Tunnel Asset Management
SCE-DOD-FS & BE-CEM Collaboration Meeting

John Osborne, Roddy Cunningham & Darragh O'Brien

SCE-DOD-FS

With input from SCE-SAM-CE and SCE-SAM-TE.

19/03/2021

SCE-DOD-FS Section 2021

Future Accelerator Studies Section (FS)

Section Leader: John OSBORNE

International Linear Collider
CLIC, Muon Collider

Engineers

Alexandra Tudora
Future Circular Collider (FCC)

Kincső Balázs
Physics Beyond Colliders (PBC)

Tunnel Asset Management

Roddy Cunningham

Darragh O'Brien (UCC)

Tunnel Photogrammetry/Fibre Optic Studies

Eliseo Perez-Duenas
Selected CE Project Delivery
Eg ISOLDE

Why Are We Here?

- Automate underground inspections as much as possible
- Reduce inspection time
- Reduce personnel presence in tunnels
- Objective inspection, to reduce report subjectivity
- Collaboration with University College Cork for R&D tunnel monitoring- how can we (SCE & BE) work better together?
- Implement R&D into future projects such as FCC

Agenda

- Roddy Cunningham (Fellow) to present methodology for LS2 underground inspections and results
- Darragh O'Brien (UCC Student) to present photogrammetry methodology and current status of studies
- Presentation of BE-CEM activities – Mario di Castro
- General discussion and way forward

Traditional Tunnel Inspections

Hand-written notes by engineer

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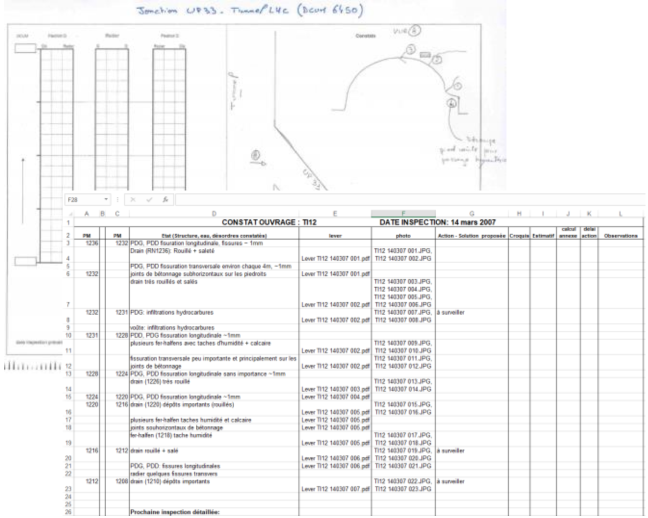

PM		PM	Etat (Structure, eau, désordres constatés)	lever	photo	Action - Solution proposée	Croquis	Estimatif	calcul annexe	délai action	Observations
			CONSTAT OUVRAGE : TI12		**DATE INSPECTION: 14 mars 2007**						
1236		1232	PDG, PDD fisuration longitudinale, fissures ~ 1mm								
			Drain (RN1236): Rouillé + saleté	Lever TI12 140307 001.pdf	TI12 140307 001.JPG, TI12 140307 002.JPG						
			PDG, PDD fissuration transversale environ chaque 4m, ~1mm								
1232			joints de bétonnage subhorizontaux sur les piedroits	Lever TI12 140307 001.pdf							
			drain très rouillés et salés	Lever TI12 140307 002.pdf	TI12 140307 003.JPG, TI12 140307 004.JPG, TI12 140307 005.JPG, TI12 140307 006.JPG						
1232		1231	PDG: infiltrations hydrocarbures	Lever TI12 140307 002.pdf	TI12 140307 007.JPG, TI12 140307 008.JPG	à surveiller					
			voûte: infiltrations hydrocarbures								
1231		1228	PDD, PDG fissuration longitudinale ~1mm								
			plusieurs fer-halfens avec taches d'humidité + calcaire	Lever TI12 140307 002.pdf	TI12 140307 009.JPG, TI12 140307 010.JPG						
			fissuration transversale peu importante et principalement sur les joints de bétonnage	Lever TI12 140307 002.pdf	TI12 140307 011.JPG, TI12 140307 012.JPG						
1228		1224	PDG, PDD fissuration longitudinale sans importance ~1mm								
			drain (1226) très rouillé	Lever TI12 140307 003.pdf	TI12 140307 013.JPG, TI12 140307 014.JPG						
1224		1220	PDG, PDD fissuration longitudinale ~1mm	Lever TI12 140307 004.pdf							
1220		1216	drain (1220) dépôts importants (rouillés)	Lever TI12 140307 005.pdf	TI12 140307 015.JPG, TI12 140307 016.JPG						
			plusieurs fer-halfen taches humidité et calcaire	Lever TI12 140307 005.pdf							
			joints souhorizontaux de bétonnage	Lever TI12 140307 005.pdf							
			fer-halfen (1218) tache humidité	Lever TI12 140307 005.pdf	TI12 140307 017.JPG, TI12 140307 018.JPG						
1216		1212	drain rouillé + salé	Lever TI12 140307 006.pdf	TI12 140307 019.JPG, TI12 140307 020.JPG	à surveiller					
			PDG, PDD: fissures longitudinales	Lever TI12 140307 006.pdf	TI12 140307 021.JPG						
			radier quelques fissures transvers								
1212		1208	drain (1210) dépôts importants	Lever TI12 140307 007.pdf	TI12 140307 022.JPG, TI12 140307 023.JPG	à surveiller					
			Prochaine inspection détaillée:								

Sketches and notes transcribed into Excel

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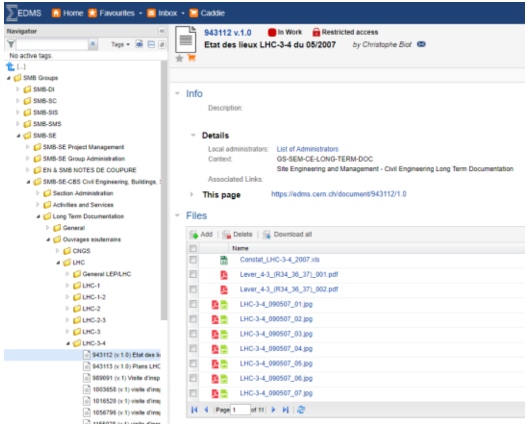
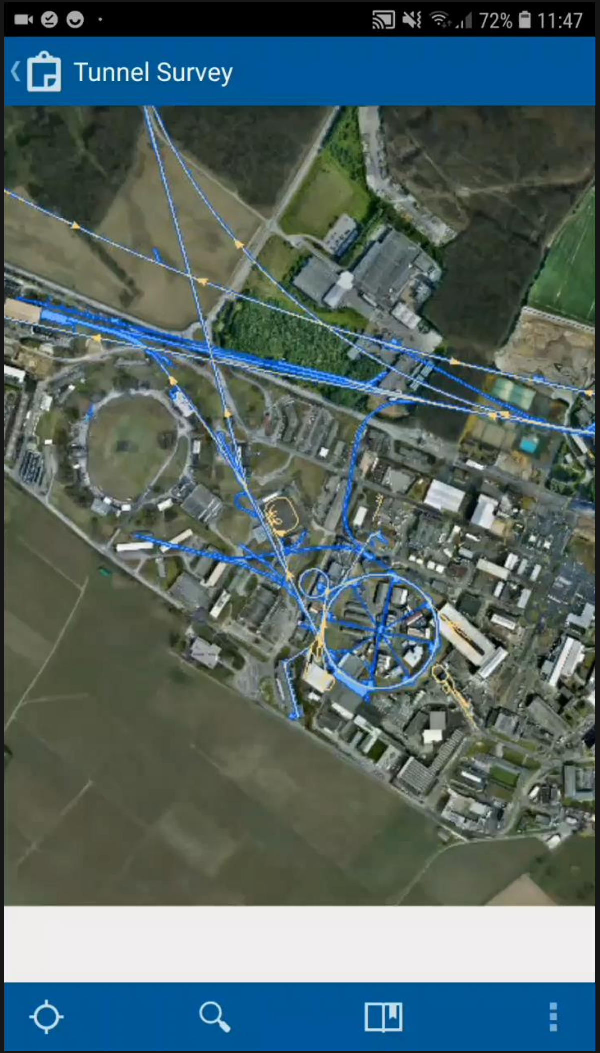


Uploaded to EDMS (maybe…)


72% 11:47
Tunnel Survey

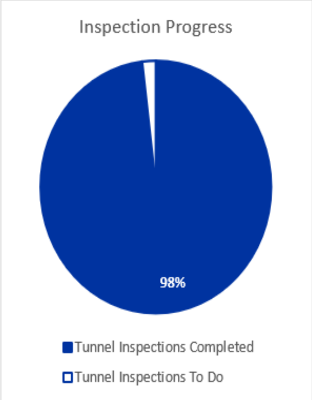
Asset Management Documentation

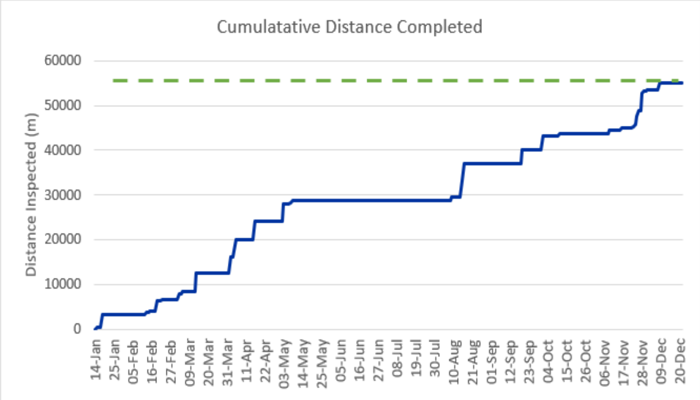
Draft copies of documents will be updated following inspections:

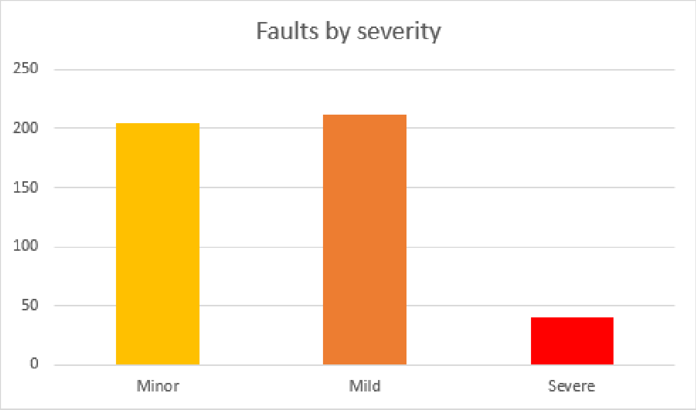
- Policy & Strategy 2043027
- SMB-SE Plan (to be renamed) 2082233
- LS2 Inspection Plan 2050104
- LS2 Tunnel Inspection Reports 2280931

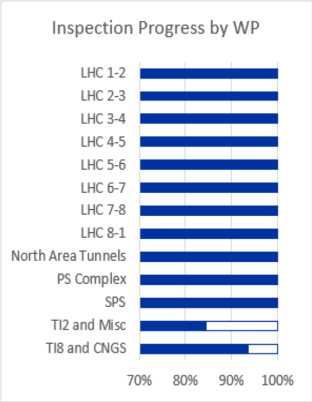
LS2 Tunnel Inspections Progress Dashboard

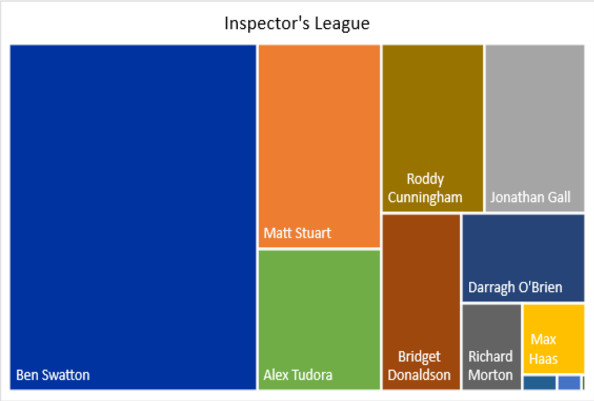
EDMS 2280931 v0.1

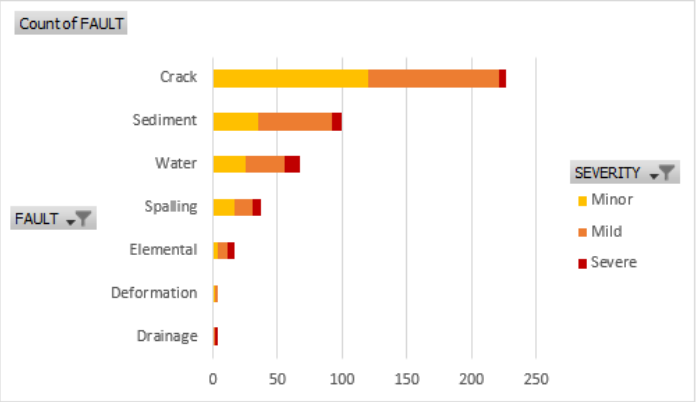




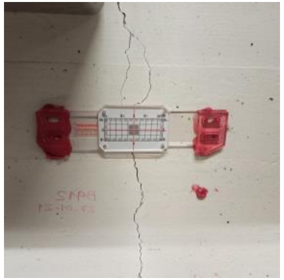








Underground Structural Monitoring



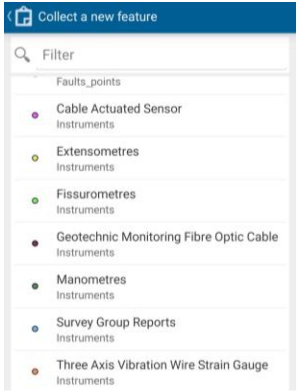
Tell Tales
(TT10, RB26
etc)

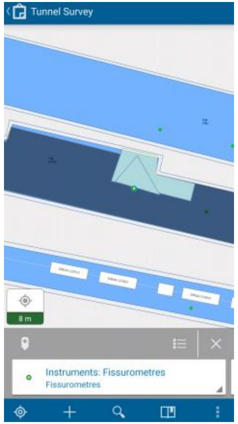
Extensometers
(LHC P.4
headwall)

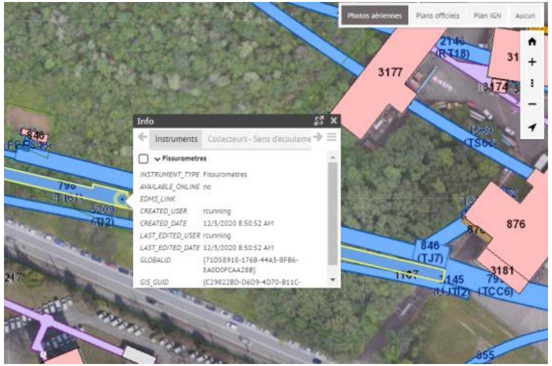
Manometers
(LHC Sect 34)

Fibre Optics in
collaboration with UCC
(TT10, Atlas cavern)

Monitoring Central Database



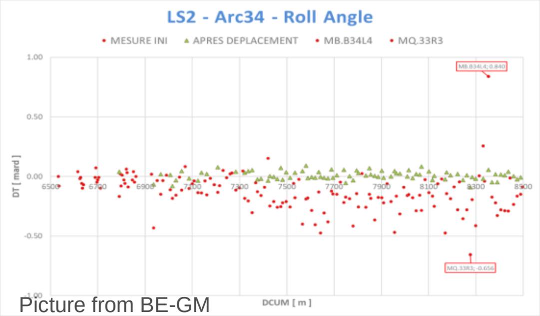




Monitoring equipment installed → Photos, details and location all recorded on TIC → Automatically uploaded to CERN GIS

Potential Collaboration Example

- In collaboration with BE-GM we are working to understand ground movement issues at sector 34.
- Beam alignment regularly a problem due to vertical movement of the tunnel structure
- Many installed monitoring that need read manually
- Access is limited and manual readings are not possible during run times
- Possibility of remotely taking photos of monitoring equipment?



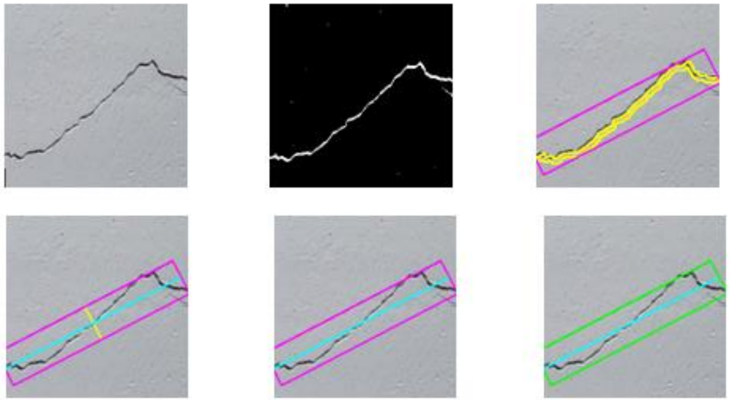
Picture from BE-GM

Photogrammetry research

The main objective of research is to automatically detected and subsequently classify crack in tunnel lining images using a **Convolution Neural Network (CNN).**

Outputs from the CNN

1. Numerical information on the crack % and crack type % in a tunnel.
2. A further breakdown of the numerical information into the chainage of the tunnel



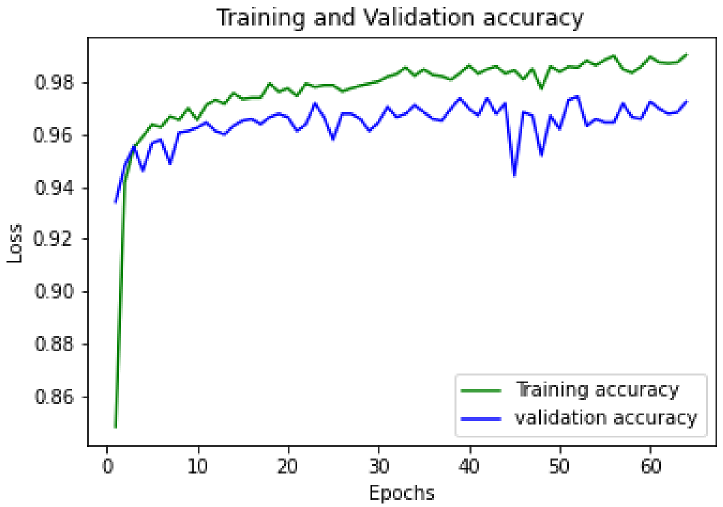
CNN for Crack Detection

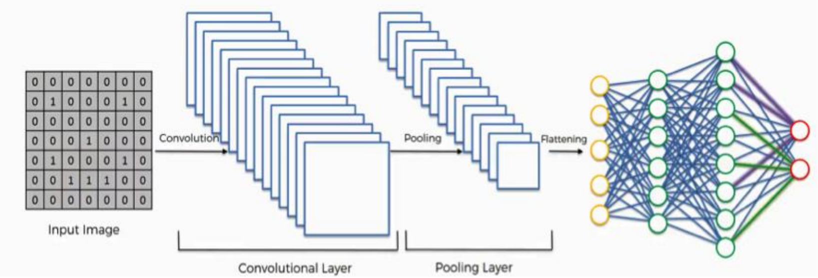
Using ~350 images of cracks from tunnels within CERN a database of 7600 smaller images of crack and non crack was created.

Using the technology of transfer leaning a CNN was developed to detect cracks in input images.

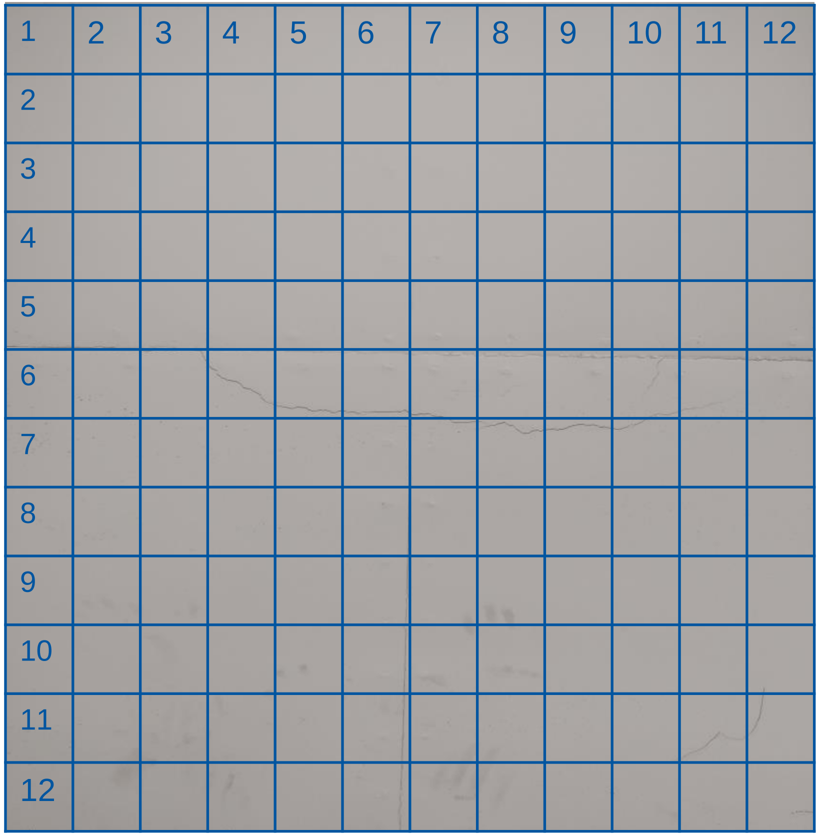
The CNN achieved an accuracy in training of ~ 97 % in relation to training and validation and out of sample test accuracy of 90%.

The CNN is now implementing the sliding window technique to detect cracks in larger Images.



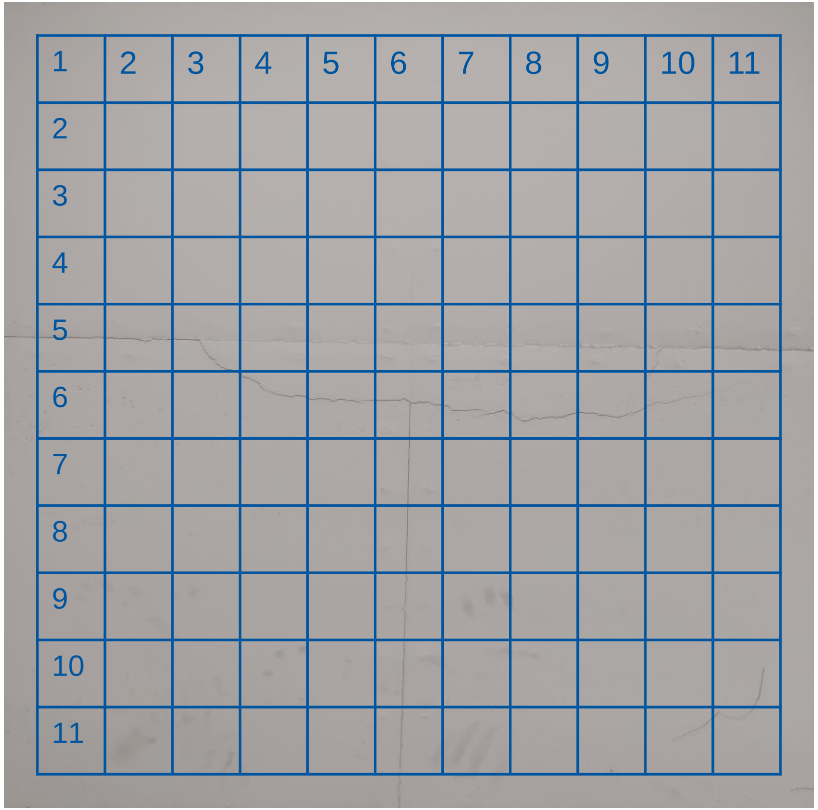


Original Image

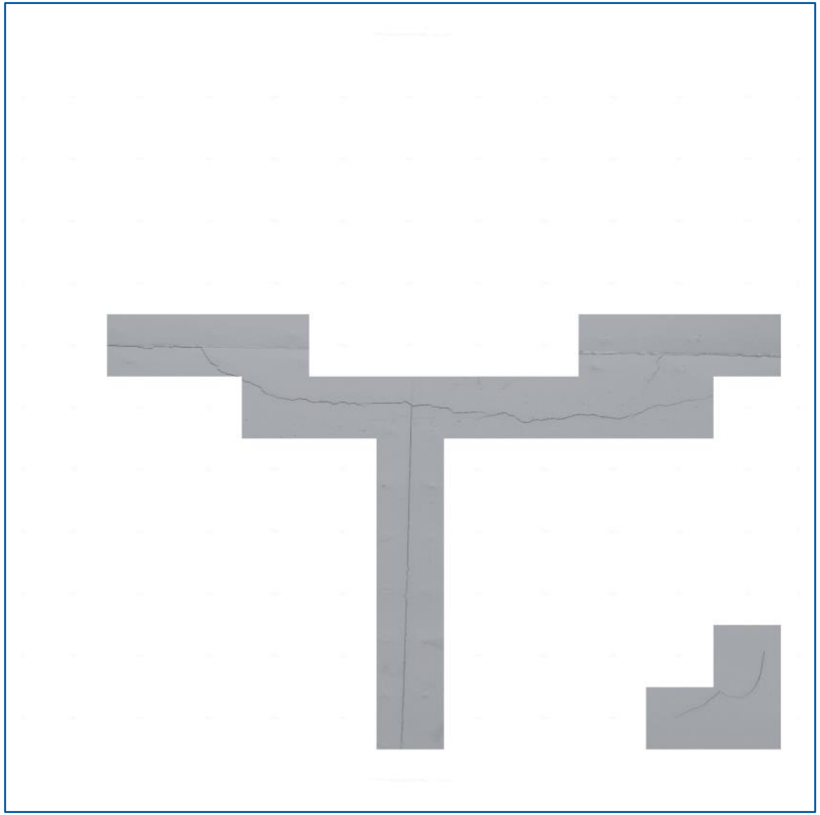


Sliding window Pass 1

Original Image

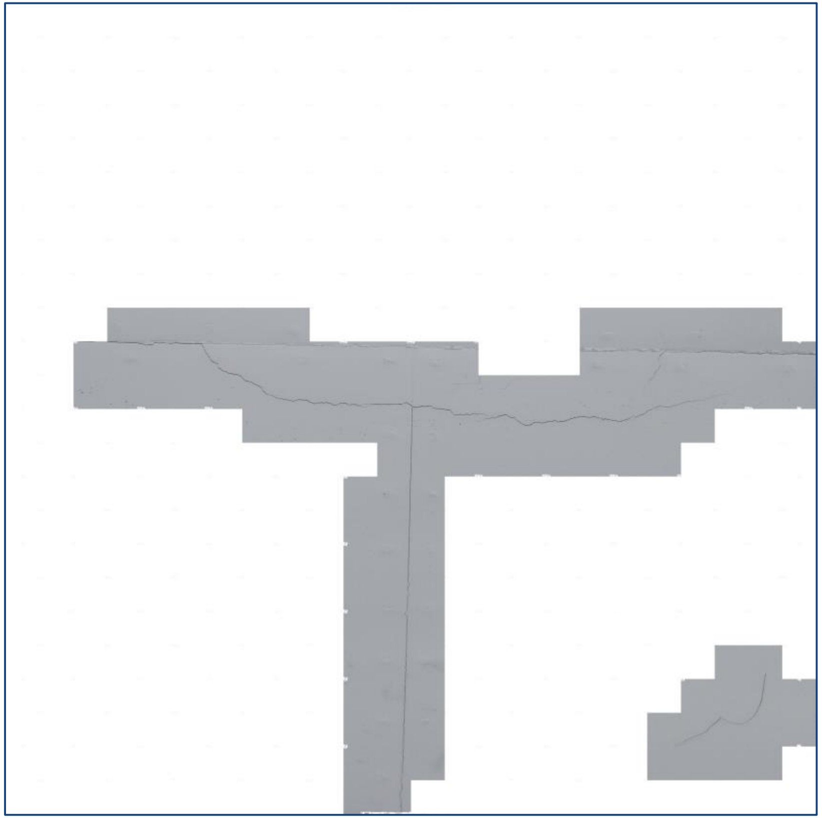


Sliding window Pass 2

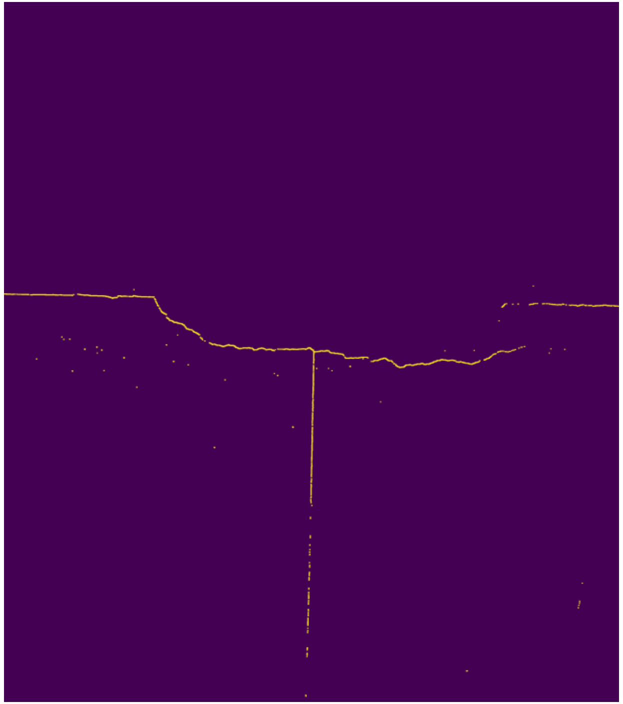


Original Image

Prediction Made



Classification of the Images



If a crack is detected in the stitched images it is then passed to be classified in 5 simple steps :

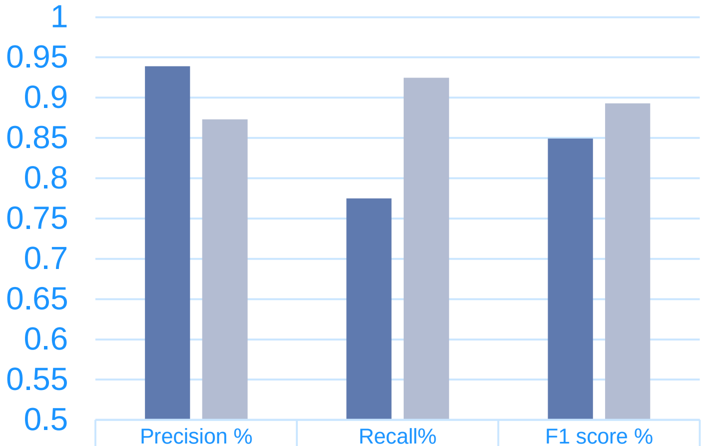
1. Images are processed.
2. Contours of the cracks located.

Classification of the Images

The stitched images are now ready to be classified in 5 steps :

1. Images are processed.
2. Contours of the cracks located.
3. Bounding Box put around the contours.
4. The angle of the bounding box defines the class.
5. Bounding box colour changes per class given.

Crack Detection Comparison with Previous Studies



	Precision %	Recall%	F1 score %
Leanne	0.939	0.775	0.849154026
darraghs	0.87315223	0.924935601	0.893121942

- Precision shows how much of the detected cracks were actually cracks.
- Recall is a measure of how much of the actual cracks were detected

(d) original image 4

(i) detection in (d)

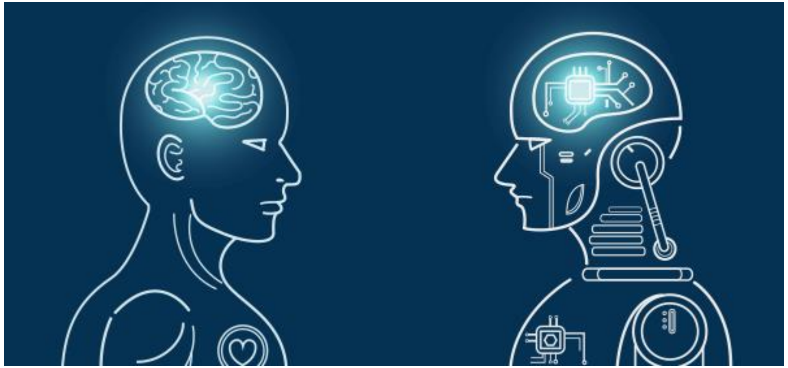
Differences

Previous work used an Intersection over Union (IoU) while current works use a CNN trained directly on smaller image sizes and implemented with the sliding window technique.

Aims of Photogrammetry Research

- A comparison of manually collected tunnel data vs CNN data for a selected section of tunnel potentially using BE image accusation technology (CERNbot or RP arm of the TIM) over a controlled designated length of tunnel.

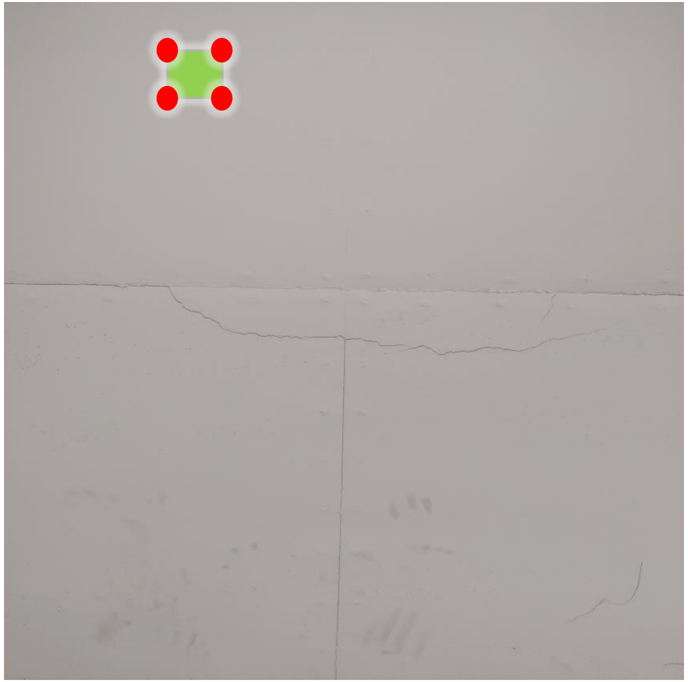
- This would give an idea of the accuracy of the algorithm and indicative the feasibility of future implementation in replacing current inspection methodology.



Camera on the RP arm extending from TIM

CERNbot

Future works



- Future work to focus on crack classification rather than identification.
- Crack classification can be further developed by adding a dimensional aspect. This is currently not possible due to an absence of a dimensional aspect within images to reference from.
- Potential to add a fixed sized laser (or other reference item) during image acquisition to add a reference area.
- This would allow crack dimensions to be determined automatically.
- Further work should also concentrate on development of hardware (cameras, TIM adaptation, CERNbot)

Future PhD Student

- University of Cork PhD student (PJAS) to start in September 2021
- Academic years 1 & 4 in Cork and years 2 & 3 at CERN
- Work to further develop crack classification software
- Relating observed tunnel defects to in-situ geotechnical conditions and tunnel structural features (e.g. tunnel junction)
- Reveal ageing tunnel performance in a large-scale continuous 3D space than previously available by conventional manual inspection
- Areas of study to be shared between photogrammetry and distributed fibre optic sensing

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

CERN

Discussion Points

- Capabilities of hi-resolution camera.
- Automatic crack width recognition.
- Hardware development and requirements for use in photogrammetry.
- The need for a TIM in FCC.