LANE INFORMATION TRAFFIC SIGNS – IMPORTANT SOURCES OF INFORMATION MOSTLY IGNORED BY ADVANCED DRIVER ASSISTANCE SYSTEMS

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Abstract: *Lane information traffic signs (LITS's) specify and spell out the arrangements of traffic lanes and provide important directional information at junctions and at other road locations for road users. The directional and lane information provided by LITS's is particularly important when the directional signs and lane markings painted on the road are not visible for some reason. Although cars equipped with advanced driver assistance systems (ADAS's) run on the roads in growing numbers worldwide and some percentage of these ADAS's provide automatic traffic sign recognition (TSR) functionality, as well, the LITS's are mostly overlooked by these systems. This is partly due to the big number of the possible lane arrangements and of the permitted vehicle directions, and therefore to the big number of the corresponding arrow- and stripe-based representations. A syntactic approach to generate, describe and recognise LITS's, particularly the LITS's used in Hungary, is presented in the paper. The approach can be incorporated in TSR systems that aim to recognise LITS's, as well. It relies on directional image features; such features can be derived in many different ways including template matching with generalized Gabor functions and from histograms of oriented gradients (HOG's).*

Keywords: *automatic traffic sign recognition, syntactic pattern recognition, morphological image processing, directional image features*

1. INTRODUCTION

1.1 Traffic sign recognition in advanced driver assistance systems

Cars equipped with *advanced driver assistance systems* (ADAS's) run on the roads in growing numbers worldwide [1]. The *development and production of ADAS's* constitute the *second fastest-growing application area* for automotive electronics – second only to the development and production of *hybrid and electronic vehicles* – and it is seen as having a *more secure investment potential* than the latter area [2].

Presently, however, only *a relatively small percentage* of the ADAS's provide *automatic traffic sign recognition* (TSR) functionality [3] and even ADAS's with TSR capabilities tend to *overlook lane information traffic signs* (LITS's). This is because the LITS's are seen by the transportation engineers and automotive experts *conveying less critical information* to the drivers than, say, the speed-limit and the no-overtake traffic signs do. Also, the *high number of the various possible road and junction layouts*, lane arrangements, permitted vehicle directions, and as a consequence, the *high number of their arrow- and stripe-based representations* appearing in LITS's, as well as the *involvedness* of the associated *visual pattern recognition* task, *impedes necessary investments* in development of TSR systems that can recognize also LITS's. If and when development of such TSR systems *becomes topical*, then the *syntactic approach* presented herein could be used and incorporated in them.

1.2 Outline of the paper

The rest of the paper is structured as follows. In Section 2, the graphical elements used in LITS's are presented in an informal manner. Also, the semantics associated with these is touched upon. In Section 3, a syntactic approach to generate and describe layouts of LITS's, and also to recognise such traffic signs in snapshots taken in real traffic, is presented. The approach makes use of directional image features. Methods for computing such directional features are touched upon in Subsection 3.3.

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In Section 4, conclusions are drawn and ways to enhance the presented LITS generation and recognition approach are indicated.

2. LANE INFORMATION TRAFFIC SIGNS

Lane information traffic signs (LITS's) specify and spell out the arrangements of traffic lanes and provide important directional information at junctions and other road locations for the road users. The information provided in pictorial manner by LITS's includes the *number* of, the *arrangement* of traffic lanes, and also *the changes of these* (e.g., lane merges, parting of lanes, lane closures). LITS's can *embed traffic signs* controlling the traffic over the individual lanes.

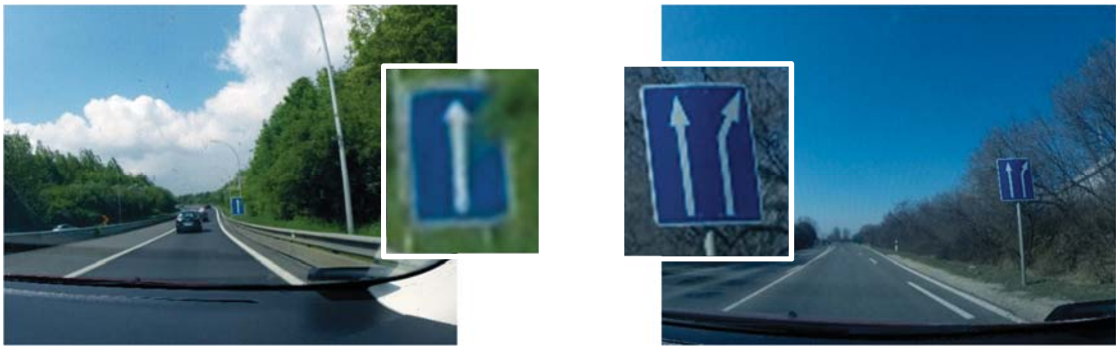

Figure 1 Two LITS's with relatively simple layout in road environments. The inlays show the respective blow-ups of the LITS image regions.

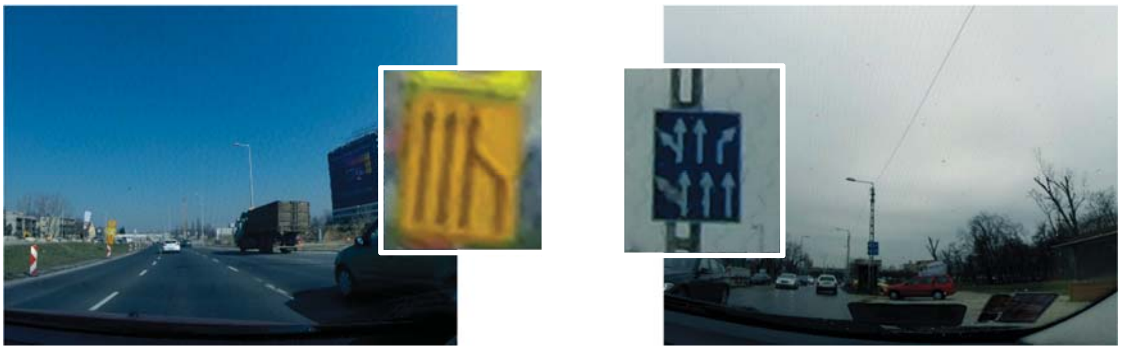

Figure 2 LITS's with slightly more complex layout. Again, the inlays show the respective blow-ups.

LITS's – *photographed in road environments* – are shown in Figures 1, 2, 4 and 6. These snapshots were taken with a *GoPro Hero 3+ camera* working in time-lapse mode (with time-interval set to 2 seconds) from a car moving in traffic. The camera was *mounted on the windscreen* using a suction cup. This *time-lapse photography* was part of a traffic sign related image and geographical data collection exercise.

2.1 Cases in which the information conveyed by LITS's are really important

The LITS's are *important sources of traffic information* particularly when

- the corresponding *directional signs* and *lane markings* painted on the road *are not visible* for some reason (e.g., the road is packed with vehicles, or the road is covered by snow),
- there has been a *temporary change* (e.g., in case of road works) of the road layout, or the arrangement of the lanes,
- there has been a recent *permanent change* in the road layout, or the arrangement of the lanes by the authorities (not promptly followed by navigation devices and applications).

In the first case mentioned above, not only a *human driver* will not be able to see the markings and the directional signs painted on the road, but a *lane marking recognition system* – such as proposed and described in [4] – will not work either.

It is clearly not to say that LITS's are always visible. Neither do we imply that the *LITS recognition systems* work better, or are more useful than lane marking recognition systems are. However, as shown above, there are situations when LITS's – and as a consequence *TSR systems with LITS recognition capabilities* (i.e., ones with *LI-TSR capabilities*) – come handy for the drivers.

2.2 Graphical elements appearing in LITS's and their semantics

2.2.1 Arrows and stripes appearing in LITS's

As a rule of thumb*, simple lane arrangements* are represented by *simple arrangements of arrows and stripes* in LITS's. Such LITS's – for instance the ones shown in Figure 1 – are fairly easy to read and comprehend. On the other hand, *complex traffic patterns* (e.g., near and through junctions with intense and/or multi-directional traffic) necessitate *setting up multiple traffic lanes* by the road authorities, and *permitting varied directions of travel* for cars moving in the different lanes. Such lane arrangements are represented by *more complex arrangements* of arrows and stripes in LITS's. These LITS's are obviously *more difficult to comprehend*, particularly when driving in busy traffic. This difficulty should *motivate the development* of TSR systems with LI-TSR capabilities. Clearly, this *motivation is not strong enough* for the automotive industry at this stage.

Two LITS's with somewhat *more complex layout* are shown in Figure 2. In the left snapshot, a LITS erected near a *road-work location* on multi-lane road, in the snapshot on the right, a LITS erected near a *busy junction* are shown, respectively. Both snapshots were taken in Budapest (Hungary).

The LITS in the right inlay is a *compound LITS*; it incorporates a LITS in its *lower half* (corresponding to the lane arrangement closer to the camera), and another one in its *upper half* (corresponding to the subsequent lane arrangement, which is farther from the camera).

Note that the *geographical locations* of the LITS's should be stated explicitly as the *shape of the arrows*, the *colour scheme* used in and the *layout* of LITS's differ considerably from one country to the other – even within Europe. To illustrate this fact, a small selection of LITS's from other European countries is presented in Figure 3.

Figure 3 Examples of LITS's from different European countries.

Apart the from the LITS's appearing in Figure 3, *LITS's located in Hungary* are presented and used as examples in the paper. It should be underlined, however, that the majority of the comments can be applied to, or at least adapted to the *LITS-styles* used in other countries.

2.2.2 Other graphical elements appearing in LITS's

Apart from the lane arrangement and permitted direction of travel, LITS's can convey *other traffic related information*, as well. There are LITS's, for example, that warn the road users of lanes designated solely for *buses* and *taxis*, and/or *cyclists*.

Also, white/yellow *solid/dashed lines* and/or yellow/grey *blocks* may appear in LITS's. These correspond to white/yellow solid/dashed lines painted on the road and to some physical inter-lane barrier (e.g., traffic island), respectively.

Various *lane-specific* prohibitory, order giving, warning and information *traffic signs* may appear embedded in LITS's. There are now quite a few *multi-lane roundabouts* on the major roads in

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Hungary. These were installed at junctions with a long record of road accidents. There are LITS's that spell out the lane arrangements and permitted directions for such junctions.

In the LITS's presented in the two inlays of Figure 4, several *lane-specific embedded traffic signs* can be identified. In the LITS on the right, a solid white line appears between the two right-most arrows (representing the solid line painted on the road between the corresponding traffic lanes).

Figure 4 LITS's with embedded traffic signs. The inlays show respective blow-ups.

3. GENERATION AND RECOGNITION OF LANE INFORMATION TRAFFIC SIGNS

As it was discussed in Subsection 2.2, LITS's are formed of *re-occurring graphical primitives.* Within LITS's, these primitives are placed next to one another according certain *geometric and connection rules*. These rules can be formulated as an *image grammar* [5]. Similarly to other *formal grammars*, see e.g., [6], an image grammar comprises a *start symbol*, a *set of reproduction rules*, a *set of nonterminal symbols* and a *set of terminal symbols*. Also, compound LITS, such as shown in Figure 2, can be generated, described and recognised via image grammars. The topic was touched upon in [5].

3.1 The simple LITS grammar

Three *nonterminal symbols* (L, T, R) – corresponding to the *left-straight-right*, *straight-right* and *right directions* of travel, respectively – were used in the *simple LITS grammar* (SLG) defined in [5] for generating a useful *subset of LITS's*. Figure 5 shows how a LITS – with no embedded traffic signs – that describes the *lane arrangement of a three-lane road location* – with its left lane used for turning left and proceeding straight, with its middle lane used solely for proceeding straight, and with its right lane used solely for turning right (such a lane arrangement and permitted directions of travel are specified in the upper half of the compound LITS in Figure 2) – *can be generated* through *application of reproductions rules* firstly to the start symbol S and then to the nonterminal symbols L, T and R. (The arrow-heads are omitted from the subsequent figures to avoid typographical difficulties.)

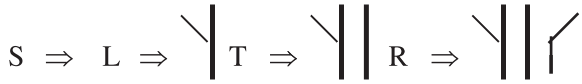

Figure 5 Generation of a LITS using the SLG production rules.

3.2 An extended LITS grammar

A *wider subset of LITS* could be generated using the *very same general approach* by making use of *six nonterminal symbols* (instead of the three used in SLG). This grammar will be referred to as *extended LITS grammar* (ELG).

The *nonterminal symbols in ELG* – namely U, E, L, T, R and I – correspond to sets of directions formed of `u_turn`, `sharp_left`, `left`, `straight`, `right`, `sharp_right` directions in the manner seen in the previous subsection. So, for example, nonterminal symbol T corresponds to the set of `straight`, `right` and `sharp_right` directions of travel, R to the set of `right` and `sharp_right` directions, and I to the set of `sharp_right` direction only.

If we stick to the general approach used in SLG – particularly, in terms of choosing the set of terminal symbols and setting up the reproduction rules – for the specification of ELG, then *many additional terminal symbols* – extending the set of 7 in SLG to that of 63 in ELG[1] – and *many (revised) reproduction rules* – replacing the set of 17 in SLG to that of 132 in ELG – will be necessary.
Clearly, the set of terminal symbols in ELG will include *many complicated arrows* (i.e., arrows with four, five and even six arrow-heads), which are *highly unlikely to appear in practice*. As we have seen in Figures 1, 2, 4 and 6, arrows with up to three arrow-heads are actually used real LITS's.
Now, if we consider only the *realistic arrows* (e.g., arrows with up to three arrow-heads) then about one third of the terminal symbols and also about one third of the reproduction rules[2] can be removed from ELG resulting in a more practical and more *realistic LITS grammar* (RLG).

Figure 6 A LITS that can be generated with ELG, but not with SLG.

Due to space limitations, the reproduction rules of ELG and of RLG are not given explicitly in the paper. Nevertheless, the *generation of the LITS* shown in Figure 6 – except for its embedded traffic sign appearing in the right arrow/lane – *according to ELG* is presented in Figure 7.
Note that this LITS cannot be generated using SLG because of its particular triple arrow on the left (corresponding to the permitted directions of travel for the left lane): one of the arrow-heads represents `sharp_left` turn, which is not used in SLG.
On the other hand, it *can be generated also with RLG*; the generation sequence will be the same as shown in Figure 7, only the ordinal numbers of the reproduction rules used in the particular generation steps will differ from those used in the generation with ELG, but these numbers are not indicated in the figure anyway.

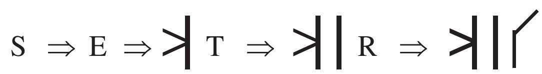

Figure 7 Generation of the LITS appearing in Figure 6 using the ELG production rules.

3.3 Methods for the identification of graphical elements in lane information traffic signs

For the purpose of *recognition of LITS's*, firstly, the *graphical elements appearing in LITS* must be identified. For this purpose, *line-segment and disk-based granulometries* – with the directions of line-segments chosen for the considered subset of LITS's – were computed and used in [5].
Other methods reportedly used for computing *directional image features* in the context of *traffic signs recognition* include *affine moment invariants* [7], template matching with *generalized Gabor functions* [8], and *histograms of oriented gradients* [9].

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1 If we denote the *number of allowed travel direction* with N, then the *number of nonterminal symbols* used in the LITS grammar is also N, the *number of terminal symbols* is 2^N -1 and the *number of reproduction rules* is 2^{N+1} + N – 2 . For SLG, the respective values are 3, 7 and 17, for ELG these are 6, 63 and 132.
2 These proportions apply only for the case of *six allowed travel directions* (i.e., N = 6).

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4. CONCLUSION

A *syntactic approach* to generate, describe and recognise *lane information traffic signs* (LITS's), particularly the *LITS's used in Hungary*, was presented in the paper. The approach can be *incorporated in TSR systems* that aim to recognise LITS's, as well. The approach relies on *directional image features*.

The *LITS grammar* described in Subsection 3.2 is an *extended version of the simple LITS grammar* proposed in [5]. This extended grammar generates a *wider subset of LITS's*, but still there are *restrictions posed on the graphical elements* that can be used and recognised (e.g., no embedded traffic signs are allowed by the grammar, the separating solid/dashed lines and blocks are not considered). These *restrictions need to be eased* in the future.

Also, *image segmentation* and *feature extraction experiments* need to be carried out using the methods mentioned in Subsection 3.3. Furthermore, *recognition tests* are required in conjunction with images taken in *real traffic* and in various *weather and light conditions* to properly *evaluate the usability and practicability of the syntactic recognition approach* presented here.

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