNA as a company, so this is a natural extension to ensure that we remain at the forefront of developments. This Chair will enable us to tap into the largest and highest internationally ranked local engineering school with an excellent transformation record. More importantly, we will make a significant contribution to South Africa to compete on an international stage in the new digital future.”

The University of Pretoria’s Vice-Chancellor and Principal at the time, Prof Cheryl de la Rey, said that technology is evolving at an exponential scale.

“It is vital for educational institutions to invest in researching and educating students about the next waves of technology. We are thrilled to have found a partner who supports us in developing high-level skills and enhancing technology education in South Africa so as to be at the forefront in the digital future.”

## PROGRESS AND RESEARCH SUPPORT

During the course of the first five years of the partnership, MultiChoice has funded a total of 13 students across various levels of undergraduate and postgraduate study: eight in the Department of Computer Science and five in the Department of Electrical, Electronic and Computer Engineering.

### COMPUTER SCIENCE

- Derrick Beckedah: PhD
- Mia Gerber: PhD
- Dr Ahmed Hassan: Postdoctoral fellow
- Rahul Kapoor: BSc Hons, MSc
- Gisele Marais: MSc
- Kyle Pretorius: BSc Hons, MSc
- Jana Sander: BSc (final year), BSc Hons
- Emilio Singh: MSc, PhD

### COMPUTER ENGINEERING

- Adolfo Almeida: BEng Hons, MEng
- Paul Claasen: BEng Hons
- Alexander Loubser: BEng Hons: MEng
- Joseph Mervitz: MEng
- David Sithole: BEng (final year); BEng Hons

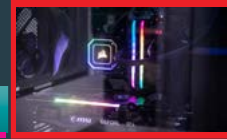
Two graduates who were supported by MultiChoice, Adolfo Almeida and Joseph Mervitz, are already working at MultiChoice, while Alexander Loubser will join them before the end of the year.

Several research outcomes emanated from the partnership, including journal articles and conference proceedings in which bursary holders are contributing authors (see page 28).

*Graduates Adolfo Almeida and Joseph Mervitz*







The research outcomes of the project not only contributed to the development of the students who were sponsored to complete their studies. It also led to the improved research standing of the two chairholders:

- Prof Nelishia Pillay's National Research Foundation (NRF) ranking improved from C1 to B2.
- Prof Pieter de Villiers' NRF ranking improved from Y2 to C1.

**Future projects will focus on challenges and opportunities with high business value for MultiChoice.**

## **FUTURE FOCUS**

With the extension of the MultiChoice Chair in Machine Learning for a further five years, the projects that are still ongoing can be concluded, with an added benefit for both MultiChoice and the University of Pretoria.

Future MultiChoice-based research projects will furthermore focus on challenges and opportunities with high business value for the company. Given that several former students are now working at MultiChoice, this will enable a closer working relationship with MultiChoice. These former students can also interact with current and future students more directly on their projects. Such interactions will give students a better understanding of industry needs, and will ensure that they experience and become used to the culture and team dynamics at MultiChoice.



# Flagship projects

## COMPUTER SCIENCE

## AUTOMATIC THUMBNAIL SELECTION

### THE NITTY-GRITTY

Kyle Pretorius, a master's degree student, developed a system for automatic thumbnail selection using genetic programming and convolutional neural networks. This entailed feeding a movie trailer into the system and playing the video frames one after each other. The machine learning (ML) system then scores the frames based on how good the image would be as a thumbnail, which can be used in DStv's menu of what to watch. Once processed, the top five frames are ranked, from which one can select the most suitable one to use. By automating the thumbnail selection process, as opposed to generating it manually, benefits of time and cost-savings are achieved.

### WHAT IS AUTOMATIC THUMBNAIL SELECTION?

Thumbnails are cover images that are used to represent a video or attract viewers. The process of manually selecting thumbnails for movies or series can take up time and resources. ML can be used to automate the system of selecting thumbnails.

The problem can be reduced to a binary classification problem, in which the following needs to be done:

- Create a dataset consisting of good and bad examples of thumbnails.
- Train a classifier to assign scores to examples, where higher scores indicate that the example is likely to be a better thumbnail.
- Use the trained classifier to assign scores to frames sampled from the video of interest.
- Select or suggest the frames with the highest scores as thumbnails for the video.

### COMPARISON OF CLASSIFICATION APPROACHES

The main aim of this project was to compare two image classification approaches when applied to automatic thumbnail selection.

The following two approaches were used:

- Convolutional neural networks (CNN): the state-of-the-art method for image classification that has been successfully applied to thumbnail selection before.
- Novel hybrid genetic programming: a new method proposed for this project utilising the strengths of convolutional neural networks to enable genetic programming to create classifiers for images.

### THE HYBRID GENETIC PROGRAMMING APPROACH

Genetic programming is an evolutionary approach that aims to search for a program that can solve the problem at hand. It has been found to perform well when used to evolve classifiers that operate on



*CNN was used to select the top three thumbnails for two trailers: “Thor Ragnarok” and “Jumanji: the Next Level”. The thumbnails are shown with the preference decreasing from left to right.*

a small number of input features. However, genetic programming struggles when applied to images due to the larger number of features and spatial correlation between pixels. The proposed hybrid programming approach aims to use the convolutional layers from a pre-trained CNN to extract features from the image.

Once images have been processed by the convolutional layers, a one-dimensional feature vector remains. The features within this vector have fewer features than in the original image, and have reduced spatial correlation. Genetic programming can now be used to evolve classifiers that operate on the extracted features, thereby removing the need to operate on images directly.

## RESULTS

It was found that CNNs outperformed the proposed hybrid genetic programming approach in terms of classification accuracy and loss. This was likely due to the fact that

the extracted feature vector was still too large for genetic programming to efficiently evolve classifiers (a minimum of 512 features were extracted). CNNs were also able to more consistently select suitable thumbnails.

## DATASET

A dataset consisting of good and bad examples of thumbnails had to be created for this project. This was done using YouTube’s developers’ application programming interface (API). Using this API, lists of video identifiers of trailers for movies and series could be obtained.

For each video identifier, examples of thumbnails were obtained as follows:

- Good examples: YouTube’s automatic thumbnail selection algorithm selected three thumbnails.
- Bad examples: Three random frames were selected within a video (the frames that were selected have a high probability of making a bad thumbnail).

A dataset comprising roughly 2 500 examples was created using this approach, with examples equally balanced between the classes.

## CONVOLUTIONAL NEURAL NETWORKS

CNNs are regarded as the state-of-the-art approach for image analysis. They differ from standard deep neural networks by adding convolutional layers at the start of the network. These convolutional layers allow CNNs to operate more efficiently on data that consists of features with spatial relationships, such as images.

The aim of this component of the project was to compare the performance of well-known CNN architectures when applied to thumbnail selection.

It was found that a modified version of ResNet-50 produced the best results in terms of classification accuracy on the created thumbnail dataset.



## COMPUTER SCIENCE

**THE AUTOMATED DESIGN OF VIDEO MULTIMETHOD ASSESSMENT FUSION****THE NITTY-GRITTY**

Dr Ahmed Hassan is a postdoctoral fellow who hails from Sudan. His project focused on video quality assessment. He assessed a system to measure the quality of video streaming. Video streaming entails several processing steps, any of which can degrade the quality of a video. Being able to measure the visual quality of a video is essential to obtain the leading edge in many sectors of society. This can be done through video multimethod assessment fusion. The ML system learns from human perceptions of quality by imitating human preferences, which are configured to obtain optimal performance.

**WHY THE NEED FOR VIDEO QUALITY ASSESSMENT?**

Video quality assessment models play a key role in the video industry. The increasing demand for videos in security, entertainment and communication has generated an interest in video-related technologies. Video streaming involves several processing steps, including compression, scaling and transmission, that can result in visual artifacts in transmitted videos. Video quality assessment models measure the amount of visual degradation in processed videos.





## VIDEO MULTIMETHOD ASSESSMENT FUSION (VMAF)

VMAF is the state-of-the-art data-driven video quality assessment developed by Netflix. It correlates well with the human judgement of video quality by combining several elementary metrics based on the premise that multiple metrics compensate for the weaknesses of individual metrics. These elementary metrics are image-based metrics, which capture the spatial information in the video (images) and the temporal information (motion). These metrics include visual information fidelity, detail loss metric and mean co-located pixel difference.

## GENETIC ALGORITHMS

Genetic algorithms proved to be effective for hard problems, especially for automated design. They belong to a class of computational intelligence techniques called evolutionary algorithms, which are inspired by natural selection. Genetic algorithms solve a problem by evolving a population of candidate solutions using biologically inspired operators (mutation, crossover and selection).

## THE AUTOMATED DESIGN OF VMAF

The design of VMAF is challenging as it involves decisions that are not straightforward to make. Moreover, it is time-consuming. Although VMAF is well designed by Netflix experts, the configuration space of VMAF is too vast to be explored manually. Ahmed proposed automating the design of VMAF using a genetic algorithm by considering three design decisions:

- The choice of elementary metrics that make up the basic components of VMAF (more than 40 metrics were used)
- The values of hyperparameters, which are model variables that affect performance
- The choice of aggregation methods that combine the scores computed per video frame

## RESULTS

The human rating of visual quality was compared to the automated design. This approach was found to agree with the human ratings on the Netflix dataset. The automated design was consequently found to outperform the latest VMAF release in two large video datasets.

## PROJECT HIGHLIGHTS

- Video quality assessment (VQA) models play a key role in the video industry.
- Netflix has recently developed a VQA model (VMAF), which correlates well with the human judgement of video quality.
- VMAF combines elementary metrics that capture the spatial information in the video (images) and the temporal information (motion).
- The design of VMAF is challenging as it involves decisions that are not straightforward to make. Moreover, it is time-consuming.
- It is proposed to automate the design of VMAF using a genetic algorithm.
- The automated design outperforms the latest VMAF release in two large video datasets.
- This study is valuable since it produces better VQA models with minimal human intervention.



## COMPUTER ENGINEERING

# END-TO-END AUTOMATED SPEECH RECOGNITION

## THE NITTY-GRITTY

Alexander Loubser, a master's degree student, developed a system for end-to-end automated speech recognition using a character-based small-scale transformer architecture. This entailed using ML to recognise the speech signals embedded in a video, as well as their unique features, in order to convert them to text. This is utilised in the automated generation of subtitles, which is currently a manual process. While the database he used made use of American and British English, the challenge was to find enough data in South African local languages to apply the model to other languages as well.

## THE RESEARCH GAP

Traditional speech recognition systems consisted of an acoustic model, to which a language model was later added. The acoustic model would transform the audio data into phonemes (distinct units of sound), while the language model would match the phonemes to existing words in language.

Modern speech recognition systems use a hybrid approach. The model uses the audio data and matches it directly to words or characters of the desired language. Using modern neural networks, the character orders or word orders are also considered. The problem with modern speech recognition models is that they are very large and can have millions of parameters that require a lot of memory to compute text from speech.

The goal of Alexander's project was thus to create a smaller end-to-end speech recognition model from a transformer architecture, which can produce satisfactory word error rates. The small-scale automated speech recognition model can be used in cases where practitioners do not have access to industrial-scale datasets and computer resources.

## MODEL DEVELOPMENT

Alexander developed a model to experiment if a small, automated speech recognition model can produce similar results to modern, large-scale transformer-based automated speech recognition systems. The model consisted of a small convolutional neural network and transformer architecture consisting of 1.488 million parameters, compared to modern speech recognition systems that have over 300 million parameters. The model is trained on limited audio of about 3 000 hours, where modern systems are trained with over 50 000 hours of speech data.

The common voice and LibriSpeech training datasets were used for training and produced a character error rate and word error rate that are comparable to larger modern speech recognition systems. Modern transformer architectures produced better word error rates on the LibriSpeech dataset. However, these architectures are 200 times larger and are trained on 53 000 hours more data than the small-scale architecture that was developed. A small 4-gram language model was added to the end-to-end speech recognition model to improve the word error rate.



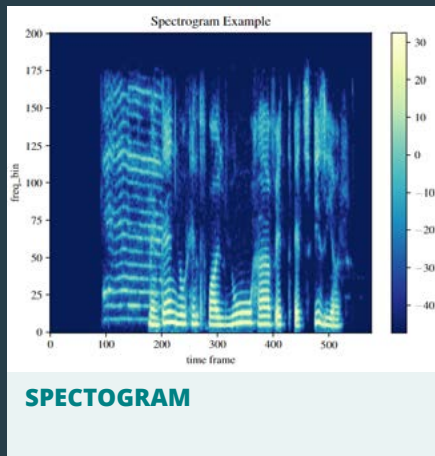
## MODEL RESULTS

The results of Alexander's research were obtained using test data from the Common Voice and LibriSpeech test datasets. The model was trained with different sampling frequencies and pre-processing techniques. The time-stretching technique produced the best results.

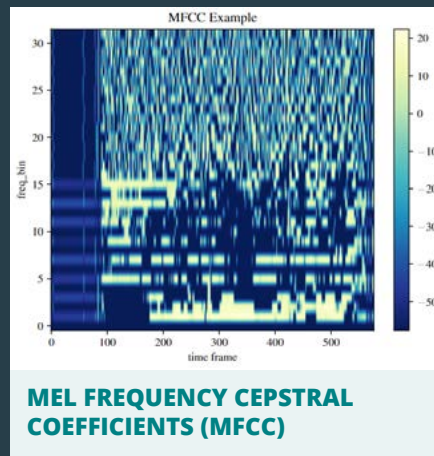
The model was used on three different output methods: greedy decoding, Beam search 500 and Beam search 500 combined with a 4-gram language model.

The Beam search with an added language model produced the best results. The automated speech recognition model is

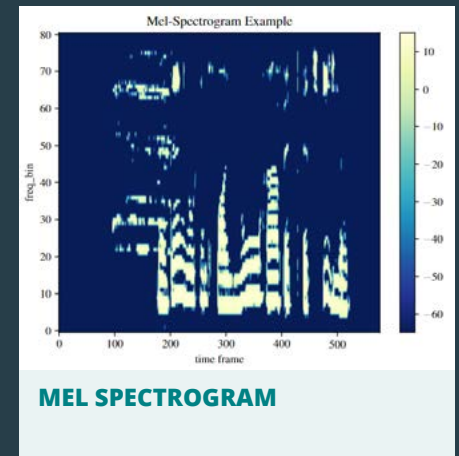
a proof of concept for under-resourced languages for which large corpuses are not available. The model can therefore be used for speech recognition in under-resourced languages such as African languages, where a lot of labelled speech data is not available, if it is trained on these languages.



*A spectrogram example of an audio track sampled at 16 kHz, with a female voice saying: "Maintain your health while you have it, it's easier". The spectrogram consists of 201 frequency bins of FFT points and 577 time bins. It is noticed that the frequency amplitudes are higher in the lower bins, therefore showing that the sampled frequency covers all the vocal data.*



*A combined MFCC and delta coefficients example of an audio track sampled at 16 kHz, with a female voice saying: "Maintain your health while you have it, it's easier". The MFCC consists of 16 frequency bins, and the delta coefficients consist of the next 16 frequency bins. There are also 590 time bins. It is noted that most of the plot is filled with usable data and the frequency features are reduced from 201 features to 32 features.*



*A Mel spectrogram example of an audio track sampled at 16 kHz, with a female voice saying: "Maintain your health while you have it, it's easier". The Mel spectrogram consists of 81 frequency bins or FFT points and 577 time bins. It is noted that the vocal data is more distinguishable from the silence data than in the normal spectrogram.*



## COMPUTER ENGINEERING

# A MOVIE RECOMMENDATION SYSTEM USING DEEP LEARNING FEATURES

### THE NITTY-GRITTY

Adolfo Almeida graduated with a master's degree in Computer Engineering in 2021 and has been working at MultiChoice for the past two years. He hails from Angola. His project focused on developing a video recommendation system using a range of deep learning features extracted from video content. What makes this system novel is that it actually watches thousands of movie trailers, making use of the same sound and visual perceptions that a human would. Based on what one has watched in the past, it makes informed recommendations within the user's viewing habits. It differed from other systems in use at the time as those systems only made use of users' viewing history and video content metadata.

### THE VALUE OF A RECOMMENDATION SYSTEM

Following the popularisation of media streaming, a number of video streaming services are continuously buying new video content to generate a potential profit. As such, the newly added content has to be handled well to be recommended to suitable users. Video-sharing websites rely heavily on video recommendation systems to assist users to discover videos they may enjoy.

With the enormous increase in the number of new videos constantly being uploaded, some video streaming services have to deal with unrated, unaudited and completely new content, which they know nothing about. Recent studies on video content analysis and video-retrieval tasks use various types of deep learning features extracted using pre-trained models due to their outstanding performance in different domains, compared to hand-crafted features.

A video recommendation system is a user-level video-filtering service that helps users explore the videos that are available to watch. It offers a more personalised

experience for users by recommending the most relevant and appropriate videos for them to watch. In order to do this, algorithms are used to analyse the information about the videos and the users, as well as the past interactions between them.

Existing recommendation systems use one of three approaches: the collaborative filtering recommendation method, the content-based recommendation method and the hybrid recommendation method, which is a combination of the first two.

Most video streaming services that use a video recommendation system to compute the video relevance based on user feedback use the collaborative filtering method because of its state-of-the-art accuracy. This feedback is used to model the user-video preference, and compute video-to-video relevance scores to provide personalised recommendations. However, this approach suffers from the new item cold-start problem.

Adolfo's research project addressed the new item cold-start problem by exploring the potential of various deep learning features to provide video recommendations.





Various deep learning features extracted from multi-modal, extremely high-dimensional information from videos are used to enhance the quality of recommendations. These features include those that capture the visual appearance, audio and motion information from video content.

In the process, Adolfo compared deep learning features against genre features and hand-crafted features. He also explored different fusion methods to evaluate how well these feature modalities can

be combined to fully exploit the complementary information captured by them. This was done to improve the recommendation quality in terms of accuracy and beyond-accuracy metrics. Experiments on a real-world video dataset for movie recommendations show that deep learning features outperform hand-crafted features.

Finally, he performed an ablation study to empirically assess the importance of using a diverse range of video content features on the overall

recommendation quality, while taking full advantage of the available data.

The results suggested that the fusion of visual, audio and action features provides more accurate video recommendations to users when compared to the fusion of only visual and audio features. In addition, the combination of various deep learning features with hand-crafted features and textual metadata yields significant improvement in recommendations compared to combining only deep learning features.



# Capacity development for MultiChoice staff

The collaboration agreement between the partners also entailed academics from the University of Pretoria's Department of Computer Science and its Computer Engineering programme in the Department of Electrical, Electronic and Computer Engineering providing capacity development in machine learning to members of MultiChoice.

## MULTICHOICE MACHINE LEARNING WORKSHOP

The Computer Engineering programme presented a short course for MultiChoice staff members on 6 and 7 February 2020. It was attended by 30 delegates from MultiChoice.

The two-day course covered the following topics:

- What is machine learning?
- Scripting languages: R and Python
- Jupyter notebook demonstration
- Introductory notebook
- Examples of getting answers on Stackoverflow – tips on information needed, efficiency
- Use case description
- R preliminaries
- Data handling/viewing
- Creating a database for large files
- Data exploration
- Revisit MultiChoice dormancy data
- Efficient data handling – how to handle seasonality
- Feature engineering with examples
- Univariate analysis
- Correlation analysis
- Dimensionality reduction (PCA – t-SNE)
- Classification
- Partitioning the data
- Model description
- Random Forest
- Model training
- Model testing and validation

## PRESENTATIONS TO MULTICHOICE

Prof Nelishia Pillay was invited to deliver the following presentations to staff members:

- Artificial Intelligence: Myth or reality for the Fourth Industrial Revolution. Naspers Group Technology Conference and MultiChoice AI Event, 13–15 November 2018, Johannesburg, South Africa.
- Automating machine learning. MultiChoice Group Artificial Intelligence Conference, 28 November 2019, Randburg, Johannesburg, South Africa.
- Recent trends in Artificial Intelligence. MultiChoice Group Artificial Intelligence Forum, 7 October 2021, online.
- Machine learning in broadcasting and media: Current trends. MultiChoice Group Leadership Forum, 18 August 2022, online.



# Student testimonials



**Derrick Beckedahl:**  
**PhD (2018–2021)**

*Viewer preference  
selection*

“Working on a project for MultiChoice has been an informative experience as it has given me an idea of what the process is like in industry, outside of academia. I would certainly consider working for MultiChoice upon completion of my studies.”

In a word: “Eye-opening”



**Mia Gerber: PhD  
(2022)**

*Intelligent video  
archiving*

“Interacting with the team at MultiChoice, I have found it to be a company that values quality and academically sound work. The company has been incredibly supportive, continually offering resources and expertise. Personally, the opportunity has grown my confidence, and academically, it has challenged me to try and push a little harder to come up with novel work that can make a significant contribution to the field of ML as a whole. I would love to work there as the company culture is very conducive to attracting like-minded individuals who want to grow and contribute to the field of ML, while producing industry-quality solutions.”

In a word: “World-class”

*Working as a  
research assistant to  
Prof Nelishia Pillay*



**Dr Ahmed Hassan:**  
**Postdoctoral fellow  
(2020–2022)**

*Automated design  
of VMAF*

“The experience has been truly amazing. The people are so helpful and well organised. I cannot ask for anything more. I was involved in the AI Forum, and I was very impressed by the quality of the work – the company is comparable to a research institution.”

In a word: “Extraordinary”

*Serving as a  
postdoctoral fellow*



**Rahul Kapoor:**  
**BSc Hons (2021);  
MSc (2022)**

*Video shorts creation*

“The people at MultiChoice are very kind. They have given me the opportunity to pursue my master’s degree. I have been to their Head Office, and it seems like a great place to work, with a good work culture and environment.”

In a word: “Fruitful”



**Gisele Marais:**  
**MSc (2022)**

*Recommender  
systems*

"I am very excited to work on a MultiChoice project. The team has been great to work with. The people there are very professional and have been very enthusiastic about the work I have done so far. Academically, working with MultiChoice has benefitted me greatly, as the company was very open to the project idea I chose, and was willing to provide the necessary data that the project required. It has been wonderful to get the opportunity to work with the MultiChoice team."

In a word: "Wonderful"



**Kyle Pretorius:**  
**BSc Hons cum laude  
(2018); MSc  
(2019–2021)**

*Automated  
thumbnail selection*

"It has been a very pleasant experience. I gained a lot of knowledge. The team is very hands-on and is always willing to discuss any problems I encounter. I appreciate the creative freedom and the wide range of research projects to choose from. It has given me a degree of industry experience and exposed me to what it is like working for a client."

In a word: "Insightful"



**Jana Sander: BSc  
cum laude (2020);  
BSc Hons cum laude  
(2021)**

*Metric for  
recommender  
systems*

Working at  
Entelect

"I found working on a MultiChoice project to be very interesting. The research topics are novel and intriguing, which encourages one to propose creative solutions and ideas. The vacation work was a great experience that allowed me to work on projects that are relevant and used in industry, but not necessarily covered in the university curriculum. I truly gained a lot of knowledge and exposure."

In a word: "Fascinating"



**Emilio Singh: MSc  
cum laude (2018);  
PhD (2019–2020)**

*Movie scene  
scheduling*

Serving as a  
postdoctoral fellow

"MultiChoice provided me with an interesting academic opportunity in terms of exposing me to working in industry. The experience was certainly enlightening with regard to showing me how corporate life operates as opposed to academia. I gained many new perspectives that have helped shape my professional decisions going forward."

In a word: "Positive"



**Adolfo Almeida:**  
**BEng Hons (2018–2019); MEng (2021)**

*Video  
recommendation  
system*

*Working at  
MultiChoice*

“It has really been a fantastic experience. The company has a learning environment, and the work that I do there is related to what I studied. I have the opportunity to work in a team, where all the members are very collaborative. The vacation work I did there was perfect for me. I experienced the staff members to be welcoming and willing to teach me. When I started working there, I was able to transition very easily as I already knew how the team worked. My present colleagues are the same team members I met during my vacation work, so I already knew who I would be working with and what I would be doing. From an academic point of view, it gave me a better perspective on the problem at hand and the business values that needed to be addressed. This helped to bridge the gap between academia and industry, and I am able to apply what I have learnt to other initiatives.”

*In a word: “Fulfilling”*



**Paul Claasen:**  
**BEng Hons (2022)**

*Automatic extraction  
of highlights from  
sports videos*

“It is exciting to work on a project that can contribute to such a large company in a meaningful way. Although MultiChoice’s employees are undoubtedly very busy, they are always open to schedule meetings with me to discuss my project, which I greatly appreciate. On a personal level, the project allowed me to explore new fields, most notably computer vision, which is something that has always interested me. The vacation work opportunities allowed me to broaden my horizons and learn valuable new skills. I am very grateful to MultiChoice for giving me the opportunity to further my academic career and enhance my employability. I would definitely consider a position at MultiChoice, should one be offered.”

*In a word: “Constructive”*



**Joseph Mervitz:**  
**MEng (2020–2021)**

*Automatic movie  
trailer genre labelling  
using video and audio  
content*

*Working at  
MultiChoice*

“I thoroughly enjoy working on projects at MultiChoice. The wide technical landscape provides for a variety of different projects and challenges. I enjoy the supportive environment that allows for growth and development, and contributing to an exciting and vibrant company culture. There are ample opportunities to work with many cutting-edge technologies. The company provides hands-on experience and in-depth understanding, which was very beneficial academically. I love the day-to-day interactions with knowledgeable and friendly colleagues. The soft skills that are developed motivate innovative ideas among the team members. The company also offers many self-study options to further develop my technical and personal skills.”

*In a word: “Uplifting”*



**Alexander Loubser:**  
**BEng Hons (2019);**  
**MEng (2020–2022)**

*Small-scale  
automated speech  
recognition*

*Will start working  
at MultiChoice*

“My experience has been very rewarding. MultiChoice has put in a lot of effort over the past three years to accommodate and teach us useful experiences and skills, together with the bursary. The projects that the company gives you to work on during the vacation work programme are usually real-life problems that the company is currently working on. This makes the projects fun and rewarding as you know that they will be used by MultiChoice. During a project, there is always someone to contact if you need any data or help, and they are more than willing to help as much as they can. During vacation work, you also learn some real work-life skills and attend development skills training sessions. You also get to know the group that you are working with and attend daily meetings to keep each other up to date with your progress. It gave me a real feeling of what it is like to work in industry. When I start working at MultiChoice, I will be able to use the research and development I performed during my studies, as well as the skills I learnt at work.”

*In a word: “Inspiring”*

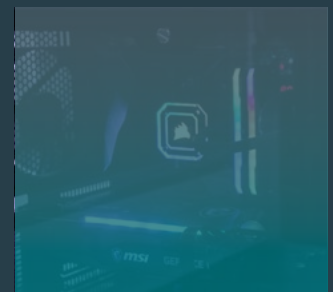
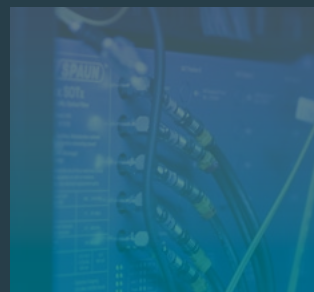
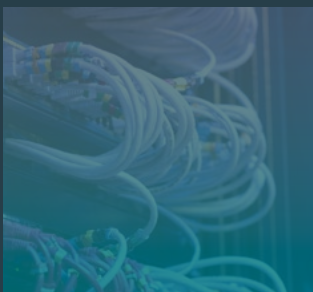


**David Sithole: BEng**  
**(2020); BEng Hons**  
**(2021–2021)**

*Text-to-speech  
systems to generate  
expressive speech*

“Working on a project from MultiChoice is an exciting experience as all their topics are innovative, making it difficult to choose just one. I had the chance to complete the three-week vacation work programme, where I explored real customer data to build a model that would identify which users are likely to have connection issues before they even reach out to customer services. This experience helped a lot as I obtained a better understanding of how the concepts that we learn are applied in real life. This made me even more excited to join the workforce. I would love to work for MultiChoice at the end of my studies. The Connected Video Department interests me the most.”

*In a word: “Enriching”*





# Research output with contributions from bursary holders

## JOURNAL ARTICLES

- Almeida, A., De Villiers, J.P., De Freitas, A. & Velayudan, M. 2022. The complementarity of a diverse range of deep learning features extracted from video content for video recommendation. *Expert Systems with Applications*, Vol. 192.
- Beckedahl, D. & Pillay, N. 2020. A study of bi-space search for solving the one-dimensional bin packing problem. 19th International Conference on Artificial Intelligence and Soft Computing, Lecture Notes in Artificial Intelligence, Vol. 12416, 277–289.
- Beckedahl, D. & Pillay, N. 2022. Bi-space search: Optimising the hybridisation of search spaces in solving the one-dimensional bin packing problem. International Conference on Artificial Intelligence and Soft Computing, Lecture Notes in Artificial Intelligence, accepted.
- Hassan, A. & Pillay, N. 2021. Dynamic heuristic set selection for cross-domain selection hyper-heuristics. *Lecture Notes in Computer Science: Theory and Practice of Natural Computing*, 10th International Conference, December 2021, pp. 33–46.
- Hassan, A. & Pillay, N. 2022. Automated design of dynamic heuristic set selection for cross-domain selection hyper-heuristics. *International Conference on Artificial Intelligence and Soft Computing, Lecture Notes in Artificial Intelligence*, accepted.
- Singh, E. & Pillay, N. 2021. Ant-based generation constructive hyper-heuristics for the movie scene scheduling problem. *Lecture Notes in Computer Science: Theory and Practice of Natural Computing*, 10th International Conference, December 2021, pp. 109–120.
- Singh, E. & Pillay, N. 2021. Ant-based hyper-heuristics for the movie science scheduling problem. 20th International Conference on Artificial Intelligence and Soft Computing, Lecture Notes in Artificial Intelligence, pp. 342–353.
- Singh, E. & Pillay, N. 2022. A study of ant-based pheromone spaces for generation constructive hyper-heuristics. *Swarm and Evolutionary Computation*, Vol. 72, July 2022, 101095.
- Almeida, A., De Villiers, J.P., De Freitas, A. & Velayudan, M. 2020. Visual comparison of statistical feature aggregation methods for video-based similarity applications. 23rd International Conference on Information Fusion, Pretoria, South Africa, 6–9 July 2020, pp. 22–29.
- Beckedahl, D., Nel, A. & Pillay, N. 2019. A study of multi-space search optimisation. International Conference on Intelligent Systems Design and Applications: Advances of Intelligent Systems and Computing, Vol. 940, Springer, pp. 1–9.
- Gerber, M. & Pillay, N. 2022. Automated design of feature extraction for unsupervised image clustering using grammatical evolution, accepted for publication in the 2022 IEEE Symposium on Computational Intelligence, September.
- Hassan, A. & Pillay, N. 2021. An investigation of automated design of VMAF. *Proceedings of the 2021 IEEE Symposium Series on Computational Intelligence*, pp. 1–8.
- Hassan, A. & Pillay, N. 2022. Automated design of hybrid metaheuristics: Fitness landscape analysis. *Proceedings of the IEEE World Congress for Computational Intelligence*, accepted.
- Hassan, A. & Pillay, N. 2022. Hybridising a genetic algorithm with reinforcement learning for automated design of genetic algorithms. *Proceedings of the IEEE World Congress for Computational Intelligence*, accepted.
- Mervitz, J., De Villiers, J.P., Jacobs, P. and Kloppers, M. 2020. Comparison of early and late fusion techniques for movie trailer genre labelling, 23rd International Conference on Information Fusion, Pretoria, South Africa, 6–9 July 2020, pp. 708–713.
- Pretorius, K.W. & Pillay, N. 2020. A comparative study of classifiers for thumbnail selection. *Proceedings of the 2020 IEEE International Joint Conference on Neural Networks*.
- Pretorius, K.W. & Pillay, N. 2021. Population-based reinforcement learning. *Proceedings of the 2021 IEEE Symposium Series on Computational Intelligence*, pp. 1–8.
- Singh, E. & Pillay, N. 2022. A parameter-based analysis of ant-based generation hyper-heuristics, accepted for publication in the 2022 IEEE Symposium on Computational Intelligence, September.
- Singh, E. & Pillay, N. 2022. A study of transfer learning in an ant-based generation construction hyper-heuristic. *Proceedings of the IEEE World Congress for Computational Intelligence*, accepted.

## CONFERENCE PROCEEDINGS



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