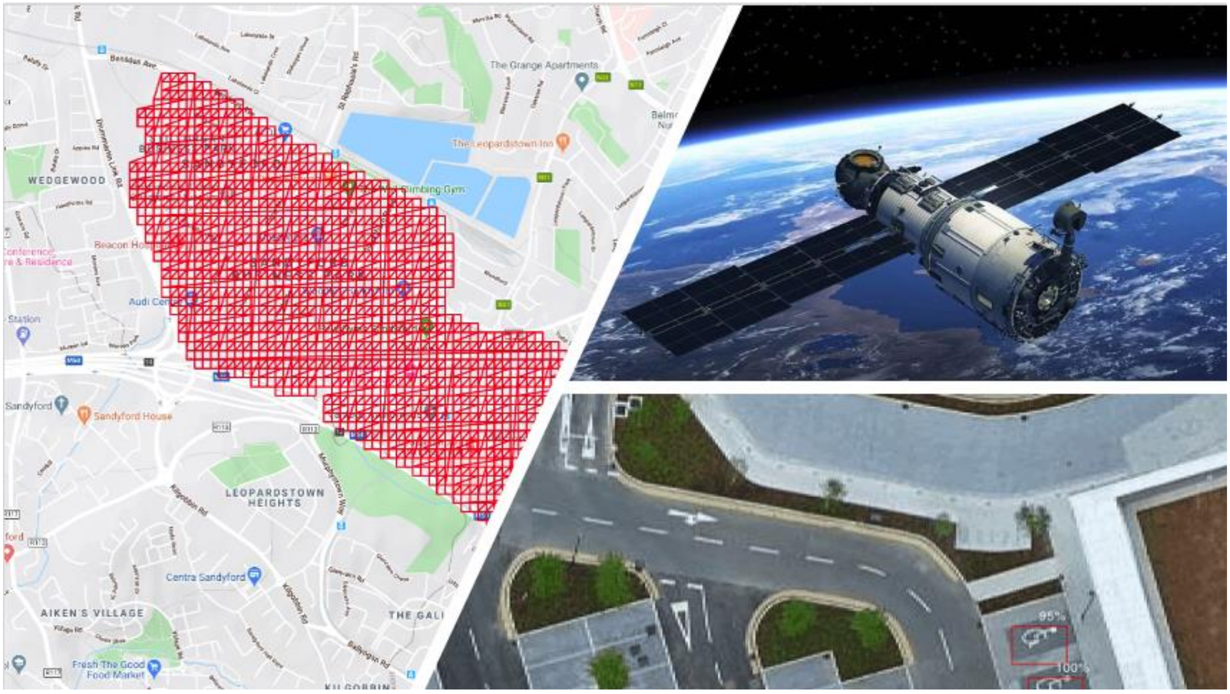
AUGUST 2020

Accessible Parking Analysis Report

A Smart Sandyford Case Study



Access Earth
Know more. Do more. Live more.

SMART SANDYFORD
A Smart Dublin District

AUTHORS

We would like to acknowledge the extended Access Earth and Smart Dublin teams who contributed to this report. Any comments or questions can be directed to the authors using the email addresses provided.

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1. INTRODUCTION

There are 643,131 people or 13% of the population in Ireland living with a disability[1]. Immediate and decisive action is needed to address the associated challenges, one of which is the need for increased and improved accessible parking. This report puts forward a new method of analysis for the availability and standard of accessible parking spaces and the corresponding issues. The report details the novel use of satellite data and it's interpretation as it was carried out by the Access Earth[2] team between February and June 2020 in Sandyford. This new approach to the analysis of accessible parking infrastructure is tested using Sandyford Dublin as an exemplar case study in partnership with the Smart Sandyford[3] research programme.

The goal of this report is to provide an informed insight into the accessible parking landscape for Sandyford. This involves analysing the total number of above ground accessible parking locations for the district where a high confidence level is achieved for accuracy of the image classifier.

This report demonstrates the power of combining satellite imagery and AI object detection classifiers for the purposes of accessible asset mapping within a built environment. The results of which will act as a starting point for the development and continued progress of additional features for the classifier that will be further discussed within the "Future Tool Improvements" section of this report.

The deployment of this system across any urban or rural environment has the opportunity to reduce the costs associated with accessible data collection, correlation and distribution dramatically and further help digitize the accessibility industry.

[1] https://www.cso.ie/en/releasesandpublications/ep/p-cp9hdc/p8hdc/p9d/

[2] https://access.earth/

[3] https://smartdublin.ie/smart-districts/smart-sandyford/

Smarter technologies have the power to help create and shape a more inclusive, accessible and prosperous society and smart cities are the perfect backdrops to test and demonstrate these solutions potential and powerful impact.

Why is accessible parking important?

People with disabilities have traditionally been an under serviced community by both the public and private sectors. This is a problem from a moral, ethical and inclusivity perspective, however, this also presents a major business opportunity as this demographic has an estimated spending power of €7 trillion globally. 65% of people with disabilities do not spend their money on travel or leisure due to a lack of, or a perceived lack of, accessibility infrastructure to cater to their needs. Accessible parking is a crucial asset that needs to be available in sufficient quantities to not just cater to individuals who already frequent business and services within an area but to also attract this massive untapped market into that area.

By adapting to cater for accessibility needs, businesses can tap into broader available talent pools, including people with a wide range of physical, cognitive and mental health abilities. We know that diverse teams produce better solutions[4], so there is a clear performance advantage to bringing together people with differences in terms of gender, ethnicity, orientation, age, background, and abilities. Employees with disabilities have higher retention rates, so for many businesses, there can be a real cost savings through reduced turnover. Studies show that consumers prefer doing business with companies that employ people with disabilities[5], so there is clear added brand value. Research has also found organizations employing people with disabilities have higher morale and employee engagement[6], which we know drives profitability. This serves to further highlight the need to provide adequate accessible infrastructure to service this demographic[7].

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[4] Van Knippenberg, D., van Ginkel, W.P. and Homan, A.C., 2013. Diversity mindsets and the performance of diverse teams. *Organizational Behavior and Human Decision Processes*, *121*(2), pp.183-193.

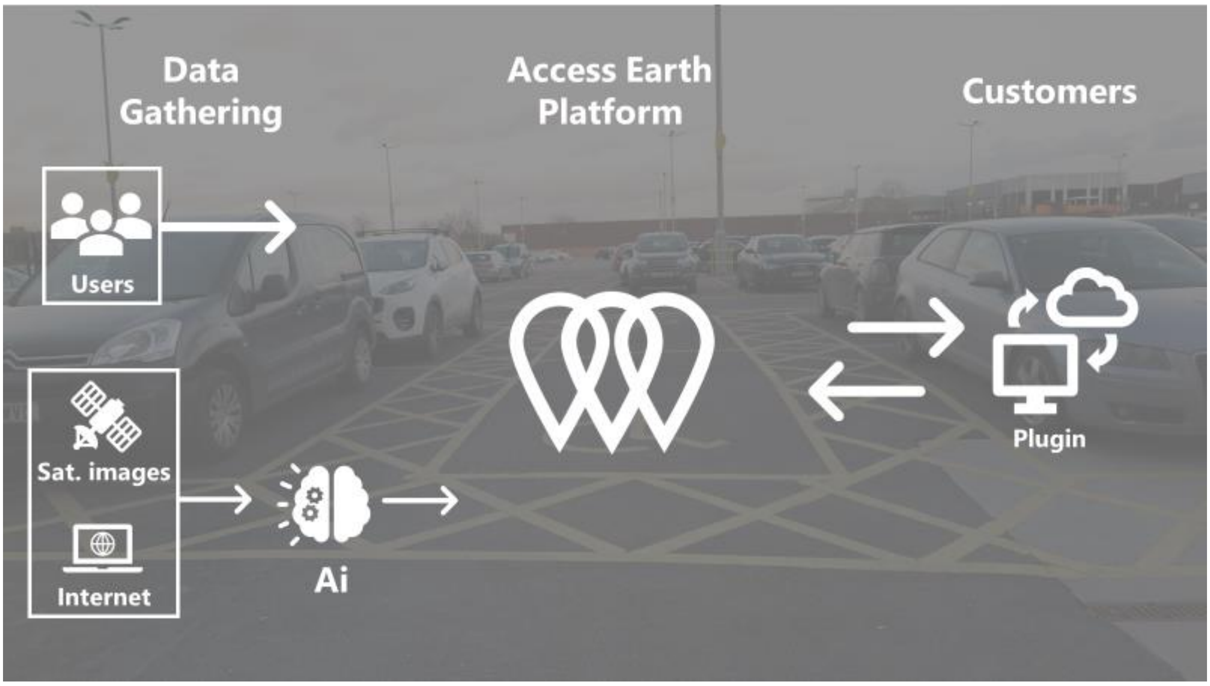
[5] Siperstein, G.N., Romano, N., Mohler, A. and Parker, R., 2006. A national survey of consumer attitudes towards companies that hire people with disabilities. *Journal of Vocational Rehabilitation*, *24*(1), pp.3-9.

[6] Lengnick-Hall, M.L., Gaunt, P.M. and Kulkarni, M., 2008. Overlooked and underutilized: People with disabilities are an untapped human resource. *Human Resource Management: Published in Cooperation with the School of Business Administration, The University of Michigan and in alliance with the Society of Human Resources Management*, *47*(2), pp.255-273.

[7] http://www.employerdisabilityinfo.ie/blog/why-hire-disabled-workers-4-powerful-and-inclusive-companies-answer

Access Earth

Access Earth is the '*Tripadvisor for accessibility information'*. Our goal is to build the world's largest database of accessibility information. We are doing this through our (1) interactive crowdsourcing mobile app for individuals and (2) by leveraging the power of Artificial Intelligence, AI, to review satellite data and online databases. These two business activities combine to expand our already comprehensive Access Earth platform. The graphic below shows how these different aspects of the business interact:



The platform integrates with our customers systems to provide them with a public facing plugin or an internal facing analytics system for deeper understanding of this accessibility data.

We have trained an AI model in object detection to create an image classifier by feeding it with multiple examples of aerial viewed accessible parking data. It can identify if an image it reads contains accessible parking locations and how many of these locations are present within the image.

This information can then be added into the Access Earth platform and be made available to all our users or curated to a specific format for a customers specified requirements.

Access Earth are a member of the European Space Agency, Business Incubation Centre[8] (ESA BIC). ESA BIC have given their support to help improve Access Earth's satellite information gathering system.

Smart Sandyford

The digitalisation of public services at all levels of government led to the need to test and validate new technologies in Dublin. Addressing this need resulted in the formation of Smart Dublin and the adoption of a 'Smart Districts' approach. Smart Sandyford has been developed as one of these districts to address the objective of using technology to trial new research initiatives and projects to benefit Sandyford and the wider Dublin region.

The programme is a partnership between Dún Laoghaire-Rathdown County Council, ENABLE and CONNECT Trinity College Dublin, and local businesses through the Sandyford Business Improvement District CLG.

Using this smart district model, Smart Sandyford is a smart city research programme designed to enhance Sandyford as a 'smart business district'. The programme aims to prioritise the needs of the business community which goes beyond simple testing of devices to advance projects that make a real impact including pre-commercial tests before city wide deployment of technology.

Workshop consultations with local district stakeholders carried out in the summer of 2019, identified mobility as the primary challenge facing the district. Smart

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8 http://www.esa.int/Applications/Telecommunications_Integrated_Applications/Business_Incubation/ESA_Business_Incubation_Centres17

technology-enabled solutions such as the Access Earth platform are sought to address this and other challenge areas.

As we move from a car-centric focus to more sustainable travel it is critical that the provision of accessible mobility options is a priority for the Smart Sandyford programme. We are delighted to work with Access Earth on this important research to determine the location and usage of accessible parking spaces, bays and drop-off areas in the district.

Assessing accessibility car parking in this manner will achieve the following for Sandyford:

- Provide a clear map of the Sandyford business district with all accessibility car spaces easy to find and access for the general public;
- Provide better knowledge of Sandyford's accessibility remit. The Irish Wheelchair Association recommendation that 1 in 15 (or 6%) of car spaces should be accessible spaces (Blue Badge), with this project we can determine the percentage that currently exists in the district and how to improve;
- Deliver an overall assessment of the necessary painting and refurbishing needs of spaces that may have deteriorated since they were installed; and
- Improve our ability to assess and communicate the usage of accessible car spaces at different times of the day (this will be a Beta feature of the project and depends on satellite frequency going forward).

2. BACKGROUND

65% of people with disabilities do not spend money on public outings or activities due to a perceived lack of accessibility infrastructure. While accessibility is a major issue for access and using services or shops, people with disabilities tend to spend 1.8 times as much money when they do choose to spend money on an outing, compared to the spending habits of people without disabilities.[9]

National Policy

The Irish Wheelchair Association (IWA)[10] is recognised by Local Authorities as the de facto expert in accessibility in Ireland. Further to the IWA access guidelines[11]; where public parking is provided, e.g. in public areas such as shops or offices, a minimum of one, and then one in 15 spaces should be designated for drivers and passengers with disabilities. Of these designated spaces, one in four should be designed to accommodate large multi-purpose vehicles. The recommendation is that these 1:4 bays would be of the largest size (5400mm x 7800mm) to accommodate

[9] https://www.cafefootball.eu/

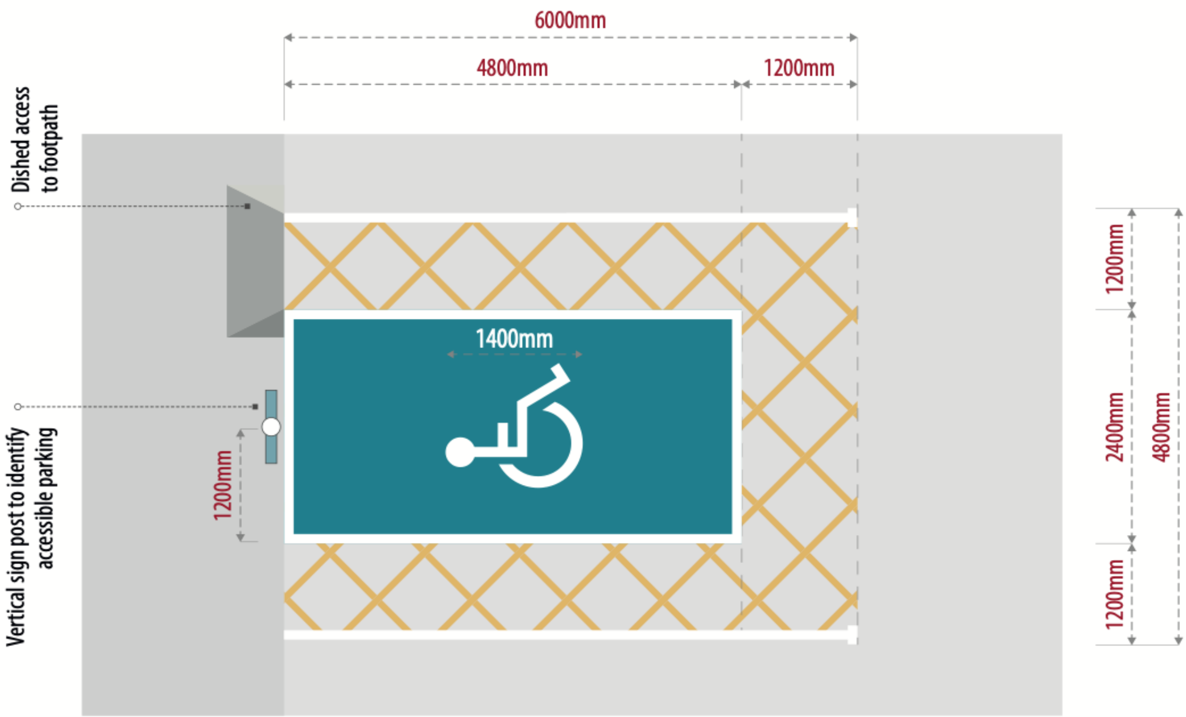
[10] https://www.iwa.ie/

[11] https://www.iwa.ie/downloads/about/iwa-access-guidelines.pdf

vehicles using all entry/exit options ie hoist/lift/ramp. For example, where 60 parking spaces are provided, three spaces should be designated for standard cars used by disabled drivers/passengers and one space designated for larger multipurpose vehicle use. Premises with high usage by people with disability may require a larger than average number of designated spaces.

The surface of the bay and adjacent accessibility zone should be firm, durable and slip-resistant. Examples of inappropriate materials are loose sand, cobbles or gravel.

The colouring used for accessible parking bays should be white markings on a slip-resistant blue surface. The adjacent accessibility zone should be cross-hatched in yellow. The colour and proportion details are visualised in the below image:



Cars and small vans

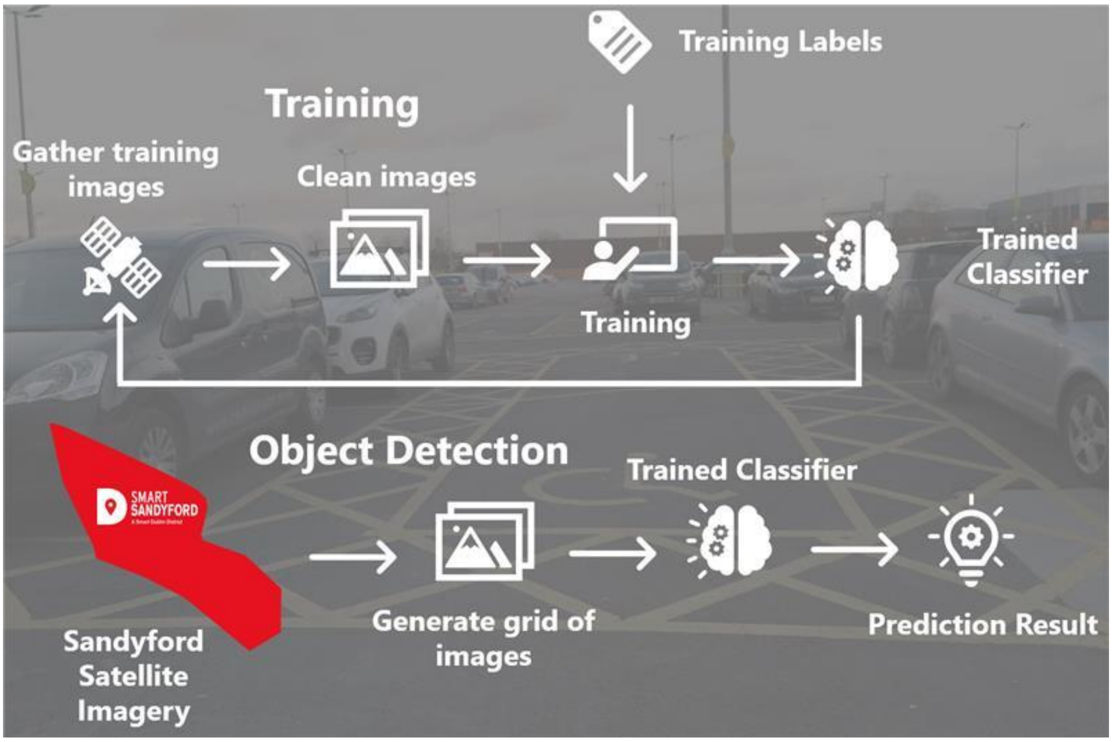
In addition to the above provision, spaces should be provided for employees who require accessible parking. Separate spaces should accommodate women who are pregnant and parents with young children. All spaces are to be clearly designated with the appropriate signage.

3. PROCESS

In this section we will explain some key concepts, go into further details on how these processes work and finally how they relate to the Smart Sandyford case study.

The steps required to train our classifier at a high level can be broken down into the following steps:

1. Gathering of data;
2. Cleansing data;
3. Training the classifier with the data;
4. applying training labels to the data to highlight the specified objects of interest; and,
5. Iterating this entire process to improve the classifiers performance.



Once the classifier has reached an adequate standard of accuracy we can then begin feeding it real world data to analyse and interpret in order to provide us with our desired results. For this report the results are based on identifying accessible parking spots within the Smart Sandyford area. To do this we need to generate the Sandyford areas satellite images into a grid before feeding them into the trained classifier.

Object Detection vs Object Recognition

Object detection is the process of finding instances of objects in images. In the case of deep learning, object detection is a subset of object recognition, where the object is not only identified but also located in an image.

For the purpose of this classifier we need to be able to not only recognise the wheelchair in the space but also identify where in the image it is located. From this we can assert not only if an image contains accessible parking but how many there are and where they are located. From the meta data provided about the specific positive image we can then locate and add the newly found accessible parking information to our database.

Data Gathering

Vast amounts of data is key to creating a robust and highly accurate classifier. The quality of the data the classifier is trained on is directly related to how well the classifier can perform.

The closer the training images are to the real world examples the classifier will be expected to interpret, the more likely a successful classification will take place.

To train our classifier we have used satellite images of accessible parking spots from around Ireland, from built up areas to rural locations, to ensure we could appropriately capture as many edge case examples of accessible parking as possible.

Data Cleansing & Applying Labels

Before we can add an image to our classifiers training pool we are required to perform a data cleansing check to ensure a number of criteria are met.

The image in question is required to be of a high enough resolution, has at least one example of the key object we hope to detect (i.e. accessible parking) and be orientated sufficiently.

If the image does not meet these standards and cannot be edited to correct them it must then be discarded. This is in order to protect the integrity of the classifiers training data. Poor examples lead to poor performance.

Once a piece of data has passed through cleansing it must then have labels applied to it. These labels help the classifier understand what objects it is being trained to detect. In the case of this project we are labelling all accessible parking found in the training images.

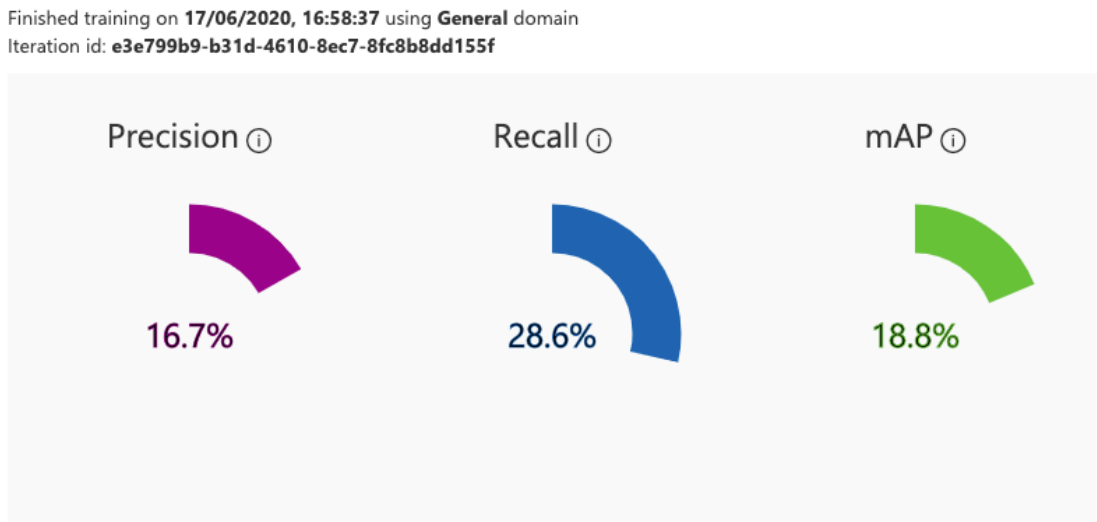
Training

Training a classifier is a largely iterative approach where one switches between data gathering, cleansing, labelling, testing and repeating.

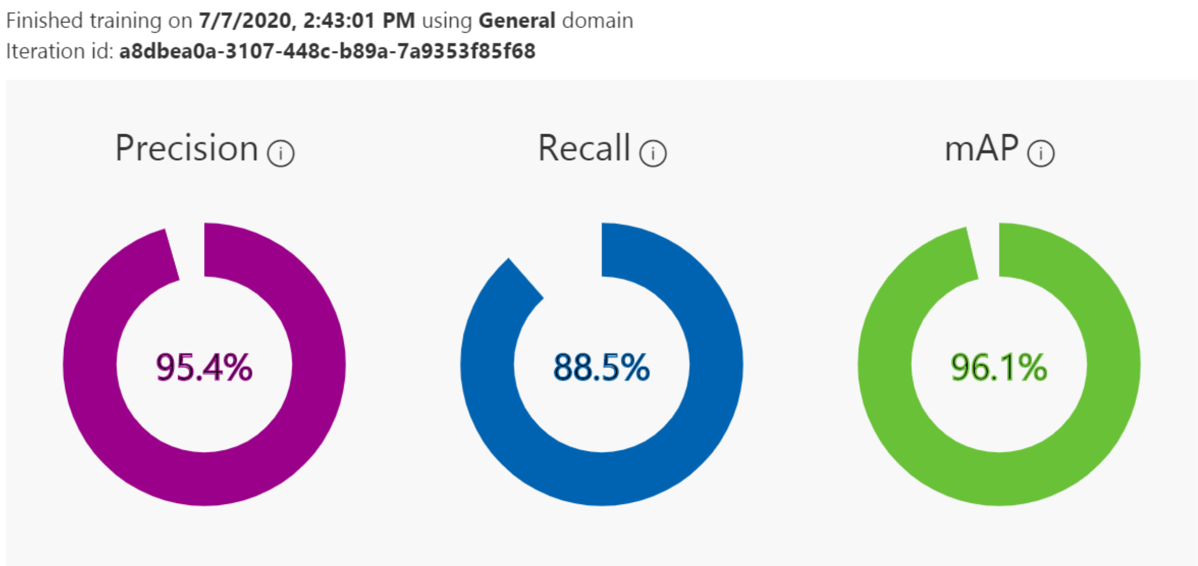
Ideally each iteration shows a marked improvement within performance from the previous, but in cases where there has been a loss of accuracy one most re-assess the previous batch of training data to ensure they haven't added in a poor quality example.

If you have lowered the accuracy of your classifier you must check to see if you have appropriately trained it with enough basic images of the most easily identifiable examples first before adding in difficult to find edge cases. Training a model too early, on difficult to interpret images, will increase the chances of it not just failing to find your desired object but also will increase the probability of you having a false positive.

For the purpose of this Smart Sandyford case study we have used Microsoft's Azure Cognitive services as our classifier. This service allows its users to add and label their training data and distinguish between the accuracy and performance of each iteration. This allows for analysis and trouble shooting in cases where a negative result has come from an iterative training session.



This image is an example of how accurate our classifier was when it first began training. By comparing this to the below image you can clearly see its improvement over time as new images and iterations where carried out.



For the sake of clarification, we have included the definitions of some of the terms used to measure how accurate an iteration has been.

Precision

If a tag is predicted by the model how likely is it to be right

Recall

Out of the tags which should be predicted correctly, what percentage did the model correctly find (essentially used during the training process to see if the model can remember what it had already been shown)

mAP

mean Average Precision (mAP): The overall object detector performance over all tags (useful if looking to detect multiple different objects but not in our case)

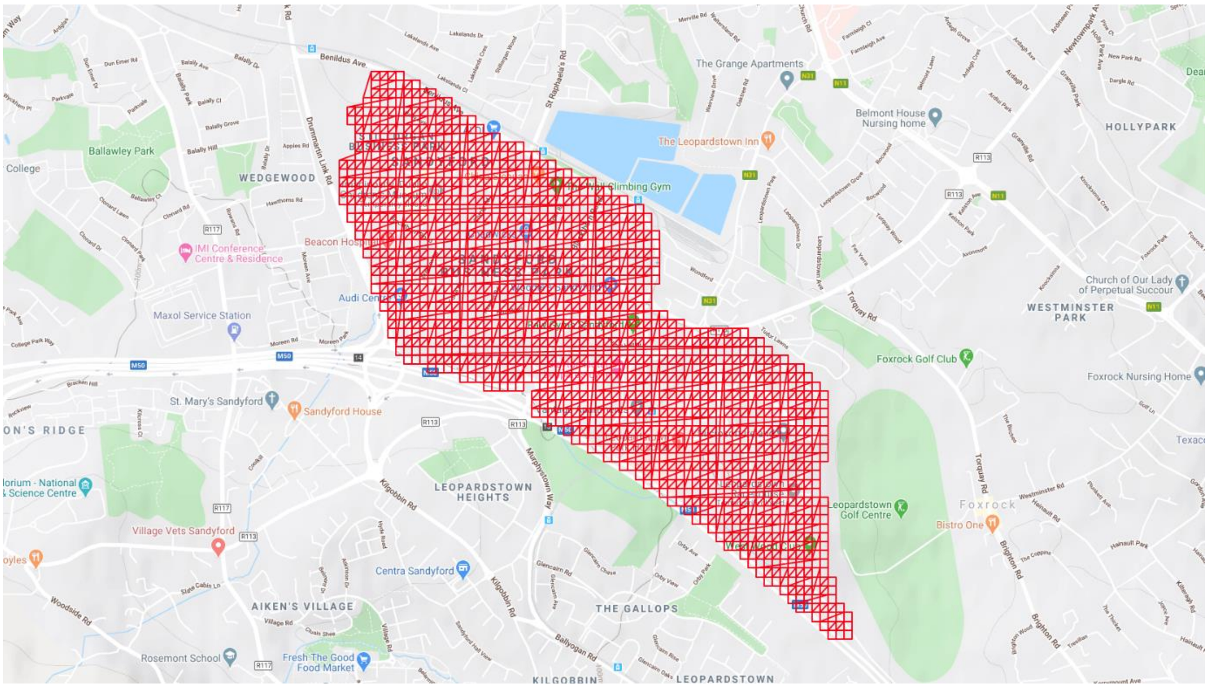
Once these iterations meet a standard of accuracy, we can then begin feeding them the data we wish to analyse.

The data being analysed needs to go through a series of steps before they can be processed. The below section on results goes through how this process applies to the Smart Sandyford case study.

4. RESULTS

To determine an area for analysis you need to first assess the bounding box for where you wish to review. This requires a series of latitude and longitude points to draw the boards where the analysis will take place within. For the case study we had the area within the Smart Sandyford zone to review.

Once this had been established, we needed to break the desired location into smaller grids to feed into the classifier. This is an important step as the classifier requires the data to be as close to the information it was trained on to increase its level of accuracy.



The smart Sandyford area was broken down into 1645 grid images of 640 x 640 pixels. These were then fed directly into the classifier to analyse where it highlighted all images that contained an accessible parking location and marked those locations with a red square and a percentage of how confident it had correctly found an accessible parking spot.

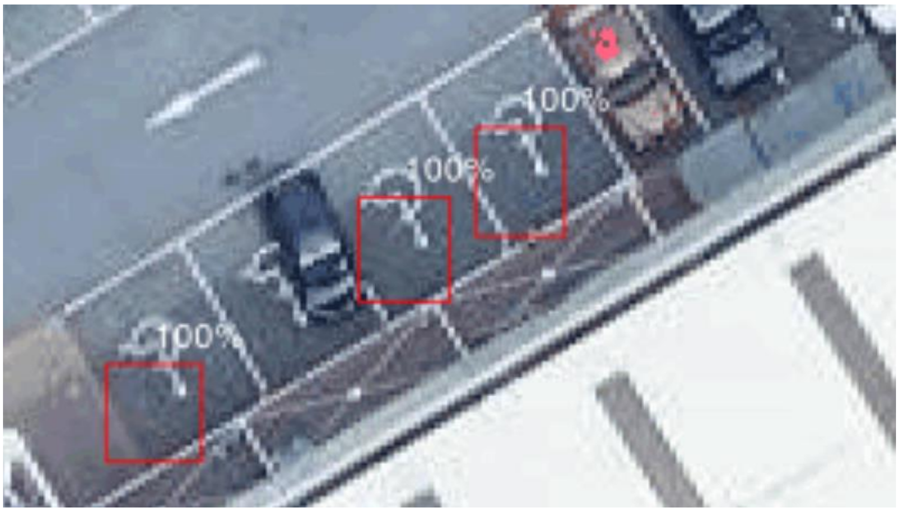
Once this had been completed the results went through a de-duplication process to ensure the parking locations were not being counted twice where grid boxes overlapped one another. Once this process had been completed, we were left with an accurate number of the total open-air accessible parking spots that are available within the Smart Sandyford area.

Edge cases

Though the ideal goal of every project is to have 100% accuracy for all targeted assets mapped, certain outliers and conditions prevent one reaching total perfection. How these challenges can be addressed and overcome is discussed further in the "Future Tool Improvements" section of the report. For now, let us discuss what these issues are and why we classify them as "edge cases".

An edge case, for the purposes of this report, can be classified as a conditional case where an inaccurate or unexpected result occurs due to circumstances beyond the original definition or expected parameters, happens during analysis.

One such example of an edge case can be found and is expanded upon below.



The expected behaviour of our classifier can be very simply defined: The classifier is fed an image and tasked with correctly identifying all the accessible parking spots within. The outliers, or edge cases, come into play when we see a contradiction with perfect behaviour resulting in imperfect results.

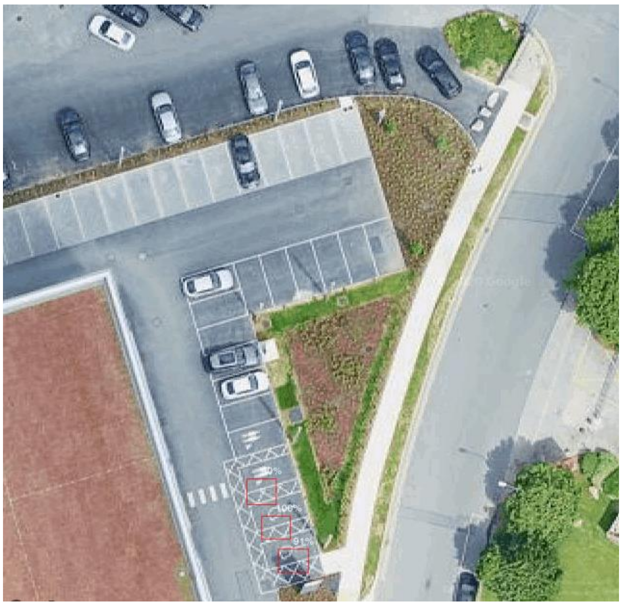
How we train the classifier with data creates expectations the classifier has of the the kind of images we want it to analyse. The classifier will look to identify cases where it is reasonably expected to find a car parking space to be of a high enough resolution for it to make a clear distinction of shapes from the surrounding area and for those shapes to be clear and unobscured by other existing objects within the image.

For the most part these expectations from the classifier about the images it is analysing can be predicted and even controlled through the training process, however sometimes these expectations can only be made known by reviewing behaviours after unexpected or inaccurate results have occurred.

In the case of this data outlier we can see that the classifier performs exemplary with a 100% confidence in its assertion that it has found 3 accessible car parking spaces during its object detection analysis of said images. However, it has failed to pick up where a car is partially obscuring the fourth space. This is where the internal contradiction comes to play. The classifier has behaved perfectly yet has still failed to get a perfect result.

False Positives

False positives are another issue faced when developing an accurate classifier model.



In the image on the left we can see the classifier has correctly identified 2 accessible hatch parking bays but has also mistakenly identified an adjacent parent and child parking space as being an accessible parking spot.

False positives occur when an object that is not of the desired classification is incorrectly identified as the desired classification. This can occur if data of insufficient quality is added as part of training data, thus confusing the classifier or if there has not been enough examples of the desired object for the classifier to properly distinguish it from similar looking objects when performing an analysis.

The only way to reduce false flags is with an improvement to the quality and quantity of training data provided to the classifier. For this case study many more images of a sufficient resolution are needed to consistently identify accessible parking reliably. This is due to many accessible parking icons being painted on without templates or those that do not follow best practices regarding sizing or colour. An example of an unusually styled wheelchair design can be found in the image on the right. Due to these divergences in colour, size and shape, the classifier needs more examples to reduce its chances of creating false positives.

5. DATA ANALYSIS RESULTS

Above ground parking results

Total Accessible Above Ground Parking	Private	Public
114	113	1

Blue Markings	Yellow Markings	White Markings
6	16	92

Parking Bays with Hatch markings	Wheelchair priority spaces
27	87

After the removal of false flags and a with a manual review of the classifiers output, we have concluded there are 114 above ground accessible parking spots within Sandyford.

These parking locations have been broken up into number of key categories regarding colour and type which can be found above.

We have also included within *appendix 1*, a full list of all parking locations and the corresponding latitude and longitude coordinates our classifier has identified with a 70% or higher confidence rating.

Underground parking results

Underground Parking Location	**Number of Accessible Parking Spaces**
Central Park	48
Aldi	5
Beacon Court Hotel	1
Beacon Court Hospital	5
Cypress Semiconductor[12]	1
Dunnes (Beacon South Quarter)	1
Total	61

[12] Although this parking space is outdoors on ground level, it is covered by the building proper which prevents it from being detected by the satellite and so for the purposes of the report it is considered 'underground'.

By triangulating the satellite data analysis with a manual underground parking analysis, we can be afforded a complete overview of the accessible landscape for Sandyford.

6. FUTURE TOOL IMPROVEMENTS

Improvements to model

Access Earth has succeeded in its application to become a member of the European Space Agency Business Incubation Centre (ESA BIC). As a result, support and funding has been given to help integrate and enhance the current classifier system using ESA satellite data.

The Copernicus satellite system's sentinel 2 satellite, takes high resolution images of the earth with round trips every 5 days storing this within the EUMETSAT databanks. Having access to such a large stockpile of images will allow Access Earth to dramatically improve the quality of the accessible parking classifier thus helping increasing the number of correctly identified accessible parking spaces and reducing the overall number of false positives.

Improvements to quality

With improved resolution images providing a more robust classifier more objects can be targeted and identified to provide a more nuanced report with higher quality results.

One such quality improvement would be the ability to identify non-accessible parking locations to compare with accessible parking spaces for a fully accurate indication on how close to achieving the minimum threshold of accessible spaces an area is.

Comparative analysis

With access to the ESAs stockpile of satellite imagery within the EUMETSAT databanks we will be afforded the ability to do a time lapse comparative analysis over areas that we have already reviewed.

This will enable such features as;

- Degradation analysis, to allow for smart notification on parking spaces which need to be repainted or maintained.
- Growth tracking, to show the increase in accessible parking location throughout a city or area over time.
- Multiple pass analysis for initial reviews of areas to capture spaces that may have been obscured due to parking being in use when the first analysis image was captured
- Fully automated update reviews to refresh an areas analysis once the sentinel 2 satellite has completed its 5 day trip offering fresh data images of the area in question to keep information up to date.

Interactive Plugin

By gathering the accessible parking data in the format presented in Appendix 1, we can appropriately digitise these points for a plethora of wide uses. Please find below a short list of examples for the immediate uses of this digitised dataset.

- Expand the current Access Earth data to make these points publicly available to existing Access Earth App users.
- Inclusion of these datapoints within an interactive publicly available map for Dún Laoghaire-Rathdown County Council.
- Inclusion of these datapoints within an interactive analysis tool for Dún Laoghaire-Rathdown County Council.

7. CONCLUSION

The classifier training steps were successfully carried out on Sandyford and highlight the potential of this Access Earth platform as a highly adaptive and accurate tool. These steps include (1) gathering of data; (2) cleansing data; (3) Training the classifier with the data; (4) applying training labels to the data to highlight the specified objects of interest; and, (5) iterating this entire process to improve the classifiers performance. The classifier can now be used to analyse accessible parking for any area in Ireland within minutes of deployment.

Following the data analysis it is safe to conclude that the current number of 175 accessible parking spaces (61 underground and 114 above ground) underserves a district of 26,000 employees and 5000 residents. While Sandyford, and Dublin as a whole, has work to do before it can achieve the goal of 1 accessible space in every 15, Access Earth and other accessibility initiatives are paving the way to a more inclusive society.

Presently the majority of the parking, and indeed the accessible parking, is provided by the private sector in Sandyford. However, the numbers of accessible parking spaces present are too low to adequately cater for current employees and visitors to Sandyford or to attract the accessible market. The private sector has a major opportunity to cater for a currently under served and valuable market. Local businesses can work with the Council to identify where and how accessible solutions can be deployed.

In addition to the low number of accessible spaces available, the quality of parking structures provided varies drastically. The Local Authorities can assist in this by, firstly, providing more information on best practices for standardised accessible parking spaces. Secondly, by recommending product designs to promote businesses to follow these practices.

It is noted that Sandyford and the wider Dublin region is well placed to adopt key aspects of accessibility integration and a path towards improved public accessibility parking. Access Earth remains a key partner of Smart Dublin and we have identified several areas within this document where Access Earth tools can provide information and insights as needed to help deliver accessibility for Dublin and Ireland. In addition to the satellite image classifier, the citizen science aspect of the Access Earth suite will also be tested working with Smart Sandyford.

This satellite classifier tool has the advantage of rapid analysis in comparison to traditional in person surveys and identification which has been used to date. Beyond accessibility analysis this tool will have a range of uses for Local Authorities and research partners going forward, these include:

- Planning mapping and zone detail analysis
- Biodiversity and tree counting
- Identification of illegal parking hotspots
- High river level and flood area analysis
- Litter and illegal dumping identification

Accessible parking is the first step in making our cities more user friendly for everyone. In addition to improved accessible parking we will also need an increase in improving all entrance and access points, easy to access facilities and increased awareness of the challenges faced by people with disabilities each day.

If you would like to find out more about the classifier tool, get involved on similar projects, or discuss working with either Access Earth or Smart Sandyford please get in touch.

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APPENDIX

Appendix 1

Classifiers Accessible parking locations with confidence rating above 70% which is statistically sufficient for this project.

Latitude	Longitude	Probability
53.27840491	-6.215531	99.9637
53.27872599	-6.2101035	99.87054
53.27428473	-6.2061339	99.82677
53.27834482	-6.2153557	99.76939
53.27440464	-6.2124801	99.75863
53.26881212	-6.1971925	99.72794
53.27385103	-6.2140118	99.6968567
53.27023288	-6.2005102	99.6751964
53.27156964	-6.1988103	99.65323
53.2743397	-6.2059884	99.60942
53.27910214	-6.2096127	99.5725
53.27651134	-6.2075236	99.5651
53.27822154	-6.2180906	99.54511
53.27387839	-6.2139878	99.5436549
53.27948183	-6.2169392	99.50796
53.26871405	-6.1971511	99.4903
53.27875461	-6.2100772	99.48486
53.26884421	-6.1972098	99.452126
53.27066164	-6.1976974	99.4211257
53.26877838	-6.1971785	99.3664265
53.2770155	-6.203897	99.330467
53.2686828	-6.1971353	99.09897
53.27158096	-6.198761	99.0512431
53.27432352	-6.2060355	98.9097059
53.27413481	-6.2085907	98.8790154
53.27665899	-6.2064821	98.833245
53.27654323	-6.2074995	98.77792
53.27667383	-6.2065324	98.72999
53.26888128	-6.2019668	98.7081349

Latitude	Longitude	Probability
53.27158525	-6.1972376	98.674047
53.27399767	-6.2183136	98.50593
53.27907911	-6.2095351	98.377
53.27048106	-6.1988321	98.32934
53.26950447	-6.1988624	97.7911055
53.28079397	-6.2208016	97.49794
53.27330895	-6.2080782	97.32124
53.27703924	-6.2038686	97.23341
53.27054265	-6.1985483	96.2401152
53.27333839	-6.2088848	96.13152
53.26887694	-6.2020157	95.68558
53.26953162	-6.1988855	95.43556
53.2770616	-6.203838	94.6472168
53.2800392	-6.2195145	94.25861
53.27621047	-6.2093911	92.3802137
53.2688916	-6.2019133	91.5651143
53.27397076	-6.2182815	91.39944
53.27161587	-6.1972165	90.93858
53.27520547	-6.2100302	90.50786
53.27471689	-6.2148167	89.43841
53.27251762	-6.2142123	88.72059
53.27063088	-6.1978173	88.4190857
53.27441242	-6.2174928	87.1076167
53.27618206	-6.2094113	82.21149
53.26874496	-6.1971571	78.97779
53.27289891	-6.2073032	73.8016844
53.26675967	-6.1985211	72.41488
53.27249493	-6.2163118	71.5652168
53.27439636	-6.2174496	70.94137