2023 AIMLAC intake, Bangor CDT project proposal

## Scholarship project title: “Smart Optimisation of Big Data for Geometry Generation and 3D Models”

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## Project description:

This project aims to explore the integration of metaheuristics and Machine Learning, alongside other AI methodologies, to semi-automate the 3D modelling of building structures [1]. The research will encompass automatic geometry reconstruction [2], semantic segmentation [3], and eventually generating BIM models. It's worth noting that one of the main sources in BIM is geometry. Furthermore, point clouds acquired through LiDAR surveys can be massive, reaching terabytes in size. To handle and process such data volumes effectively, the use of Supercomputing Wales is imperative for this research.

Building Information Modelling (BIM) is a widely used methodology for obtaining comprehensive knowledge about the current state of buildings, centralizing digital data related to their structure, including detailed geometry. On the other hand, 3D point clouds, often obtained from LiDAR, have become a standard method for recording and surveying building structures, especially heritage monuments. These point clouds provide a continuous representation of the geometry of built environments and objects. However, generating 3D models from 3D point clouds poses challenges due to irregularities in the cross-sections of surfaces and the complex geometries of the structures, among other reasons. The process can be subjective, time-consuming, and error-prone when performed manually.

The potential real-world applications of this work are diverse and impactful. These include preserving heritage monuments, visualisation, conducting structural tests, performing heating analysis, mapping the locations of WIFI access points, and virtual reality, among others. The project aims to provide innovative solutions to streamline these processes and enable practical applications across various domains.

## The candidate.

The candidate for this position must demonstrate strong teamwork skills, effective communication abilities, and a willingness to engage with and visit various companies, including heritage organizations and architects. Moreover, they will have the advantage of an existing collaboration with the Faculty of Architecture at the University of Lisbon and will be required to visit the research group there. Applicants must possess proficiency in programming and software tool developing (such as Python and Java or C++), have substantial programming experience, and an appropriate first degree along with a solid foundation in mathematics. It is desirable that the candidate has practical experience with AI, metaheuristics and Machine Learning algorithms, 3D modelling and an understanding of optimization principles.

### Outline plan:

* Become familiar with 3D point clouds, 3D modeling, and architectural software such as MeshLab, and Rhinoceros 3D.
* Propose Metaheuristics and Machine Learning algorithmic solutions for the main geometry reconstruction.
* Investigate Machine Learning approach for semantic segmentation of the outcome of geometry reconstruction.
* Generate BIM models from the outcome of the last two objectives.

#### REFERENCES

[1] V. A. Cotella. “From 3D point clouds to HBIM: Application of Artificial Intelligence in Cultural Heritage”, *Automation in Construction*, Volume 152, 2023.

[2] M. Bazargani, L. M. Mateus, and A. Loja. “Planar surfaces recognition in 3D point cloud using a real-coded multistage genetic algorithm”*, European Conference on the Applications of Evolutionary Computation*, 2015.

[3] L. Tchapmi, C. Choy, I. Armeni, J. Gwak and S. Savarese, "SEGCloud: semantic segmentation of 3D point clouds", *International Conference on 3D Vision (3DV)*, 2017.

MANYLION PENODOL Y PROJECT

Derbyn myfyrwyr AIMLAC 2023, cynnig project Canolfannau Hyfforddiant Doethurol Bangor

## Teitl project yr ysgoloriaeth: “Smart Optimisation of Big Data for Geometry Generation and 3D Models”

**Goruchwyliwr 1af:** [Dr Mosab Bazargani](https://www.bangor.ac.uk/staff/computer-science-electronic-engineering/mosab-bazargani-646489/en)/ Ysgol Cyfrifiadureg a Pheirianneg

**2il oruchwyliwr:** [Yr Athro Jonathan C. Roberts](https://www.bangor.ac.uk/staff/computer-science-electronic-engineering/jonathan-roberts-015994/en)/ Ysgol Cyfrifiadureg a Pheirianneg Electronig

## Disgrifiad o’r project

Nod y project hwn yw archwilio integreiddio metahewristeg a Dysgu Peirianyddol, ochr yn ochr â methodolegau deallusrwydd artiffisial eraill, i led-awtomeiddio’r modelu 3D o strwythurau adeiladau [1]. Bydd yr ymchwil yn cwmpasu ail-greu geometreg awtomatig [2], segmentu semantig [3], ac yn y pen draw yn cynhyrchu modelau BIM. Mae'n werth nodi mai un o'r prif ffynonellau yn BIM yw geometreg. Hefyd, gall cymylau pwynt a geir trwy arolygon LiDAR fod yn enfawr, gan gyrraedd terabytes o ran maint. Er mwyn trin a phrosesu meintiau data o’r fath yn effeithiol, mae’n hollbwysig defnyddio Uwchgyfrifiadura Cymru ar gyfer yr ymchwil hwn.

Mae Modelu Gwybodaeth am Adeiladau (BIM) yn fethodoleg a ddefnyddir yn eang ar gyfer cael gwybodaeth gynhwysfawr am gyflwr presennol adeiladau, gan ganoli data digidol sy'n ymwneud â'u strwythur, yn cynnwys geometreg fanwl. Ar y llaw arall, mae cymylau pwynt 3D, a geir yn aml gan LiDAR, wedi dod yn ddull safonol o gofnodi ac arolygu strwythurau adeiladau, yn enwedig henebion treftadaeth. Mae'r cymylau pwynt hyn yn darparu cynrychiolaeth barhaus o geometreg amgylcheddau adeiledig a gwrthrychau. Fodd bynnag, mae cynhyrchu modelau 3D o gymylau pwynt 3D yn peri heriau oherwydd afreoleidd-dra yn y trawstoriadau o arwynebau a geometregau cymhleth y strwythurau, ymysg rhesymau eraill. Gall y broses fod yn oddrychol, cymryd llawer o amser, ac yn agored i wallau wrth ei wneud â llaw.

Mae cymwysiadau byd go iawn posibl y gwaith hwn yn amrywiol ac yn cael effaith. Mae'r rhain yn cynnwys cadw henebion treftadaeth, delweddu, cynnal profion strwythurol, gwneud dadansoddiad gwresogi, mapio lleoliadau pwyntiau mynediad WIFI, a rhithrealiti, ymysg eraill. Nod y project yw darparu atebion arloesol i symleiddio'r prosesau hyn a galluogi cymwysiadau ymarferol ar draws gwahanol feysydd.

## Yr ymgeisydd

Rhaid i'r ymgeisydd ar gyfer y swydd hon ddangos sgiliau gwaith tîm cryf, galluoedd cyfathrebu effeithiol, a pharodrwydd i ymgysylltu ac ymweld â gwahanol gwmnïau, gan gynnwys sefydliadau treftadaeth a phenseiri. Ar ben hynny, bydd ganddynt y fantais o gydweithio eisoes gyda'r Gyfadran Pensaernïaeth ym Mhrifysgol Lisbon a bydd yn ofynnol iddynt ymweld â'r grŵp ymchwil yno. Rhaid i ymgeiswyr feddu ar hyfedredd mewn rhaglennu a datblygu offer meddalwedd (fel Python a Java neu C++), profiad rhaglennu sylweddol, a gradd gyntaf briodol ynghyd â sylfaen gadarn mewn mathemateg. Mae'n ddymunol bod gan yr ymgeisydd brofiad ymarferol gyda deallusrwydd artiffisial, metahewristeg ac algorithmau Dysgu Peirianyddol modelu 3D a dealltwriaeth o egwyddorion optimeiddio.

### Cynllun amlinellol:

* Dod yn gyfarwydd â chymylau pwynt 3D, modelu 3D, a meddalwedd pensaernïol fel MeshLab, a Rhinoceros 3D.
* Cynnig atebion algorithmig Metahewristeg a Dysgu Peirianyddol ar gyfer y prif adluniad geometreg.
* Ymchwilio i ddull Dysgu Peirianyddol ar gyfer segmentiad semantig o ganlyniad ail-greu geometreg.
* Cynhyrchu modelau BIM o ganlyniad y ddau amcan diwethaf.

#### Cyfeiriadau

[1] V. A. Cotella. “From 3D point clouds to HBIM: Application of Artificial Intelligence in Cultural Heritage”, *Automation in Construction*, Volume 152, 2023.

[2] M. Bazargani, L. M. Mateus, and A. Loja. “Planar surfaces recognition in 3D point cloud using a real-coded multistage genetic algorithm”*, European Conference on the Applications of Evolutionary Computation*, 2015.

[3] L. Tchapmi, C. Choy, I. Armeni, J. Gwak and S. Savarese, "SEGCloud: semantic segmentation of 3D point clouds", *International Conference on 3D Vision (3DV)*, 2017.