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CLASSIFICATION OF AUTOMATIC DOORS

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Abstract

The present paper proposes a classification of automatic doors. It includes research on automatic doors, that are used in different application areas. The classification is composed of six classification criteria, each having further branching, forming a tree-like hierarchy. In the definition of the classification criteria, an aim at maximizing orthogonality is sought. The criteria are explained in detail, examples of existing solutions are given and classified according to the criteria. The proposed classification is with an open structure, so it can be easily extended. The application area of the classification is in engineering design, aiding in the early stages of design, when market research, requirements list creation and concept generation are carried out.

Keywords: automatic doors; classification; hierarchy; automation; engineering design.

1. Introduction

The automatic doors are part of the architectural systems, which have major application in building. They are found at malls, shops, institutions, offices, hotels, restaurants, gas stations, etc., in practice, there is almost no public building that does not boast a door of this kind. Besides in public buildings, automatic doors are used in private homes, usually when there are big open areas, and when using heavy leaves with relatively big overall dimensions.

According to the current European law, the automatic doors are considered “machines”, which means, that every new door of this kind must comply with the European directive on machinery [1]. In fact, in the harmonised standards [2], [3], [4] and the related [5] standard, the term “automatic door” is not used, but a distinction between manual and power operated doors is made. In [6] the following types of doors are indicated: revolving, balanced, swing, folding, and sliding.

In the standard [7] of the American national standards institute (ANSI), the term “power operated door” is defined, and in brackets, after this term, is added “automatic door”. The following definition is given: “The combination of door, operator and controls constituting the system. Also called an Automatic Door.” [8]. In this standard, four types of automatic doors are indicated: swing, sliding, balanced, and folding. In contrast to the mentioned European standards, where the term “power operated” door is encountered, and the American standard, in which power operated and automatic door coincide as concepts, in the current paper the term “automatic door” is adopted, i.e., a distinction is made between “power operated door” and “automatic door”.

In this way a certain clarity is achieved, and is taken into account the fact that the term "power operated" [8], [9], suggests the need of an operator during the whole operating cycle, and the term "automatic" suggests partial or full level of autonomy during one or more operating cycles [10]. Thus, in general, the distinction between three types of doors can be made: manually operated, power operated, and automatic. In the specialized literature there is relatively small number of publications dealing with classification of automated doors. In [11] are indicated three design types of sliding doors: bi-parting, single slide, and telescopic. In [12] is proposed a classification of revolving doors according to the criterion "drive", separating this type of doors into three groups: manually operated, manually operated with auxiliary drive, and automatic.

At the moment of the paper's writing, to the authors' knowledge, there is no publication in the specialized literature that proposes a classification of automatic doors. In addition, the classification of sliding doors proposed in [11] is based only on one classification criterion, as the focus of the publication is completely different: simulation of a control system for sliding doors. The creation of a classification of automatic doors, will facilitate their design process and will aid the systematic study of the separate functions, systems, and components used in automatic doors building. The aim of the present paper is to propose such a classification.

2. Classification of automatic doors

The proposed classification of automatic doors is shown in Fig. 11. It is composed of six classification criteria (Fig. 1): energy used for the drive, type of motion for the leaf, leaf material, application, activation method, and leaf count.

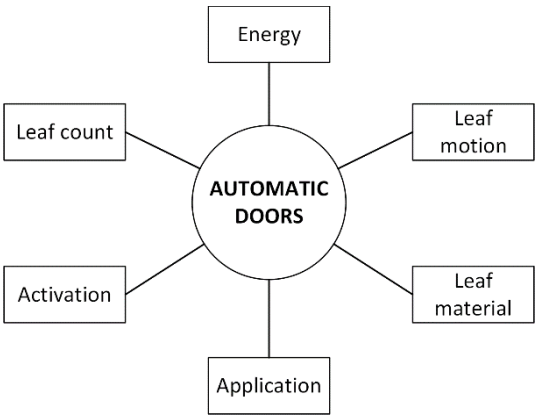

Fig. 1. Automatic doors classification – classification criteria

2.1. Energy

To eliminate the need for manual drive, and ensure autonomy, it is required to use motors for driving the mechanical system of automatic doors. The application of three types of motors is common: electrical [13], pneumatic [14], and hydraulic [15] (Fig. 2).

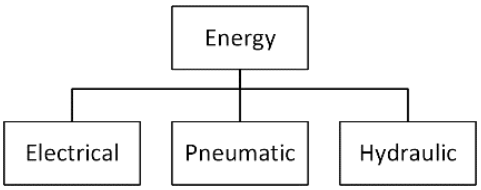

Fig. 2. Automatic doors classification – energy classification criterion

The most common drive is the electric drive. This is due to a number of advantages of those drives: accessible power source – buildings are electrified; precision control for position and speed [16], [17], [18]; the control devices and sensors also use electrical energy, therefore, there is no need for mixing power sources; high efficiency, which is important when considerning environmental impact [19], [20]; low noise levels.

Pneumatic and hydraulic drives, also called fluid drives, are used in special cases. Fluid drives are appropriate where high forces are required, i.e., very heavy leaves or high opening forces. In addition, fluidic drives are more compact than the electrical drives, for the same force/torque requirements, which in some situations can be a decisive decision-making factor, i.e., small spaces and integration into existing structures. When linear motion of the leaves is required, as per number of structural variants of automatic sliding doors, fluidic drives offer economic solution without the need of mechanism for transforming motion. There are also situations in which using electrical energy is hazardous, i.e., applications in explosive or flammable environments.

Use of fluid drives in automatic doors, can be justified also, because of its low cost (especially pneumatic drives) compared to electric drives. Some significant disadvantages of the fluid drives, hinder its widespread use with automatic doors, such as: leaks having negative environmental impact; higher energy cost; complicated precision control of position and velocity; higher noise levels; have to buy energy source and build infrastructure, as fluid systems are common in a small number of buildings – mainly industrial.

2.2. Leaf motion

A variety of motions used for moving the door leaves can be observed with automatic doors. Those motions can be classified in three major groups: rotation, translation, and planar (Fig. 3).

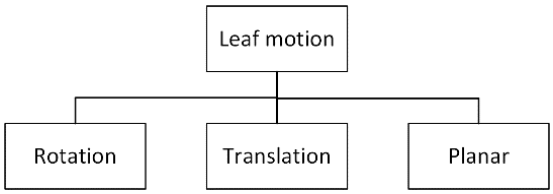

Fig. 3. Automatic doors classification – leaf motion classification criterion

In the rotation group there are three types of automatic doors: swing [21], revolving [22], and pivot [21] (Fig. 4).

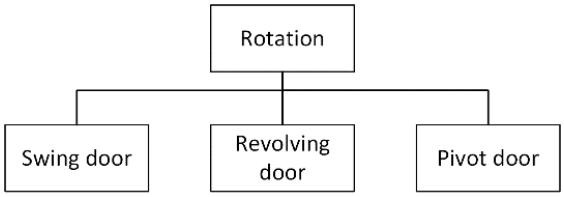

Fig. 4. Leaf motion rotation – door types

The swing automatic doors are similar to the traditional manual doors, but with added automatic drive and control. The motion is rotation around an axis situated on the left or right side of the leaf, provided with a corresponding number of hinges. A common automatic drive for this type of doors is by a motor and linkage mechanism, often integrated into one assembly unit, offered as a module [13]. Characteristic feature is that the drive unit is visible.

The automatic revolving doors are offered in a great variety of structural variants [6]. This type of automatic doors realizes the rotational motion of the leaves through a central axis. In contrast to the swing doors, here the drive module usually is integrated, and not visible. The application of these doors is in public buildings with large pedestrian traffic. The pivot doors are an alternative to swing doors in the cases where the leaf is large and heavy. In those cases, the use of hinges is not eligible due to the large forces and the risk of leaf displacement. In this type of doors, the rotation is provided by an axis, which is placed close to the right or left side of the leaf, and in contrast to the revolving door, it is not central.

Translational motion is realized in the sliding automatic doors. The latter are not only very common in public buildings, but also in vehicles and safety applications, i.e., safety systems in metro stations. Some common types are: sliding panoramic systems [24], lift and slide [25], and folding doors [26] (Fig. 5). The sliding panoramic systems are becoming very popular. They are not only utilized in public buildings, but also in private residences. These systems provide maximum concealment of the aluminum structure for achieving maximum transparency and good heat insulating and noise suppressing characteristics.

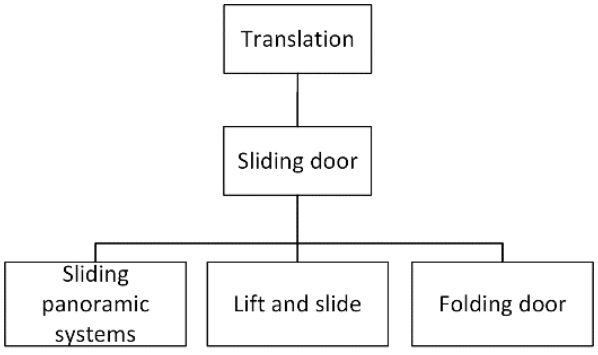

Fig. 5. Leaf motion translation – door types

Lift and slide are a combination of two translational motions of the leaf in the same plane. This type of doors provides better insulation (thermal and noise) characteristics with regard to the normal methods for insulating sliding doors. Usually, the drive is concealed and not visible. With folding doors, the leaves can be compactly packed (folded) during the translational motion. To enable folding, the leaf is divided into separate, flexibly linked parts, which rotate and orient parallel to each other when the leaf is slid.

Under planar motion it is understood movement of the leaf, which is composed of several simple (rotations and/or translations) motions, executed in one plane. The following door types are considered belonging to this group: roller doors [27], sectional doors [28], up-and-over doors [29], and volkswagen [30] (Fig. 6). Automatic roller doors combine translational motion (sliding) and rotation (rolling) in a longitudinal to the leaf plane. Usually, the translation is made to lift or lower the leaf, which necessitates that the rotation (the rolling) is executed over the door opening. Here, similar to folding doors, the leaf is composed of smaller elements, which can flexibly move relative to one another, which makes possible to roll them. The activation of this door type is usually from a distance or using a control panel. Used in applications for garage doors, storage rooms, and also as part of security systems, i.e., in shops.

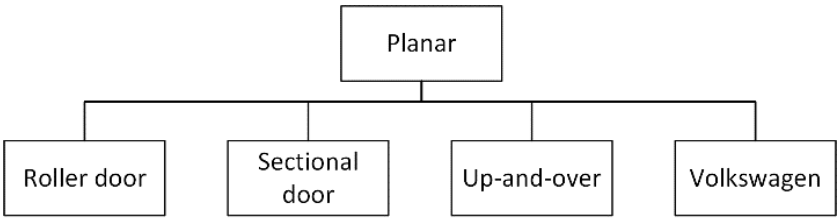

Fig. 6. Leaf motion planar – door types

Characteristic for the leaf's motion type, in sectional doors, is the complex planar movement, combining translation and rotation. By this movement the leaf is lifted and rotated, so that from vertical position it assumes horizontal position. The leaf of a sectional door is similar to the leaf of a roller door in that it is built from separate sections, which can move relative to each other. The difference is that the sections are bigger, and because of this the leaf cannot be rolled. Thus, instead of rotating for opening the leaf, it is lifted above the door opening, and assumes horizontal position.

Up-and-over doors have the same planar movement like sectional doors, but they are not sectioned – the whole leaf moves as one, from vertical to horizontal position. Automatic volkswagen doors use a combination of two translations in a transverse to the leaf plane. The first translation is in "front-back" direction, and the second – "left-right". Thus, the first translation moves the leaf away from or in direction of the door opening, and the second translation moves the leaf to the side of the door opening so it is possible to go through the door. This type of doors is used in automobiles, hence the name. In buildings, only manually operated volkswagen doors are used.

2.3. Leaf material

Automatic doors can be distinguished also by the material, from which the door leaves are made. According to this classification criterion they are made from wood [31], polymer (PVC) [32], steel [33], aluminum [22], glass [34], and hybrid (aluminum-wood) [35]. The automatic doors with wooden leaves have good thermal and noise insulation parameters. They can be renovated if damaged. Main disadvantage is the difficult maintenance, and high price.

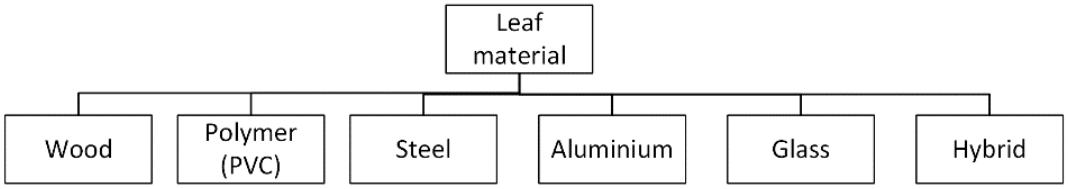

Fig. 7. Automatic doors classification – leaf material classification criterion

Polymer (PVC) automatic doors have their place in architectural systems. They are cheaper than wooden automatic doors and have good noise and thermal insulation. Their maintenance is easier in comparison to the wooden automatic doors. Can be recycled. Polymer doors are not suitable where big sized leaves are required.

Aluminum automatic doors are one of the most commonly used in practice. Aluminum is good heat conductor, and because of this, for exterior automatic doors, insulated (warm) profiles are used, in which the inner and outer parts of the profile are divided by polyamide or another polymer. The aim is to disrupt the thermal flow and to provide better thermal insulation. Uninsulated (cold) aluminum profiles are suitable for inner premises. These doors are also recyclable.

Steel doors provide greater anti-theft protection than other door materials. Steel doors are also fire resistant, and do not allow fire to spread in other rooms. Steel profiles can be also insulated and uninsulated. Steel doors allow for large leaves, and therefore large doors to be produced. These doors are recyclable. One disadvantage is the not so good thermal insulating properties.

Glass automatic doors are used for maximizing transparency. They can be with one or two sliding leaves. Mainly used in inner premises of buildings. Hybrid automatic doors (aluminum-wood) combine wooden door from the interior side, and aluminum material on the exterior side of the building, for better weather resistance. Limitation of such doors is the size in which they can be produced.

2.4. Application

As mentioned, the application of automatic doors is not limited to only buildings. According to application automatic doors can be divided into: entrance doors, garage doors, access portal, vehicle doors, and safety doors (Fig. 8). As entrance doors sliding and revolving doors are more frequently used, and less frequently automatic swing doors. Activation of the automatic entrance doors is usually contactless – by camera or proximity sensor. Most common are the electrically driven automatic entrance doors.

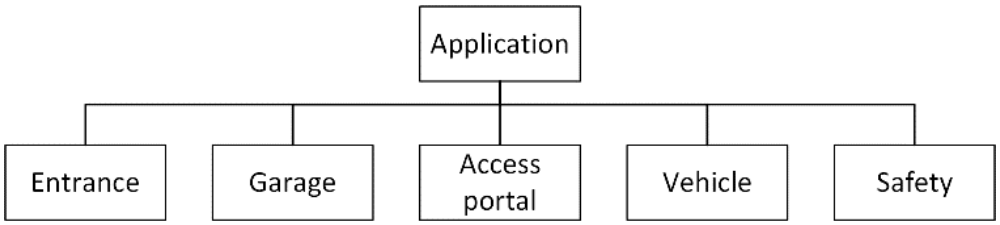

Fig. 8. Automatic doors classification – application classification criterion

Mostly sectional and roller doors are used as garage doors. Frequently used are also sliding doors, usually as a fence, obstructing the access to the area of a yard intended for use as a garage. Usually, activation is remote, and the drive is electric. Access portals are used for limiting access to certain rooms or whole buildings. In such applications the automatic door is usually integrated with a system for access control and/or security system. Access systems for public facilities, with sensor control and automatic elements, are offered in a variety of designs. They provide convenient, contactless entry to a variety of public places such as swimming pools, SPA centers, entertainment areas, museums, and public transportation.

Automatic doors are used also in vehicles. Often, this type of doors is sliding, and in a number of applications they are pneumatically actuated. Activation is typically through contact, but in automatic (robotic) vehicles it can be contactless. Automatic doors can be used also as safety devices. An example for such application is safety doors at metro stations and in automatic railway transport (robotic trains). The openings in the safety fences of these applications are opened and closed by automatic doors.

2.5. Activation

One of the main factors for autonomy of automatic doors is the method of detecting when to open and close the door by the control system. According to the activation method, automatic doors are contact or contactless activated (Fig. 9). Contact type activation can be done by sensitive mat [36] and by control panel [37], [38]. Contactless activation methods include remote activation [37], camera activation [39], [40] or presence sensor [39].

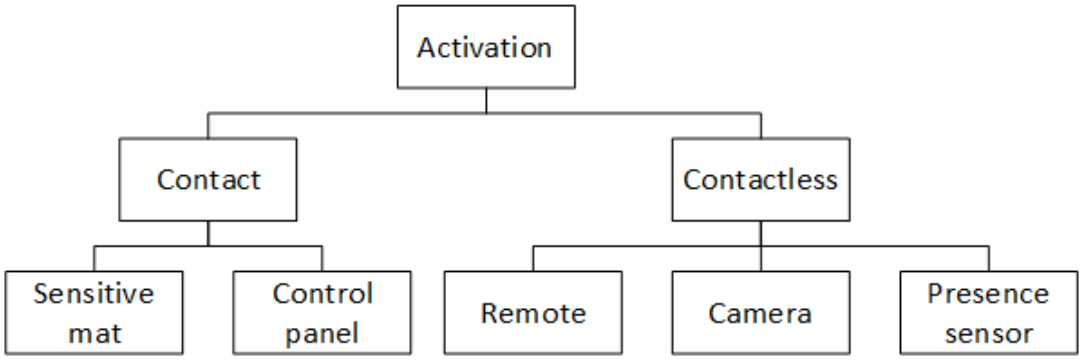

Fig. 9. Automatic doors classification – activation classification criterion

Activation through a sensitive mat is an activation method used also in safety systems. There are three operation principles of this type of device: electrical, pneumatic, and optical. For electric type, stepping onto the mat leads to contact between conductive elements, changing the electric characteristics of the circuit in which they are part of. These characteristics are monitored from the control system. For the pneumatic type, inside the mat there are flexible tubes, arranged in a particular layout. The tubes conduct air with low pressure, which when stepped on, produce pulses in the airflow of the system. For the optical type, stepping on the mat leads to the displacement of optical fibers that are inside the mat, which leads to a change in the received light from a photodetector.

Control panel activation for automatic doors can be done in the case where the door control system allows for autonomous operation after activation. Otherwise, the door is not automatic, but power operated, and would require user operation for the duration of opening and closing of the door. Variety of panels are utilized, which usually provide manual mode of operation for the automatic door. The integration of additional functions is possible, such as requirement for identification, and other procedures for authorized access, which places the application of such activation type in security systems.

Contactless activation is more common method of activation for automatic doors. Remote activation assumes the presence of activating device called a remote control. This device can be made as a conventional remote control – mobile control panel, which is wired or wirelessly connected to the door control system. Current systems for remote activation allow activation from mobile devices such as smartphones.

Activation through presence sensor allows door activation when a moving object is detected in the sensor sensing range. It is necessary to adjust the system before operation in order to define the sensing area and the size of the sensed objects. Infrared, microwave, and other presence sensors are used. Camera activation presents the possibility for recognition of characteristic features of the person approaching the door. This type of activation can be used for authorized access. In addition to this supplementary function, an advantage over using a presence sensor is the ability to include more decision-making parameters for the door activation (whether it opens or not in front of the approaching person or object). With a camera, objects that are not moving can also be detected.

2.6. Leaf count

Great variety, not only for automatic doors, but for doors in general, introduces the leaf count. There are automatic door designs with one [41], two [41], and more than two [26] leaves (Fig. 10). Most common are designs with one or two leaves. Automatic doors with more than two leaves typically are used for big openings, and for panoramic views, i.e., for terraces and balconies.

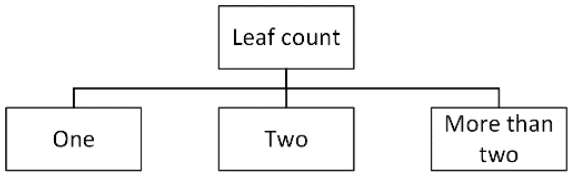

Fig. 10. Automatic doors classification – leaf count classification criterion

3. Conclusion

A classification of automatic doors is proposed including six classification criteria. The classification has a treelike structure (Fig. 11), with each of the classification criteria branching into a number of levels. The last level of each branch indicates particular automatic door design.

This classification structure is designed to be open, allowing for adding more criteria to it, and classifying new types of doors, easy and fast.

Each classification criterion and branch are explained in detail, and examples of existing designs are given with corresponding citations based on market research. The proposed classification is intended as a tool for aiding the design process of automatic doors in the following ways:

- Standards – a number of standards are cited, having relation to the design, building, and safety of automatic doors;
- Design – quick reference into the existing designs, and finding examples of such from the cited manufacturers;
- Drive – reference into the methods of driving automatic doors;
- Application areas – situations in which automatic doors find common application and are appropriate solution;
- Methods of activation – quick reference into the sensors and activation methods commonly used with automatic doors.

Accepting the proposed classification as a design aid in the design process of automatic doors, will have a positive impact on the design effort, speeding it up by providing plenty of information regarding posible structures, drives, door types, etc. The classification is also useful when trying to design innovative automatic doors, by showing what is already available, and thus aiding the idea generation process.

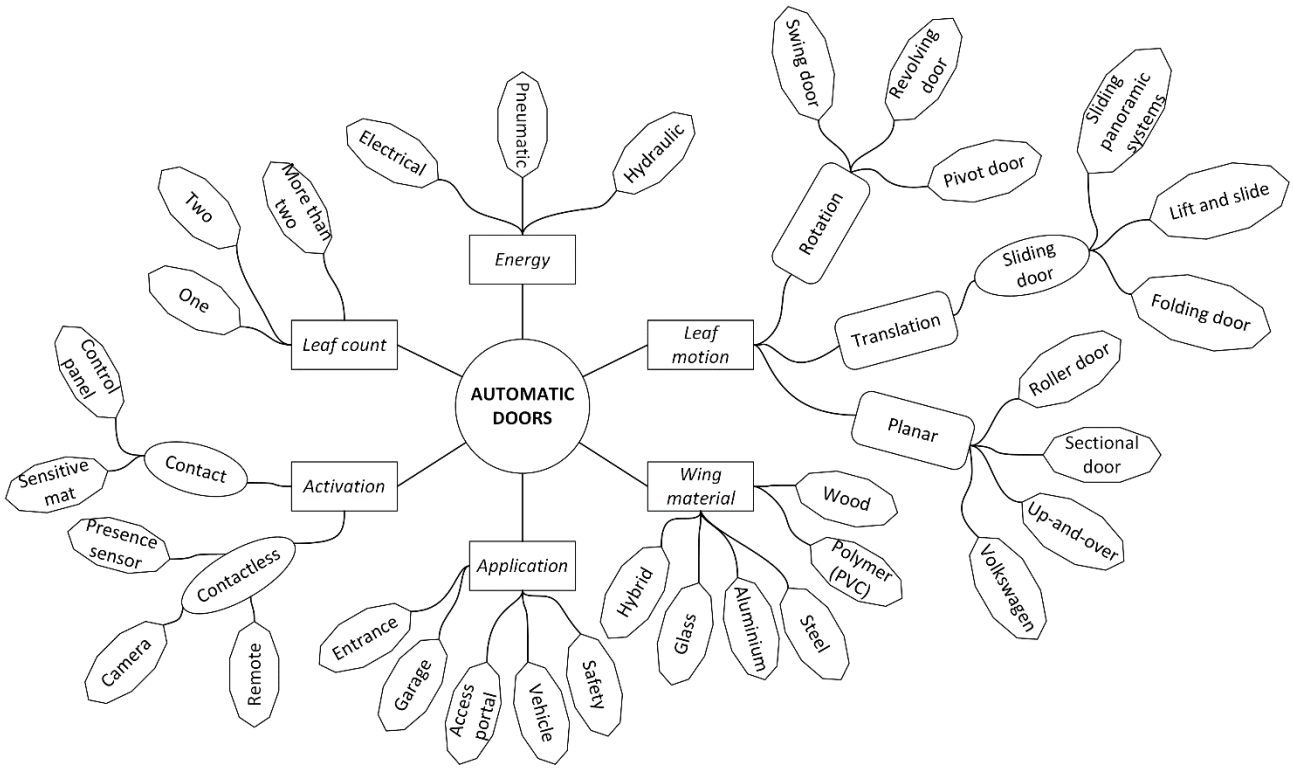

Fig. 11. Automatic doors classification

Some of the negatives of using classification schemes in the design process, are the tendency of going in the direction of the already known, and somewhat lowering the potential for new ideas. Nevertheless, the benefit of shortening the time for the initial idea generation, often is a more significant factor in practice.

The proposed classification is the first part of a research on sliding automatic doors, on defining the main systems and functional structures of this type of doors, their place amongst other types of automated doors, and common structures that they share. Future work is the use of the classification in the design of a base structure for a new sliding door of the type of the panoramic sliding systems, and a corresponding size range.

4. Acknowledgments

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