UrbanAccess: Query Driven Urban Analytics Platform for Detecting Complex Accessibility Event Patterns using Tactile Surfaces

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ABSTRACT

The smart city concept has now become one of the key enablers in urban city management. The adoption and permeation of ICT and AI-driven techniques have enabled the authorities to resolve poor urban planning issues with improved delivery of citizen services. Major urban problem is addressing the accessibility issue across cities road crossing and facilitating visually impaired people via well-defined infrastructure. The research presented in this paper emphasized urban analytics that studies the road crossings and challenges one faces when accessing the footpaths of a city using the Tactile surfaces. This work demonstrates a distributed event analytics platform- GNOSIS to detect complex accessibility event patterns. GNOSIS ingest video data streams from cities infrastructure such as CCTV and detect tactile surface event patterns using an ensemble of deep learning models using a declarative query language. The work analyzes mainly three types of tactile surface - Blister, Cycleway and Directional, collected from different cities in Ireland using crowd-sourcing techniques. GNOSIS makes decisions in real-time based on the type of tactile surface, colour and the making pattern.

CCS CONCEPTS

• **Computer vision**; • **Image processing**; • **Human-centered computing** → *Accessibility technologies*;

KEYWORDS

urban analytics, accessibility, complex event processing, deep neural networks, tactile surfaces

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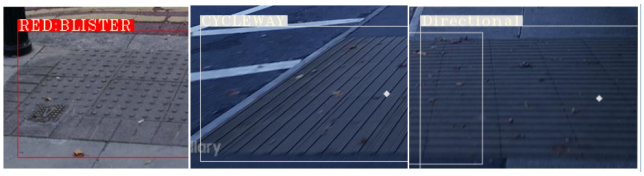

Figure 1: Annotated Output for different Tactile Surface event queries using GNOSIS : (*Left*) Red Blister paving, (*middle*) Cycleway paving with vertical bars (*right*) Directional paving with horizontal bars.

1 INTRODUCTION

The lack of robust and safe autonomous mobility solutions is one of the critical urban infrastructure challenges [4]. WHO Global Disability Action Plan 2014-2021 [7] is to strengthen and extend assistive technology. With the advancement of analytics and research, a vast number of assistive technologies has become available [5]. However, such technologies need to be intelligent enough to identify objects, manage colour correction, process real-time data and be economical in resource consumption. One way to address assistive navigation problems is by composing Tactile pavements to handle accessibility challenges and possibilities [6].

The proposed work focuses on assistive and accessibility analytics via Tactile pavement detection. Tactile surfaces come in all shapes and colours intended to denote different situations and hazards. Major Tactile surfaces are Blister, Cycleway and Directional [2]. As shown in Figure 1 (left), Blister paving uses square blocks with an array of small spheres inside. They are used to indicate pedestrian crossing with dropped kerbs. The red blister pavements are installed at controlled intersections, while the buff or grey coloured pavements occupy the non-controlled ones [1]. Cycleway paving uses continuous vertical flat bars to indicate a cycle lane (Figure 1 (middle)). The bars run parallel to the direction of travel so as not to impede cycles. Finally, directional paving stands for the safest direction of travel for the visually impaired (Figure 1 (right)) [2].

This demonstration introduces GNOSIS [14], an event processing platform to perform near-real-time video event detection in a distributed setting. GNOSIS uses a pipeline of DNN models and visual

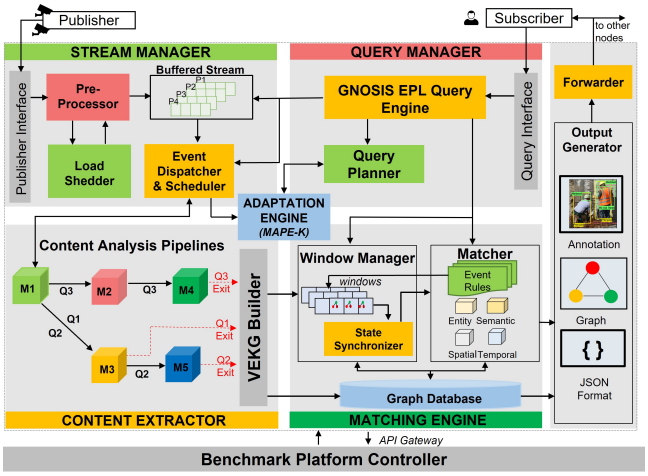

Figure 2: GNOSIS components act as pluggable services that convert the incoming media source into a structured graph stream using DNN models' pipeline and performs the graph-based event matching. [14]

query language to process and reason urban streams. It facilitates the execution of pre-defined visual queries that make decisions without any human intervention. The applicability of GNOSIS is manifold, where multiple urban analytics-based ML/DNN models can be chained together as distributed services to detect complex spatio-temporal [12] urban event analytics patterns. The work demonstrates three tactile detection queries that set an initial pathway towards accessibility and assistive applications in the urban analytics domain. It is economically expensive to create a beforehand digital inventory of every area of the city. Such query-based automation saves time and effort and can play a vital role in aiding accessibility analytics that helps city planners and authorities.

2 GNOSIS EVENT ENGINE

GNOSIS [14] is a multi-modal event processing system (Figure 2) that performs stateful and stateless multi-modal event matching using expressive queries. GNOSIS has a pluggable interface that enables a cascading of DNN services. A Directed Acyclic Graph (DAG) of DNN models, pre-trained on specific datasets, form the control flow in a GNOSIS Pipeline. Each DNN model makes independent predictions in the information chain. The information cascades onto another service in the DAG. This chain of information forms Video Event Knowledge Graphs (VEKG) [9, 11, 13] that stores information in the form of nodes and edges. A declarative query language called GNOSIS Event Processing Language (EPL) later queries VEKGs to obtain the final output. GNOSIS supports spatial and temporal analysis [10] through windowing functions.

3 USE CASE: TACTILE SURFACE DETECTION

Approach. Tactile Surface Detection is a DNN service trained on 1800 pavement images and uses the Darknet [8] library to make predictions. The model is a part of the Crowd4Access [3] initiative, a Citizen Science project that investigate the accessibility of the footpaths of Irish cities. Initially, a stream of road images acquired through the camera goes through the GNOSIS pipeline. The DNN cascade that includes Tactile Surface Detection and other models make predictions. Three GNOSIS EPL queries are now presented using COUNT aggregation operator with boolean argument to make decisions.

Q1: Identify whether the given crossing is access-controll - ed. Q1 uses the cascading of three DNN services - TactileSurfaceDetection detects the boundaries of the tactile surface, PavingTypeDetection detects the paving type of surface, and ColorDetection detects the colour of the identified tactile surface. The output from these services results in VEKG graph. The MATCH and WHERE clause makes sure that the detection made is of the object of the class TACTILE_SURFACE with attribute type 'BLISTER'. Finally, the RETURN clause outputs AccessControlledCrossing as True or False based on the colour of the pavement being red or not.

```
Q1: REGISTER QUERY AccessControlledPathDetection
OUTPUT ANN_IMAGE_BBOX, ANN_IMAGE_QUERY_OUTPUT
CONTENT TactileSurfaceDetection, PavingTypeDetection, ColorDetection
MATCH (surface:TACTILE_SURFACE)
WHERE surface.paving_type = 'BLISTER'
FROM video_Q1.mp4
RETURN surface.color = 'RED' AS AccessControlledCrossing
```

Q2- What percentage of crossings in the city are access-controlled. The given query calculates the percentage amount of access-controlled pathways across the city.GNOSIS executes the MATCH clause on the VEKG and produces output as presented in the RETURN clause. The MATCH clause detects two types of surfaces - red_blister_surface and buff_b- lister_surface, restricted by the parameters in their curly braces. The RETURN clause calculates the percentage amount using the COUNT of the tactile surfaces detected.

```
Q2: REGISTER QUERY GetProportionOfAccessControlledCrossing
OUTPUT ANN_IMAGE_BBOX, ANN_IMAGE_QUERY_OUTPUT
CONTENT TactileSurfaceDetection, PavingTypeDetection, ColorDetection
MATCH (red_blister_surface:TACTILE_SURFACE color:'RED',paving_type:
'BLISTER') OR (buff_blister_surface:TACTILE_SURFACE color:'BUFF',
paving_type:'BLISTER')
WHERE surface.paving_type = 'BLISTER'
FROM video_Q2.mp4
RETURN COUNT(red_blister_surface) / COUNT(red_blister_surface) +
COUNT(buff_blister_surface)) * 100 AS PercentageAccessControlledCrossing
```

Q3- Identify whether the path is bicycle friendly or not. After processing the output of TactileSurfaceDetection and PavingTypeDetection models, Q3 produces True or False based on the paving type being CYCLEWAY OR NOT. The query has a Tumbling count window of 10, meaning it takes ten different images of a single pathway to make a decision.

```
Q1: REGISTER QUERY isPathBicycleFriendly
OUTPUT ANN_IMAGE_BBOX, ANN_IMAGE_QUERY_OUTPUT
CONTENT TactileSurfaceDetection, PavingTypeDetection
MATCH (surface:TACTILE_SURFACE)
FROM video_Q3.mp4
WITHIN TUMBLING_COUNT_WINDOW(10)
RETURN surface.paving_type = 'CYCLEWAY' as Bicycle-Friendly
```

4 CONCLUSION AND FUTURE WORK

The work presents GNOSIS an urban analytics event engine that continuously monitors the incoming stream of pavements. The system demonstrates guidance clues for visually impaired people in various assistive notifications such as Text-To-Speech. The output is then available to be consumed by any navigation applications.

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