JOURNAL OF MODERN SCIENCE
SPECIAL ISSUE
3/57/2024
www.jomswsge.com


DOI: doi.org/10.13166/jms/191145

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# ENHANCING AUTISM REHABILITATION: THE ROLE OF EXPERT SYSTEMS IN SUPPORTING THERAPY WITH INTELLIGENT ROBOTICS

# WZMOCNIENIE REHABILITACJI AUTYSTYCZNEJ: ROLA SYSTEMÓW EKSPERCKICH WE WSPIERANIU TERAPII ZA POMOCĄ INTELIGENTNEJ ROBOTYKI

## Abstract

Autism is a complex neurobiological disorder that affects brain development and manifests itself primarily in difficulties in communication and social interactions. Autistic people may also experience a restricted set of interests and repetitive behaviors. Among the promising tools supporting autistic people, systems supporting diagnosis, planning therapy, monitoring progress, and even conducting direct interactions with autistic children are becoming increasingly important. The article describes an expert system created to support the rehabilitation of children with autism. The presented expert system, for instance, can analyze the child's speech patterns and suggest appropriate communication strategies, or it can monitor the child's behavior and propose activities to address repetitive behaviors. The system is part of a more extensive solution consisting of three main components: the patient interface, the rehabilitator's expert system, and the machine learning module. The presented environment was used during therapeutic sessions with young patients. On the one hand, it provides promising results in patient interactions; on the other hand, it supports the work of rehabilitators. It is worth noting that the main strength of the solution is the inference and suggestions proposed by the system during a session with the patient; taking into account the dynamic development of artificial intelligence systems and the fact that each subsequent session provides new data, we can count on the beneficial impact of the presented system on both the progress in the patient's rehabilitation and also the quality and effectiveness of the rehabilitator's work.

## Streszczenie

Autyzm, to złożone schorzenie neurobiologiczne, które wpływa na rozwój mózgu i objawia się przede wszystkim trudnościami w komunikacji i interakcjach społecznych. Osoby autystyczne mogą również doświadczać ograniczonego zbioru zainteresowań i powtarzalnych zachowań. Wśród obiecujących narzędzi wspomagających osoby autystyczne coraz większe znaczenie zyskują systemy wspomagające diagnozę, planowanie terapii, monitorowanie postępów, a nawet prowadzenie bezpośrednich interakcji z dziećmi autystycznymi. W artykule opisano system ekspercki stworzony do wspomagania rehabilitacji dzieci z autyzmem. Prezentowany system ekspercki jest częścią większego rozwiązania składającego się z trzech głównych komponentów: interfejsu pacjenta, systemu eksperckiego rehabilitanta i modułu uczenia maszynowego. Przedstawione środowisko wykorzystywane było podczas sesji terapeutycznych z małymi pacjentami. Z jednej strony dając obiecujące rezultaty interakcji z pacjentami,

z drugiej zaś strony wspierając pracę rehabilitantów. Warto zauważyć że główną siłą rozwiązania jest wnioskowanie i sugestie proponowane przez system podczas sesji z pacjentem, mając na uwadze dynamiczny rozwój systemów sztucznej inteligencji, oraz fakt że każda kolejna sesja dostarcza nowych danych możemy liczyć na korzystne oddziaływanie przedstawionego systemu tak na postępy w rehabilitacji pacjenta jak również jakość i skuteczność pracy rehabilitanta.

**Keywords:** *Autism, Expert systems, Artificial intelligence*

**Słowa kluczowe:** *Autyzm, Systemy eksperckie, Sztuczna inteligencja*

## Introduction

Autism is a complex neurobiological disorder that affects brain development and manifests itself primarily in difficulties in communication and social interactions. Autistic people may also experience a restricted set of interests and repetitive behaviors. Although autism has no cure, some various therapies and supports can help autistic people develop their skills and reach their full potential. Among the promising tools supporting autistic people, expert systems are becoming increasingly important, supporting diagnosis, planning therapy, monitoring progress, and even conducting direct interactions with autistic children. Expert systems are intelligent computer programs that mimic the knowledge and skills of a human expert in a given field. They use an extensive knowledge base and advanced reasoning algorithms to solve complex problems and make accurate decisions. In the rehabilitation of autistic children, expert systems can be a precious tool supporting therapy and education in many areas:

1. Supporting the diagnosis of disorders by analyzing the child's symptoms and behavior. They can also help identify co-existing conditions and determine your child's needs.
2. Expert systems can help create personalized therapy plans based on the diagnosis and analysis of the child's profile. They may suggest appropriate exercises, therapeutic techniques, and development goals.

3. Expert systems can track a child's progress in therapy and provide information about their condition and development. They can also identify areas that require additional attention and modify the treatment plan if necessary.
4. Expert systems can facilitate communication with autistic children with difficulty speaking or understanding speech. They may use techniques such as symbols, pictures, and sounds to help children express their needs and feelings.
5. Expert systems can teach autistic children social skills such as making connections, recognizing emotions, and collaborating. They can also simulate social interactions to help children practice their skills in a safe and controlled environment.
6. Expert systems can inform parents and caregivers of autistic children about their condition, available therapies, and coping strategies. They can also educate autistic children about various topics, such as emotions, social behavior, and the world around them.
7. Expert systems can be accessed on various platforms, such as computers, tablets, and smartphones, making them easily accessible to children and their families. These systems can be tailored to each child's needs and abilities, providing personalized therapy and education. Expert systems provide objective and unbiased information to help make good therapy decisions. However, it should be remembered that these systems do not replace therapists and specialists but are only valuable tools supporting therapy.

Rehabilitation systems for autistic children use techniques such as symbols and images to help them learn to communicate. They may also include games and activities that help children develop language skills. Applications based on the principles of CBT (cognitive behavioral therapy) can help autistic children deal with difficult emotions and behaviors, anxiety, stress, and aggression (Szymona et al., 2021). Such systems can analyze a child's profile, considering their age, development level, needs, and preferences, to generate personalized content and activities. They can monitor the child's reactions to stimuli and adjust the course of interactions in real-time. For example,

suppose a child reacts negatively to a particular activity. In that case, the app can automatically switch to another more engaging and appropriate one for their current emotional state. Using elements of gamification motivate children to learn and interact. Points, rewards, leaderboards, and virtual avatars can provide incentives to continue exercising and developing new skills. At the same time, expert systems can analyze a child's progress and provide detailed feedback to the child and their caregivers. This information may include indicators of skill development, goal achievement, and areas requiring additional attention. Expert systems can support sensory integration therapy, which aims to improve the processing of sensory stimuli by a child. Apps can provide controlled visual, auditory, and tactile stimuli to help a child become familiar with different sensations and develop emotion regulation skills. Expert systems can teach autistic children social skills such as making connections, recognizing emotions, and collaborating. Apps can simulate social interactions, team games, and cooperation exercises to help children develop these essential skills. The systems can also offer autistic children emotional support and help in dealing with difficult emotions. Apps can include relaxation games, stress management techniques, and positive visualizations to help children feel better and increase their self-esteem. At the same time, apps can provide parents and caregivers of children with autism with information about their condition, available therapies, and coping strategies. An essential aspect is collecting data and monitoring the progress of a large number of autistic children, which may help in autism research and the development of new therapies. Apps can anonymously collect information about children's behavior, reactions, and progress, further providing valuable data to researchers. Once again, however, it should be noted that mobile applications using expert systems do not replace human therapists and specialists. They are only a valuable tool supporting therapy and education. Autistic children must have access to regular treatment provided by qualified specialists who can monitor their progress and adapt the therapy plan to their individual needs. Combining expert systems with therapy conducted by qualified specialists can bring several benefits to autistic people and their families. As technology and research on autism develop, expert systems have increasing potential to become an essential element of a comprehensive support system for autistic people and their families.

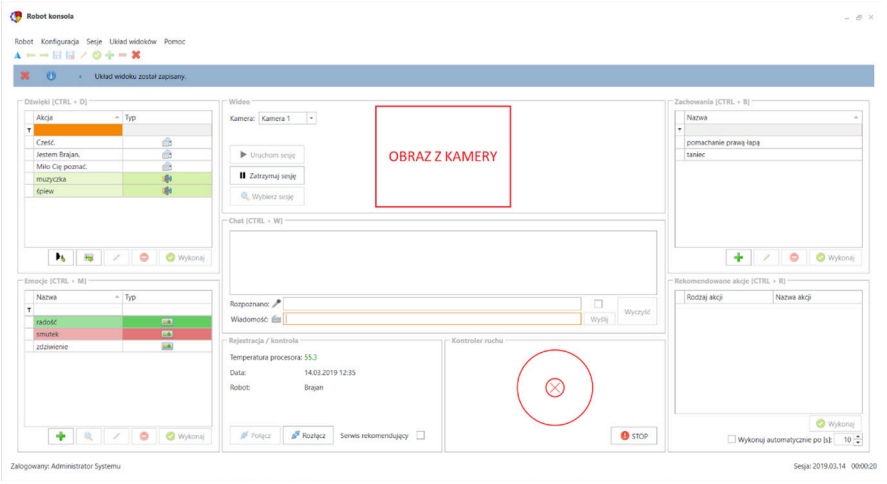
We are observing dynamic development in therapy for people with autism. The variety of methods allows the opportunity to tailor support to each patient's needs. Initially, behavioral models dominated, with Applied Behavior Analysis (ABA) at the forefront. This technique focused on strengthening desired behaviors, reducing undesirable ones, and consolidating the effects of therapy. Currently, rigid behavioral patterns are being abandoned. Non-directive methods play an increasingly important role (Lord et al., 2018; Smith, 2012), in which establishing contact between the therapist and the child plays a key role. The therapist becomes a play partner, imitates the child's behavior, and accepts their autonomy. Research confirms the effectiveness of non-directive therapies. Their impact on building social relationships and developing a child's creativity and independence is undeniable (Bluestone, 2010). Among the non-directive methods in autism therapy, Growth through Play (GPS) holds a unique position. This method, developed by K. Houghton, focuses on stimulating the child's social, communicative, emotional, and cognitive development. Research confirms the effectiveness of play development therapy. It has been shown that in children with autism spectrum disorders, this method benefits overall psychomotor development (Parsons et al., 2019; Henning et al., 2016). Developmental play therapy is a valuable option for children with autism. It can be used both individually and in groups. It is a flexible method that can be adapted to each child's individual needs and capabilities.

## System components

An expert system is a computer program that simulates the knowledge and skills of an expert in a given field. To use the full potential of technological achievements, the presented system was designed as an intermediate link between the rehabilitator and the patient. The idea of the solution is for the patient to play and interact with the device interface (it can be a phone or tablet, but also an individualized or specially created toy, e.g., a robot). During such play, the system is supervised by a specialist who orders content and tasks to be displayed to the patient according to the current progress in rehabilitation. During the

session, the specialist is supported by machine learning systems that propose appropriate tasks based on their knowledge and experience.

**Figure 1.** *Expert system rehabilitator interface*




The system consists of three main components: the rehabilitator's application, the patient's application, and the data storage and machine learning module (Niderla and Maciejewski, 2021). The patient application, initially built as a mobile robot resembling a rabbit, can be rebuilt into a different type of application, e.g., a mobile application, thus making the solution more accessible to patients (despite the limitation of the patient's physical interaction with the device).

The rehabilitator's application (Fig. 1) is an integral part of the expert system for the rehabilitation of children with autism. Its purpose is to make it easier for the therapist to conduct therapy and monitor the child's progress. The system offers several functions. The therapist can constantly monitor the child using a mobile device camera. Thus, the child's reaction to stimuli and general emotional state should be assessed. The therapist can create and launch personalized statements and questions tailored to the child's needs and conduct a dialogue with the patient via the application. It is also possible to use ready-made templates of statements and questions prepared in advance and saved in the application, creating a scenario for future therapeutic sessions.

The main interface window of the application used by the rehabilitator is divided into nine elements. The upper part contains the system menu and the information bar. The menu allows you to launch individual application functionalities, while the information bar displays messages about non-standard situations requiring quick user intervention. Next, starting from the left, the operator has the emotion definition window at his disposal (Fig. 2).

**Figure 2.** *Emotion definition window*


This window allows you to define emotions using a scripting language in the JSON format (Fig. 3). Emotions are displayed in the form of simplified graphics resembling an animal snout. Defined emotions saved in the system can be used anytime during a therapeutic session. This solution allows you to determine the content presented to the patient at any time without the need for special programming or graphic tools.

The second functionality implemented in the system is the definition of sounds and multimedia files (Fig. 4). This dictionary allows you to prepare and save selected messages used during a therapeutic session. Defining text messages converted into sound using a speech synthesizer and playing back to the patient through questions or information during the session is beneficial. It is also possible to create Ad-Hoc audio messages using the patient communication window (Fig. 5). Additionally, the communication window records and displays a text transcription of the patient's statements, creating material for later use in progress analysis and machine learning.

**Figure 3.** *Definition of emotions*


**Figure 4.** *Definitions of statements and multimedia files*

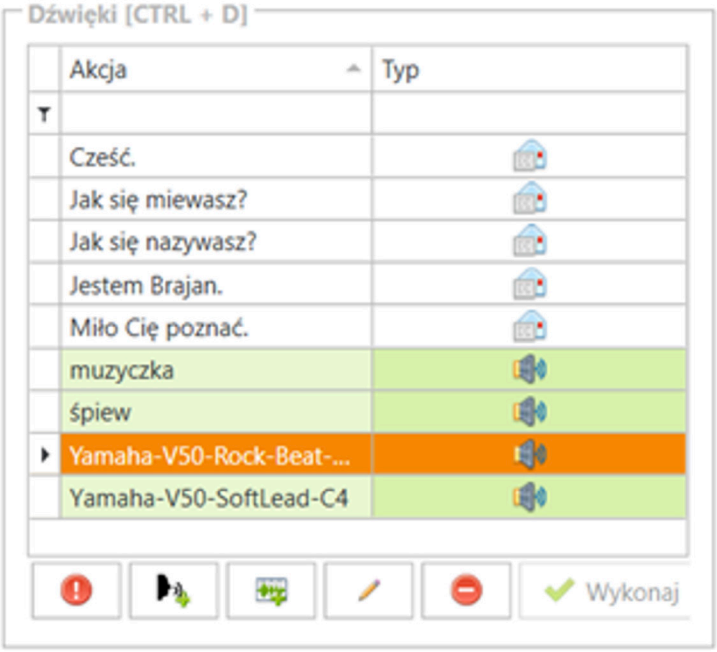


**Figure 5.** *Communication window*


Another essential function of the operator panel is the behavior panel. This panel is used when we use a patient interface built in the form of a robot with the ability to move and move around (Fig. 6). As mentioned; the system was tested with a mobile robot, enabling the relocation and movement of limbs, head, ears, etc. In the behavior panel, we can define sequences of movements used during the session. They simulate the actual movement of the toy, giving the impression of great independence.

**Figure 6.** *Behavior window*

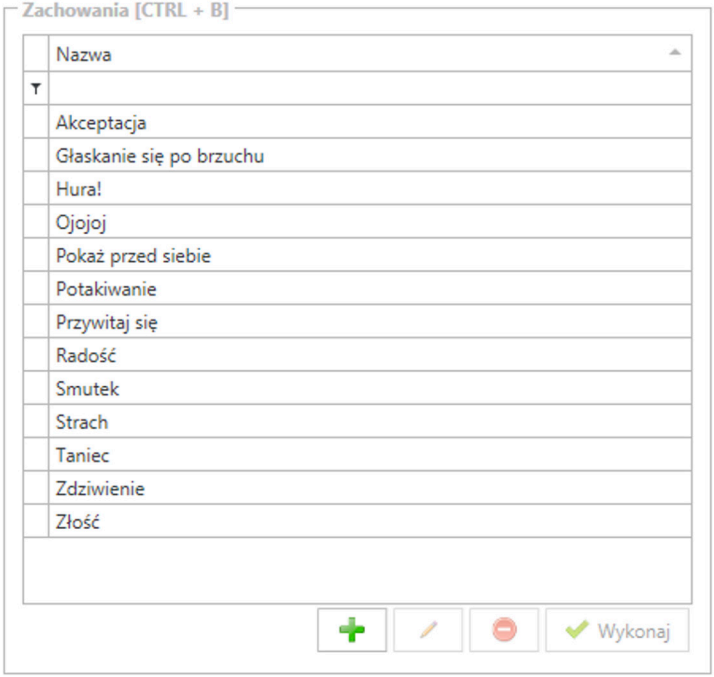
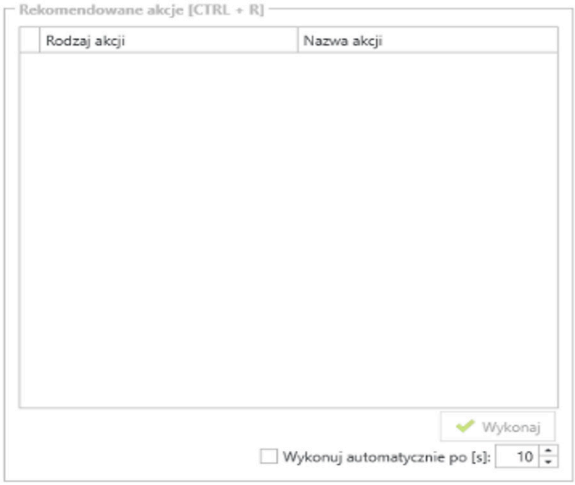
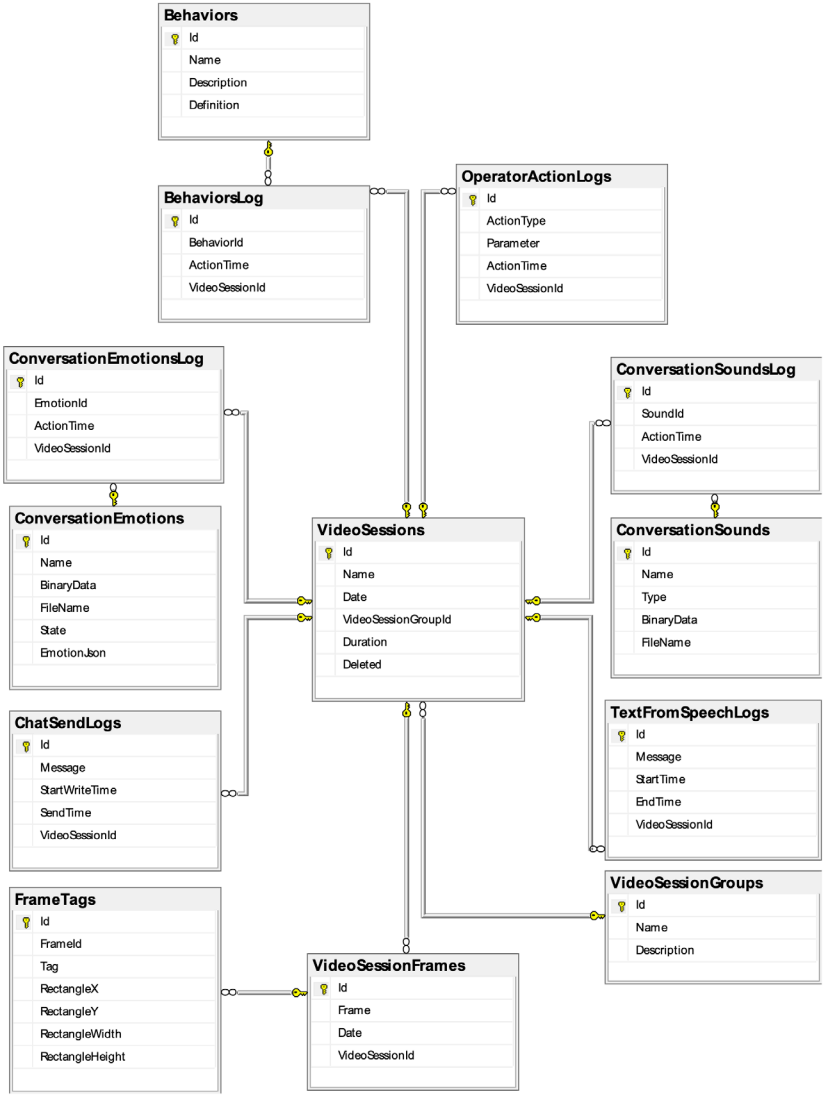


**Figure 7.** *Recommended actions window*




The system's key functionality is recommended actions (Fig. 7). During the session with the patient, the operator receives suggestions for actions that should be performed on the patient's device. It may be a statement, a presented emotion, a gesture, or a reproduced multimedia file such as sound, video, or graphics. The machine learning system subsystem proposes recommended actions. The machine learning subsystem uses data collected during therapy sessions. Figure 8 shows the data structure of recorded therapy sessions. These data include the patient's behavior, statements, reactions, emotions, responses, commands, and tasks assigned to the patient by the rehabilitator. Images from the camera and sound from the microphone of the patient's device can also be recorded for further analysis, e.g., for automatic detection of current emotions, as well as a transcription of the patient's statements and the rehabilitator's statements (defined by text). The application uses artificial intelligence to analyze the child's statements and behavior. Based on this analysis, the system suggests appropriate tasks and exercises to the therapist. The therapist can manually control the system's reactions or use suggestions proposed during the session. All therapy is recorded in the app, allowing the therapist to review later and assess the child's progress. The recordings can also be used for educational purposes and shared with other professionals.

**Figure 8.** *Structure of primary data for recording therapeutic sessions*




The application uses speech recognition and synthesis technology to enable the child to communicate with the system using voice. Artificial intelligence

systems create a transcription of the patient's statements, which in subsequent stages is used to recognize the meaning of the uttered sentences and evaluate them in the context of the therapy.

Play therapy with a device, e.g., a tablet or robot, combines elements of game, learning, and rehabilitation. The device, equipped with a screen, moving elements, graphics, and sound functions, becomes a friendly companion for the child on his development path. We do not impose play patterns on the child; the device adapts reactions to the patient's behavior, stimulating natural curiosity and the desire to explore. The system responds to the child's gestures, sounds, and emotions, creating an engaging interaction and strengthening the child's sense of agency. The device can praise and reward your child's positive reactions, building their self-confidence and motivation to continue playing. The difficulty level of the games and the topics match the child's age and skills, providing appropriate challenges and stimulating development. All this is done under the supervision of a therapist who, invisible to the patient, directs the play process in a way that ensures the achievement of rehabilitation goals. Physical exercises, watching movies, and listening to music stimulate cognitive functions, memory, and concentration. The child learns to express emotions and gestures and communicate verbally and non-verbally. A positive play atmosphere reduces the child's tension and anxiety. Play therapy is suitable for children of all ages. It can be used as the primary therapeutic method or complement other methods with similar assumptions. Research confirms the effectiveness of play therapy with devices, e.g., a robot. This method is becoming more and more popular among specialists and parents who notice its positive impact on the development of children with various disorders.

The application allows the child to present various emotions on the device screen using simple graphics, which can help the patient learn to recognize and understand emotions. The application also allows you to talk to your child using text or speech. The system can automatically generate responses to the child's utterances, maintaining the conversation and stimulating the child's language development. The therapist can also play audio and video files on the patient's device to enrich the therapy and engage the child. The system also allows you to record therapy sessions for later analysis, train artificial intelligence models, and assess the child's progress.

## Conclusions

The presented expert system for the therapy of children with autism brings several significant benefits that significantly facilitate and enrich the therapeutic process. The application allows the therapist to conduct personalized treatment tailored to each child's needs. Using advanced algorithms, artificial intelligence analyzes session data and proposes responses that can significantly increase the effectiveness of treatment. What distinguishes the system is its ability to dynamically respond to the child's changing behaviors and emotions, which allows for ongoing adjustments to the therapeutic approach. Additionally, integrated multimedia elements, such as graphics depicting emotions and audio and video files, play a key role in engaging children in therapy. These innovative tools make it easier for children to understand complex emotional and social concepts and significantly increase their motivation to attend sessions regularly and develop new skills. Interactive games and tasks are adapted to the child's individual development level, which allows for the gradual introduction of more complex tasks in line with the child's progress.

Using the application, the therapist can conduct therapy and constantly monitor the child's progress. The application automatically records and provides invaluable information when planning further therapy stages while minimizing the specialist's bureaucratic work. The ability to conduct therapy sessions in different places and times also includes flexibility for therapists and children's parents, which is especially important for families living in remote locations or those with limited access to specialized care. Although the application is a modern tool with unique features supporting the therapeutic process, it cannot and should not replace direct interactions with qualified therapists. The support of a human specialist is irreplaceable, especially in the case of children with autism spectrum disorders, who require an individual approach and often intensive, multidisciplinary therapy. Parents and guardians of these children need to remember the need for regular consultations with professionals who can assess progress, adapt the therapeutic program to the child's changing needs, and provide support in other areas of development.

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