An Automatic License Plate Recognition (ALPR) System

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Applications of Automatic License Plate Recognition

- Parking
- Access Control
- Motorway Road Tolling
- Border Control
- Journey Time Measurement
- Law Enforcement

License Plate Recognition Algorithms and Technology

- Automatic license plate recognition has two essential technological issues:
  - the quality of the license plate recognition software with its applied recognition algorithms, and
  - the quality of the image acquisition technology, the camera and the illumination.

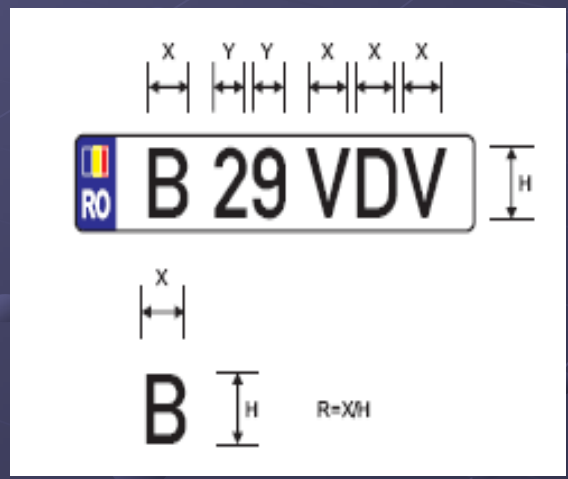
License Plate Recognition Algorithms and Technology

- Key factor: recognition software

- The better the algorithms are, the highest the quality of the recognition software is:
  - the highest recognition accuracy it has,
  - the fastest processing speed it has,
  - the most type of plates it can handle,
  - the widest range of picture quality it can handle,
  - the most tolerant against distortions of input data it is.

License Plate Recognition Algorithms and Technology

- License plate geometrical structure



License Plate Recognition Algorithms and Technology

- There are six primary algorithms that the software requires for identifying a license plate:
  - ***Plate localization*** – responsible for finding and isolating the plate on the picture;
  - ***Plate orientation and sizing*** – compensates for the skew of the plate and adjusts the dimensions to the required size;
  - ***Normalization*** – adjusts the brightness and contrast of the image;
  - ***Character segmentation*** – finds the individual characters on the plates;
  - ***Optical character recognition***;
  - ***Syntactical/Geometrical analysis*** - check characters and positions against country specific rules.

License Plate Recognition Algorithms and Technology

- Difficulties:
  - **Poor image resolution**, usually because the plate is too far away but sometimes resulting from the use of a low-quality camera;
  - **Blurry images**, particularly motion blur and most likely on mobile units;
  - **Poor lighting** and **low contrast** due to overexposure, reflection or shadows;
  - An **object obscuring** (part of) the plate, quite often a tow bar, or dirt on the plate;
  - A **different font**, popular for vanity plates (some countries ban such plates, eliminating the problem);
  - **Circumvention techniques**.

License Plate Recognition Algorithms and Technology

- Difficult image examples

	Rezoluție scăzută (cameră cu rezoluție slabă sau distanță mare)
	Imagine ștearsă (vehicule aflate în mișcare)
	Contrast scăzut (timp de expunere mic / iluminare slabă)
	Supraexpunere (timp de expunere mare / iluminare puternică)
	Umbrire (condiții de iluminare slabe)
	Distorsiuni de formă (unghi de vedere mare sau plăci deformate)

The OCR task

- License Plate Recognition is special type of OCR and therefore the definition of License Plate Recognition should clearly reflect that it is indeed an OCR.

The OCR task

- Steps:

1. Plate localization

2. Plate enhancement

3. Character segmentation

4. Character recognition

Complete License Plate Recognition Systems

- A typical ALPR system comprises:
  - a video/image acquisition subsystem (camera + frame grabber or digital camera + large-bandwidth digital interface such as FireWire, USB2, or CameraLink);
  - a processor for image processing, control and communication;
  - a software that given an image, finds the plate (or plates) in the image and reads the plate characters;
  - a control software that manages triggers, communication, storage etc;
  - an illumination system that guarantees a sufficient lighting on the plate;
  - since the system is required to function in any condition of ambient illumination (day, night, sun shadow), a proper lighting is a necessary condition for robust performance.

Complete License Plate Recognition Systems

- There are two types of installation: controlled access or free flow:
  - Controlled access means that vehicles are forced to go through a gate at low speed or to stop in front of a barrier (parking)
  - Free flow means that vehicles are moving without specific restrictions

System Architecture

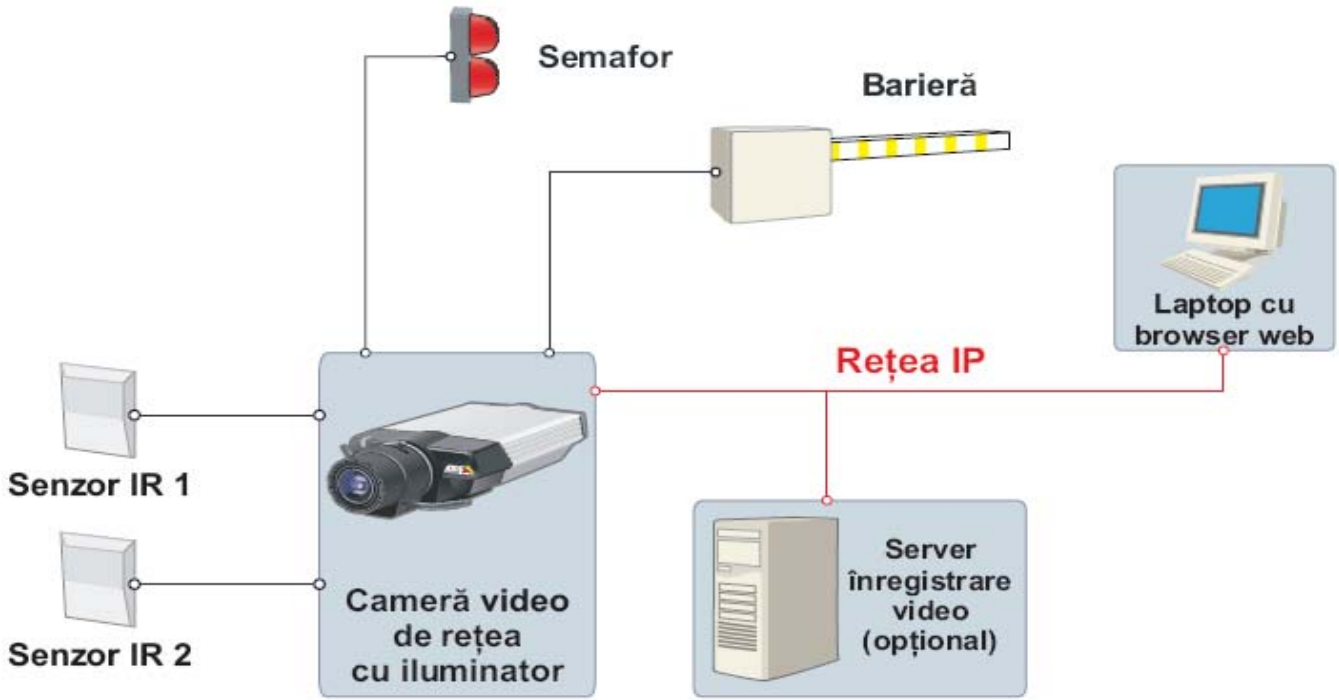
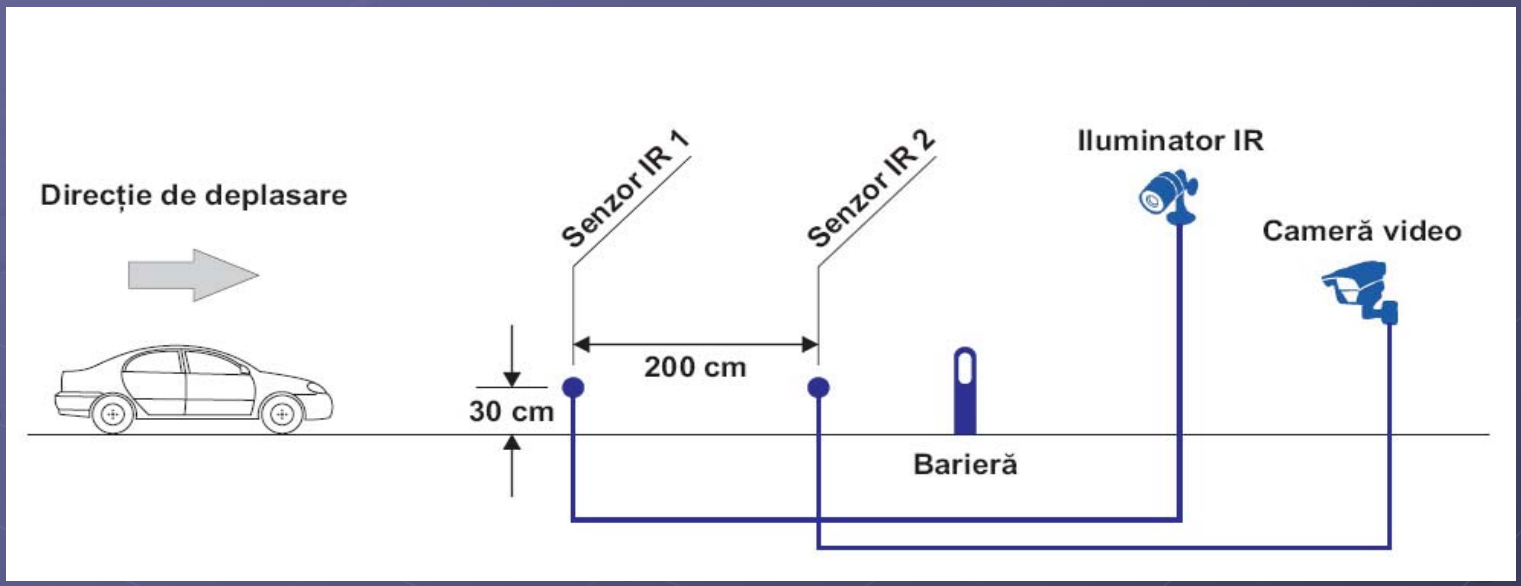
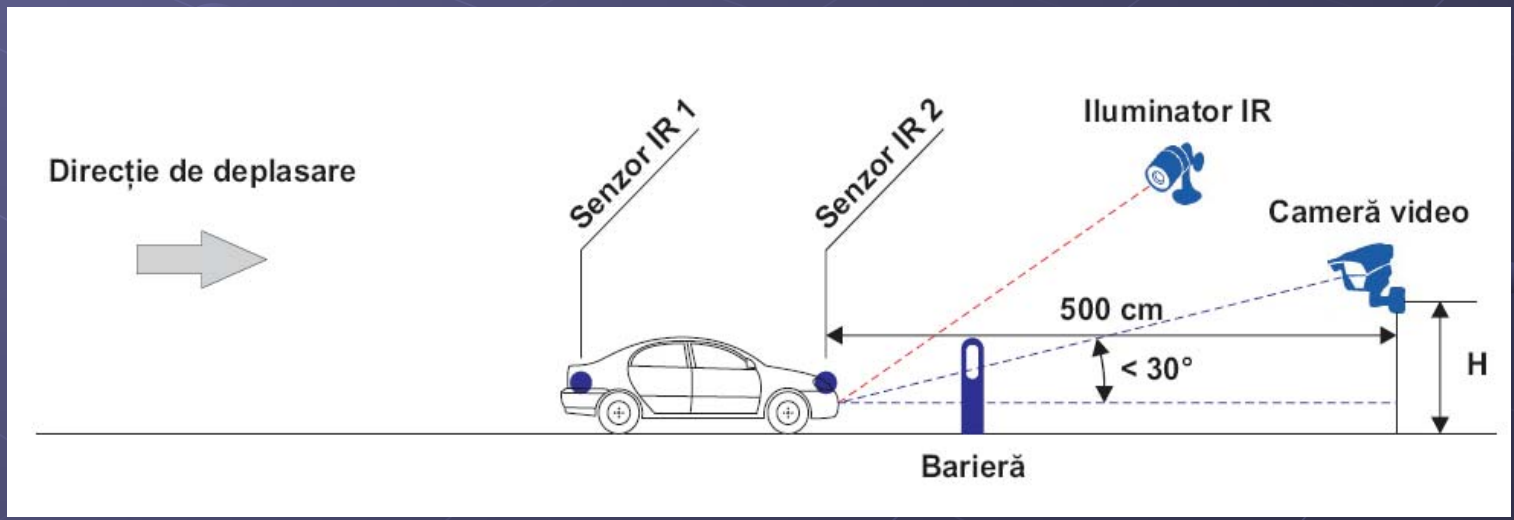


Figura 3.1: Schema bloc a sistemului de supraveghere

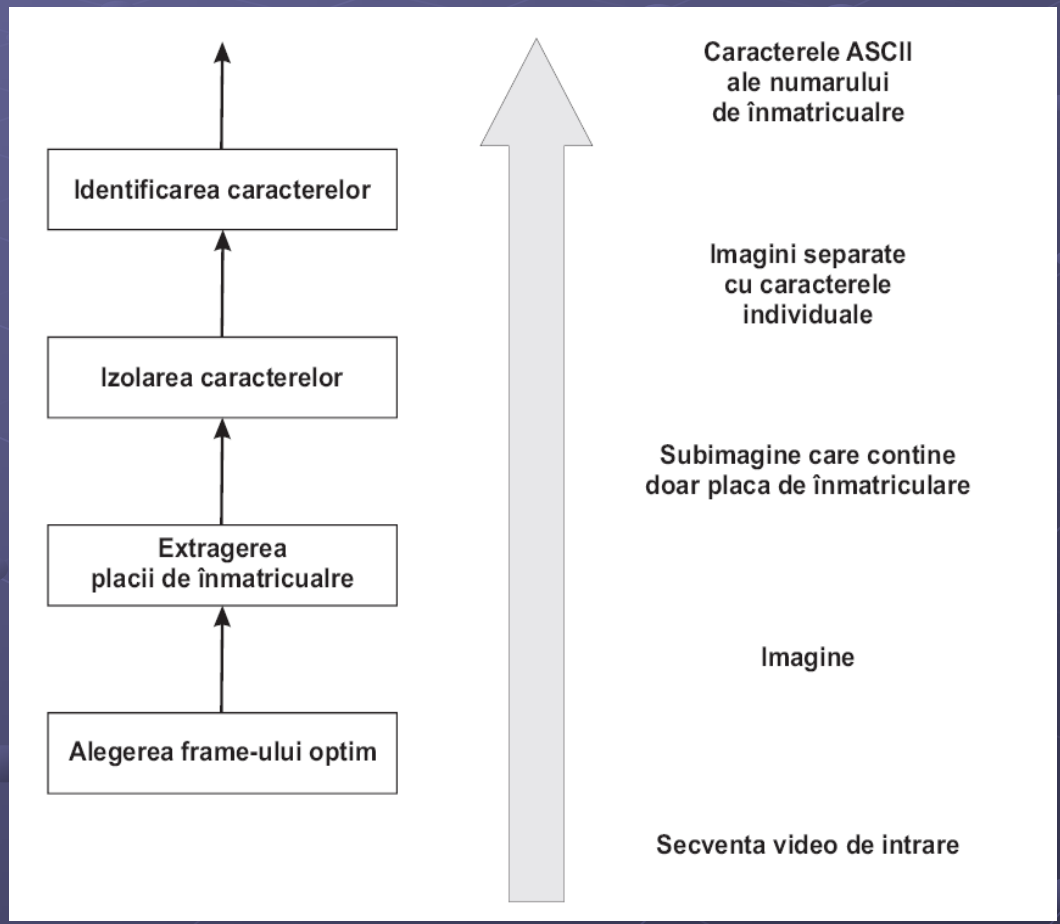
System Architecture





Processing Flowcharts

- Data abstraction level



Romanian Car License Plates

- The plate has the dimensions (*w* x *h*) 504 x 120 mm and has all the characters written in a single line.
- The *standard Romanian License plate* consists of a blue vertical strip (the European-strip) on the left side of the plate containing the Flag of Romania and the country code of Romania (RO), always followed on a white surface, using black font, by the county code and a combination of two digits and three letters.

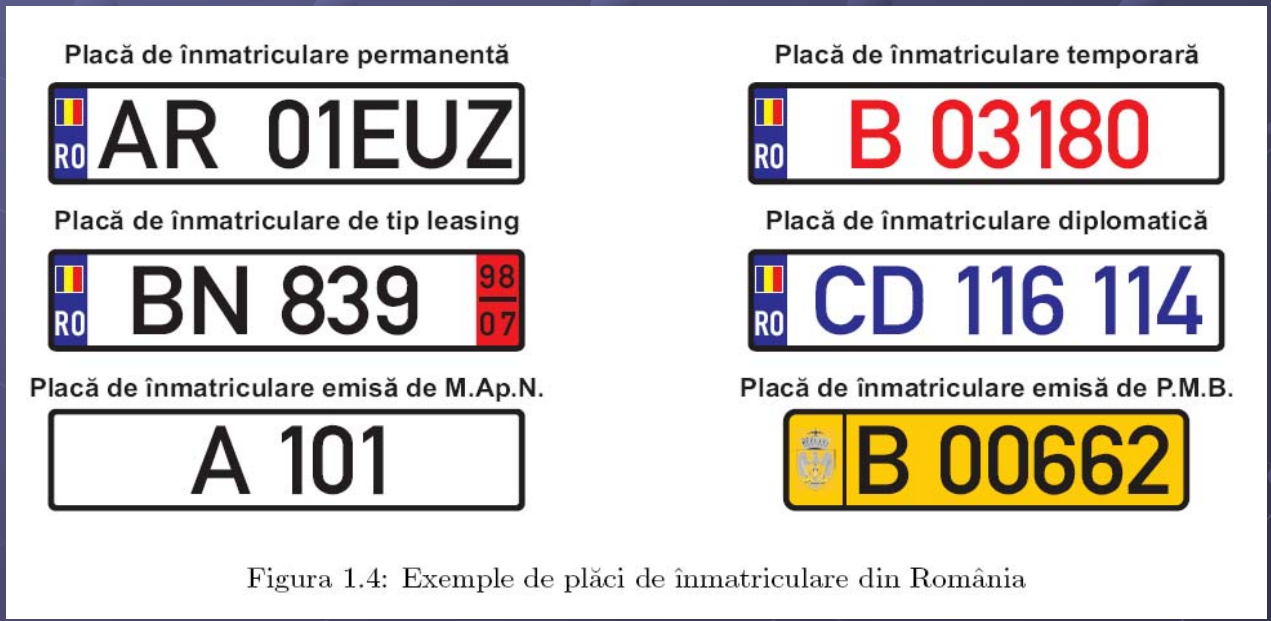


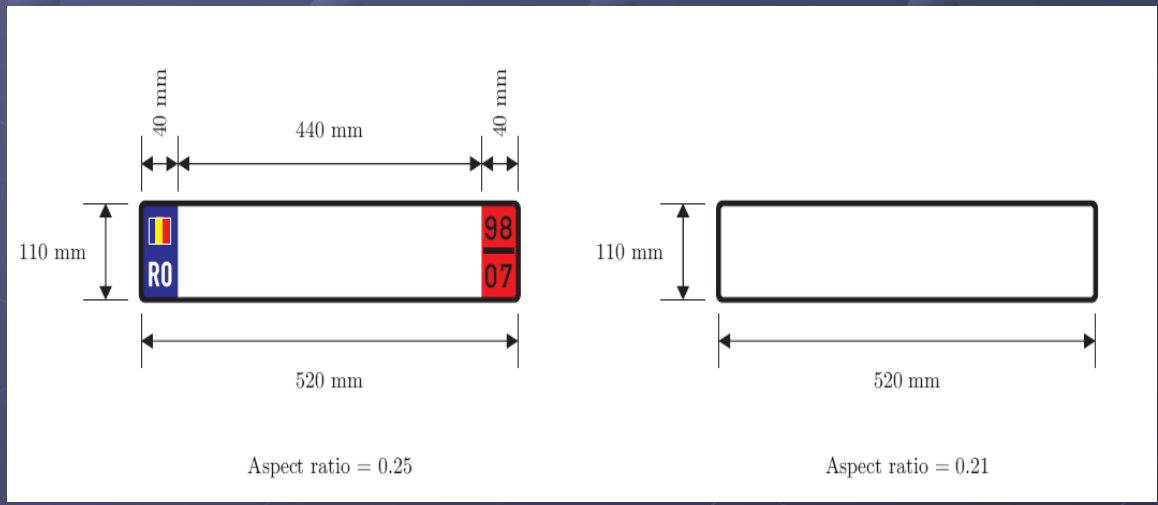
Figura 1.4: Exemple de plăci de înmatriculare din România

Romanian Car License Plates

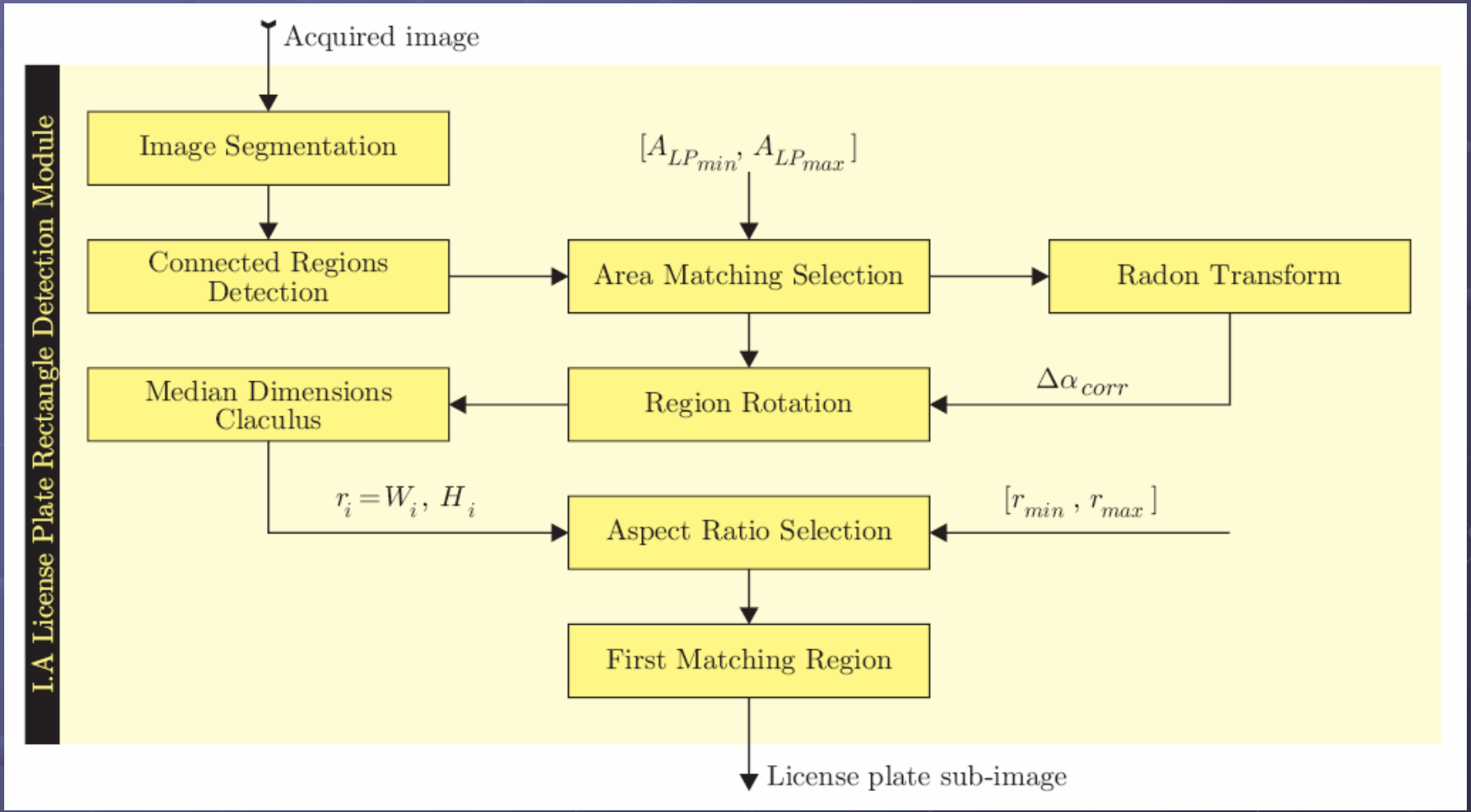
- ***The Yellow background Plate***, used by the municipal public transport vehicles;
- ***The Red Plate***, consisting of the European-strip, followed by the county code and three to seven numbers. All the writing outside of the European-strip on this plate are in red font - these plates are valid for 30 days, and are usually issued by car dealers as temporary registration for their new cars;
- ***The Black Plate***, same as the red plate, except for the black number, and a right-sided red strip, containing the end date of the plate's validity (YY/MM format). This kind of plate is used for cars that fall under a leasing agreement, with the plate's validity ending when the contract expires;
- ***The Diplomatic Plate*** contains the European Strip, followed in blue by the text CD (Corp Diplomatic), or TC (Technical Cooperation, usually issues to lower-ranking service staff) and 6 numbers. The first three numbers stand for the country or international organization, the last three usually for the rank of the owner.
- ***The Special Plates*** can be issued by agencies, ministries and local administration for use on their vehicles. Currently, the army, the Ministry of Internal Affairs and Mayor's Offices are allowed to issue such numbers.

License Plate Extraction

- Assumptions:
  - The license plate is a rectangular region of an easily discernable color.
  - The width-height relationship of the license plate is known in advance.
  - The orientation of the license plate is approximately aligned with the axes.
  - Orthogonality is assumed, meaning that a straight line is also straight in the image and not optically distorted.

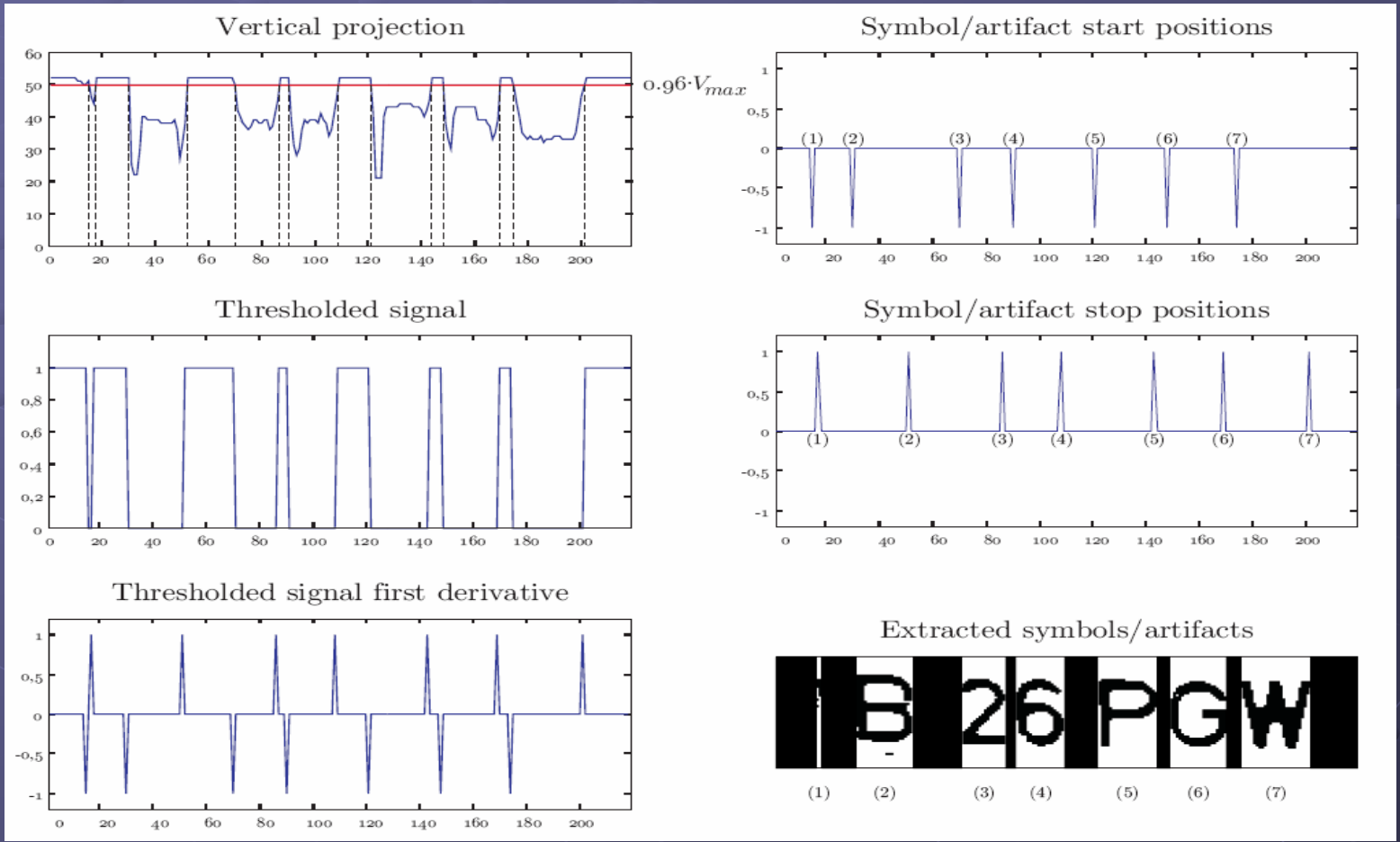


License Plate Extraction Flowchart



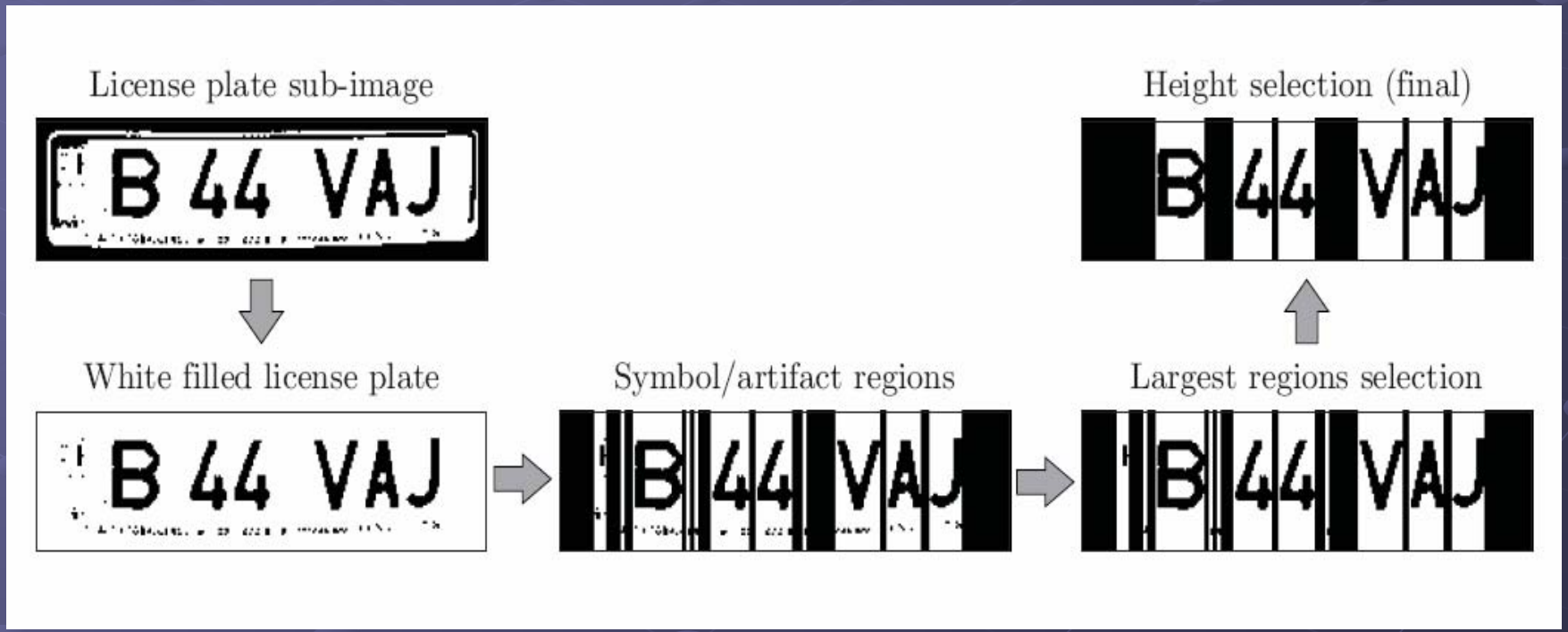
Character Isolation

- Simbol/artifact extraction -

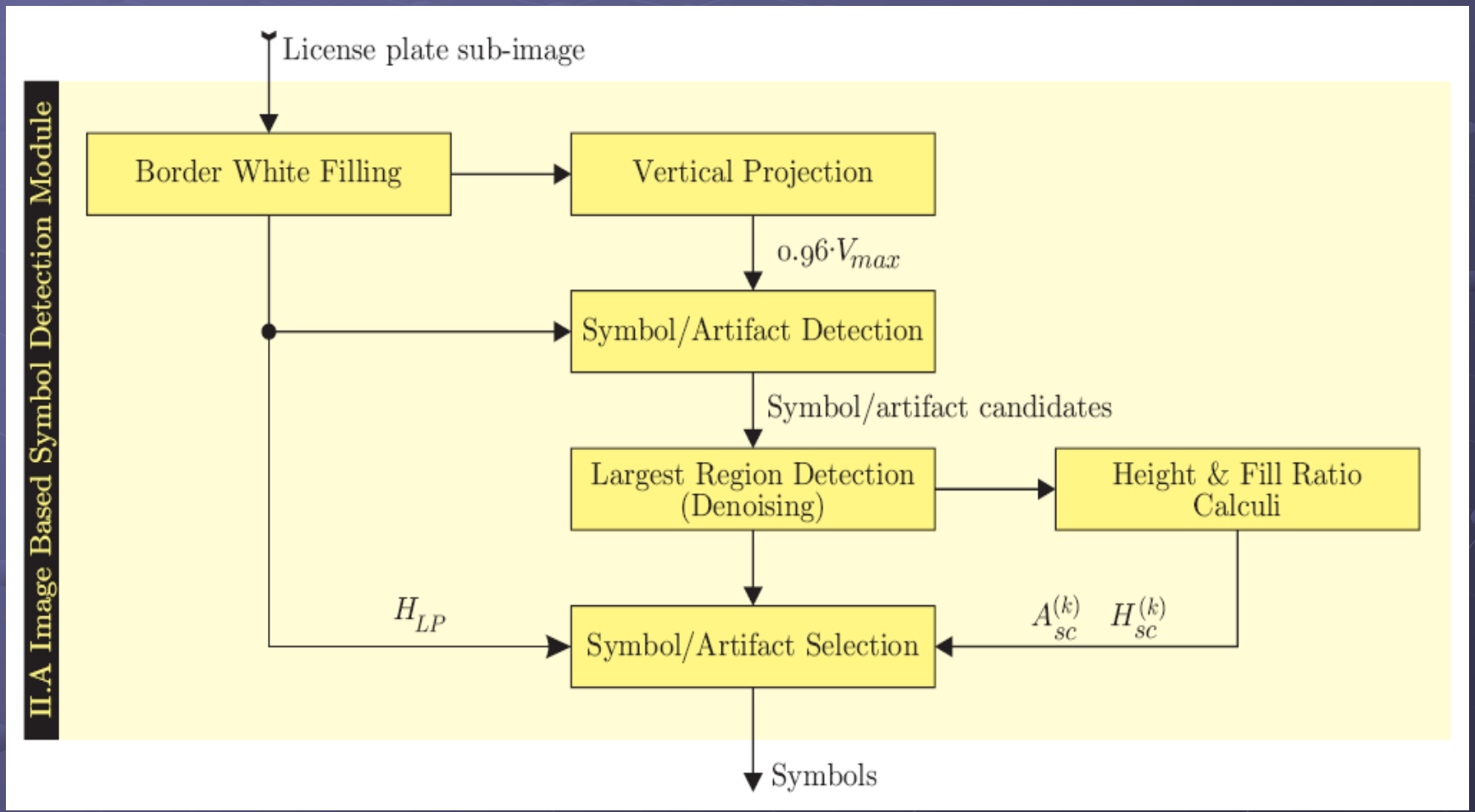


Character Isolation

- Simbol/artifact discrimination -



Character Isolation Flowchart



Character identification

- Pre-classification with Euler number
- Parallel Classification with
  - Skeleton features classifier
  - Template matching classifier
  - Neural network classifier
- Meta-classification (decision fusion)

Euler number pre-classifier

Tabelul 5.2: Numărul Euler al simbolurilor plăcilor de înmatriculare

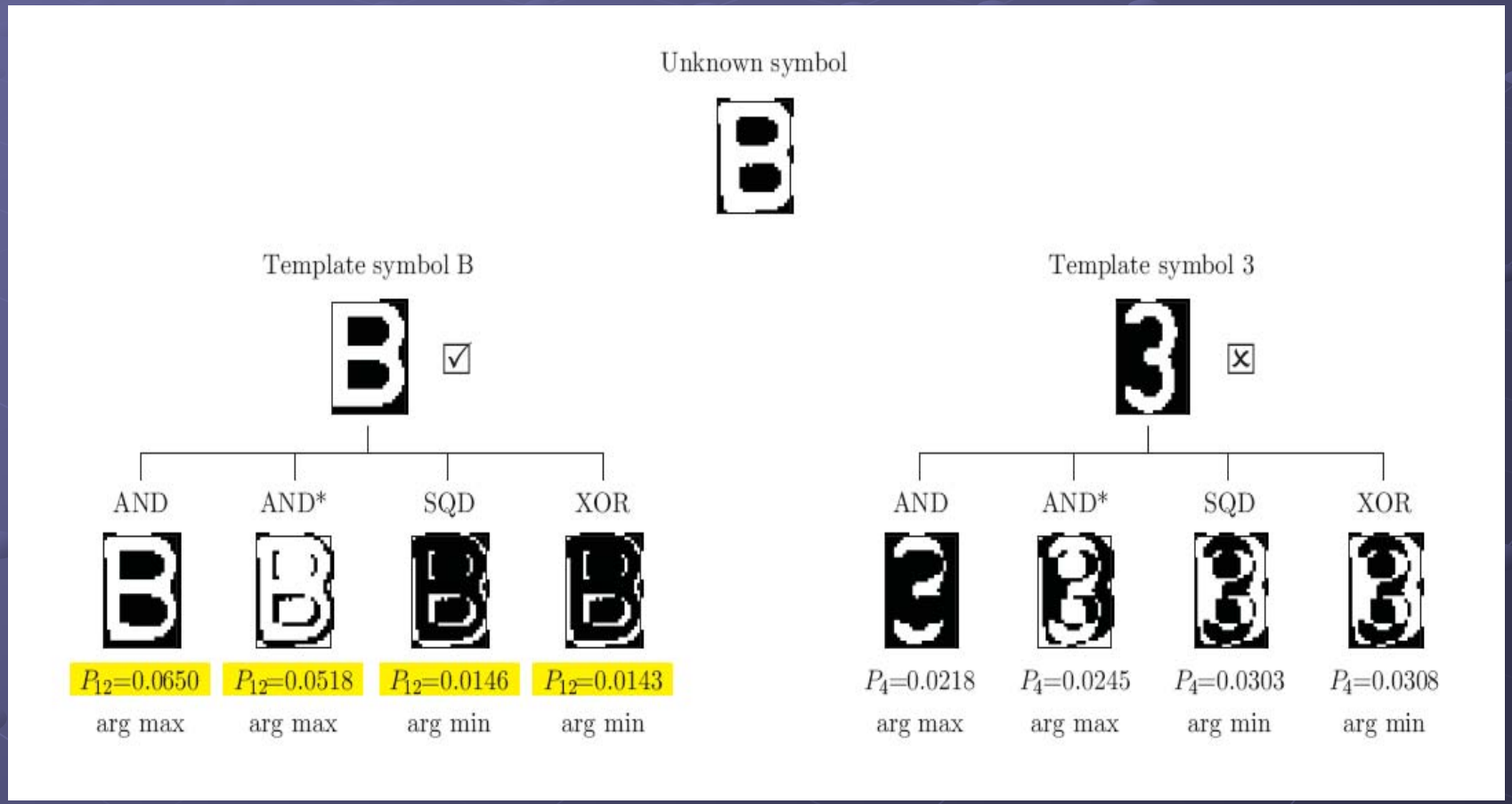
Clasă	Număr Euler	Lista membrilor
Class I	0	1 2 3 5 7 C E F G H I J K L M N S T U V W X Y Z
Class II	1	0 4 6 9 A D O P R
Class III	2	8 B

Skeleton features classifier

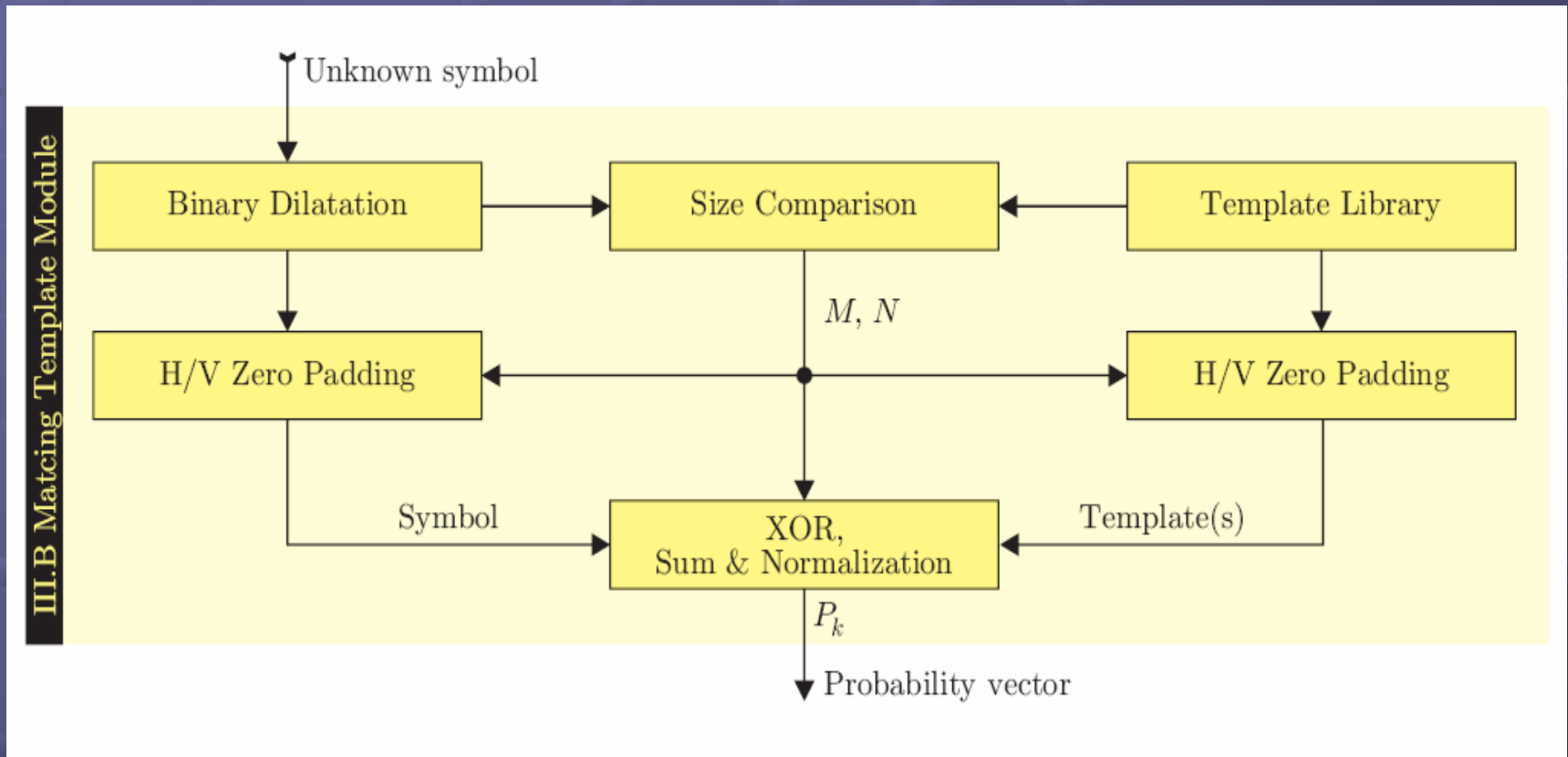
Tabelul 5.6: Valorile teoretice ale parametrilor de schelet ale simbolurilor

Class	TP	TJ	XJ	Member list
Class I	0	0	0	**0 D O**
Class II	0	2	0	**8 B**
Class III	1	1	0	**6 9 D P**
Class II	1	3	0	**B**
Class IV	2	0	0	**1 2 4 7 C G I J L S U Z**
Class V	2	0	1	**4**
Class VI	2	2	0	**R**
Class VII	3	1	0	**3 4 5 E F T V Y**
Class VII	3	3	0	**A**
Class VIII	4	2	0	**H K M N X**
Class IX	5	3	0	**W**

Template matching classifier



Template matching classifier



Neural network classifier

- Image pixels as inputs / cca. 32x56 pixels
- 35-outputs layer (0 to 9 and A to Z / {Q})
- Gradient descent training
- Training database of 1200 images

Decision fusion

- Inputs:
  - Pre-classifier
  - Skeleton features classifier
  - Template matching classifier
  - Neural network classifier
  - Symbol occurence probabilities
- Output:
  - Decision probabilities

Symbol occurrence probabilities

Tabelul 5.4: Variante de sintaxe bazate pe numărul de simboluri (C=literă, D=cifră)

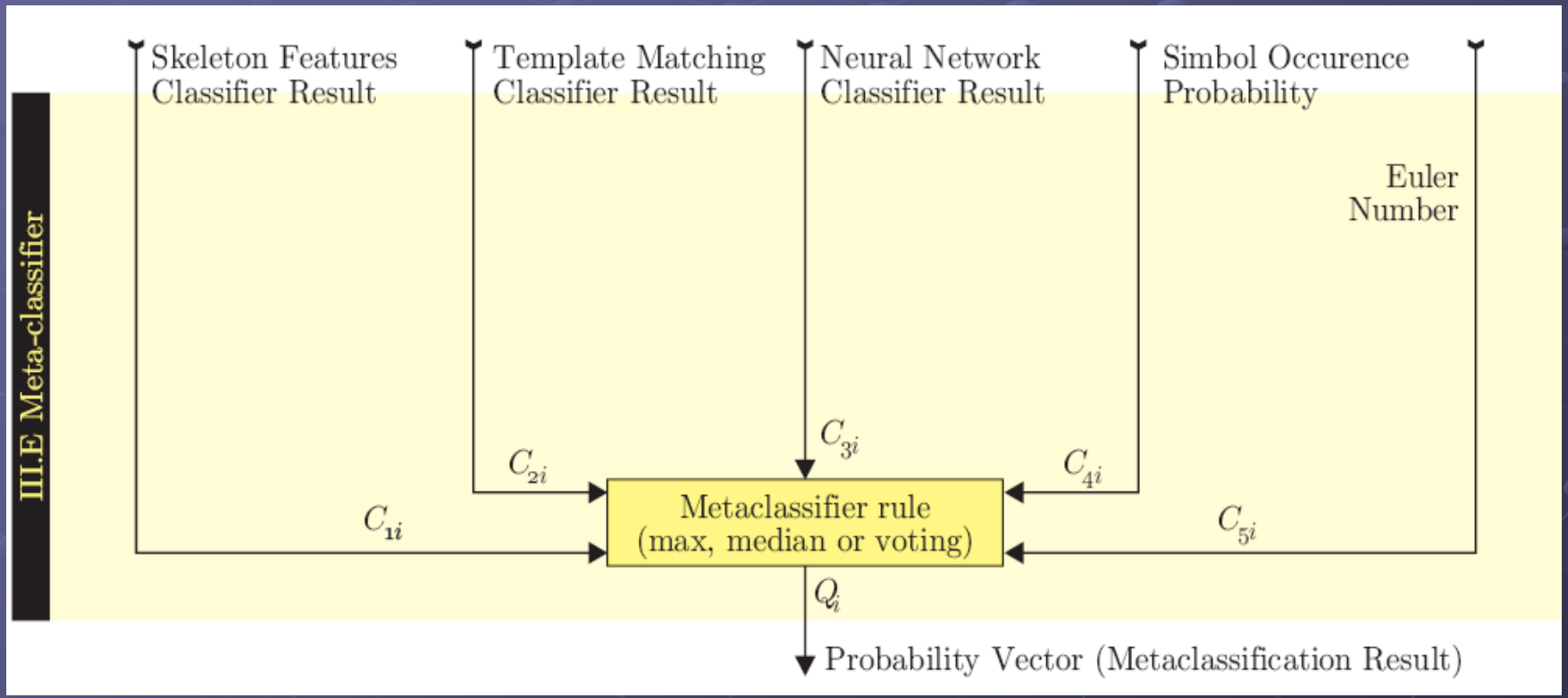
Simboluri	Variante de sintaxă	Tipuri de placă de înmatriculare	Exemple
4	C DDD	armata	**A 124**
5	CC DDD	temporar/leasing	**CT 104**
	C DDDD	temporar/leasing	**B 2272**
6	CC DDDD	temporar/leasing	**SJ 5263**
	C DDDDD	temporar/leasing, transport	**B 26360**
	C DD CCC	ordinar	**B 45 UUZ**
7	CC DDDDD	temporar/leasing	**CL 04818**
	C DDDDDD	temporar/leasing	**B 117754**
	CC DD CCC	ordinar	**CJ 27 GSM**
8	CC DDDDDD	temporar/leasing	**SB 014953**
	CC DDD DDD	ambasade/organizații	**CD 116 114**

Symbol occurrence probabilities

Tabelul 5.5: Probabilitatea de apariție a caracterelor

Simboluri (n)	$P_C^{(n)}(1)$	$P_C^{(n)}(2)$	$P_C^{(n)}(3)$	$P_C^{(n)}(4)$	$P_C^{(n)}(5)$	$P_C^{(n)}(6)$	$P_C^{(n)}(7)$	$P_C^{(n)}(8)$
4	1	0	0	0	-	-	-	-
5	1	1/2	0	0	0	-	-	-
6	1	1/3	0	1/3	1/3	1/3	-	-
7	1	2/3	0	0	1/3	1/3	1/3	-
8	1	1	0	0	0	0	0	0

Decision fusion flowchart



Decision fusion rules

- Max rule: search for the biggest trusted classifier (fuzzy inputs)

$$Q_i(\mathbf{x}) \sim \max_j \{C_{ij}(\mathbf{x})\};$$

- Median rule: independet classifiers, more robust than the max rule (fuzzy inputs)

$$Q_i(\mathbf{x}) \sim \text{median}_j \{C_{ij}(\mathbf{x})\}.$$

- Voting rule: applied on hard inputs of the classifiers

$$Q_i(\mathbf{x}) \sim \text{vote}_j \{hard\{C_{ij}(\mathbf{x})\}\}$$

Conclusions

- Template matching classification rate: 72 to 74 %
- Neural network classification rate: 75 %
- Decision fusion classification rate: 85 % to 91 %
- Causes:
  - Non-uniform distributed database symbols
  - Unappropriate image acquisition system

Perspectives

- Build up a new image acquisition system with better focus and illumination.
- New database designed as it follows:
  - For the template matching classifier:
    - Best individual images at the same scale
  - For the neural classifier:
    - Best & worst images
    - Uniform distributed symbols
- Decision fusion using adaptive weights (Dempster-Shaffer type)

Examples