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Smart home subsystems during emergency situations

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Abstract. *The vulnerability of smart home systems to natural disasters driven by climate change. It finds that existing technologies, designed for comfort and efficiency, are ineffective in extreme events like floods or earthquakes. The paper substantiates the urgent need to develop adaptive models to enhance resilience, ensure occupants' safety, and protect infrastructure in crisis situations.*
Keywords: *smart home, emergency situations, natural disasters, Internet of Things (IoT), adaptive systems, security, climate change.*

Global climate change, accompanied by a significant increase in the frequency of natural disasters such as floods, hurricanes, earthquakes, and extreme temperature fluctuations, poses serious challenges to residential infrastructure. According to the World Meteorological Organization, the number of extreme weather events has nearly doubled over the past 20 years, and the economic damage caused by them exceeds US$300 billion annually [1]. These changes not only affect the economy and social stability, but also threaten the viability of modern life support systems, including the concept of the Smart Home.

Modern smart home models use artificial intelligence, machine learning, and Internet of Things (IoT) algorithms to integrate sensors and devices [2]. They are capable of automatically optimizing systems, for example, regulating heating or ventilation in response to changes in the environment [3]. However, most such systems are unable to respond effectively to sudden natural phenomena, which limits their functionality in crisis situations [4]. This requires the adaptation of smart homes to ensure their resilience to external threats.

Research and development efforts are focused on integrating sensors that respond to emergencies with automated algorithms. For example, systems can shut off gas or electricity supplies during earthquakes [5]. However, their widespread implementation is complicated by high costs [6]. Research also considers energy consumption management algorithms based on weather data, but their adaptation to emergencies such as storms or floods remains underdeveloped [7]. Thus, despite advances in energy efficiency, improving the security of smart homes in crisis situations remains a key challenge [8].

A smart home is an integrated system of Internet of Things (IoT) and automated control technologies, but most systems have limitations that affect their effectiveness in crisis situations. To analyze the main advantages and disadvantages of these technologies, the results of the analysis of existing smart home systems in study [9] are presented in Table 1.

Table 1. Analysis of technologies and adaptability to natural phenomena and disasters

№	Technology	Advantages	Disadvantages	Adaptability to Natural Disasters
1	Honeywell Home T9 Smart Thermostat	Zonal temperature control, adapts to human presence	Vulnerable to power outages	Limited, does not account for catastrophic events
2	Tesla Powerwall	Autonomous power supply, integration with solar panels	Dependence on solar light availability during long-term disasters	Can provide autonomy, but efficiency is limited by the scale of the disaster
3	Alarm.com Smart Home Security	Integration of video surveillance, motion sensors, and gas leak detection	Requires a stable internet connection	Minimal adaptability, can partially respond to gas leaks or intrusions
4	Panasonic HomeX	Energy autonomy, energy consumption optimization	Limited autonomous operation during severe disasters	Capable of adapting to energy crises but not to other types of natural disasters
5	Ecovacs Deebot OZMO Pro	Adapts to various cleaning conditions, responds to increased humidity	Designed for household use, incapable of responding to complex emergencies	No adaptability to large-scale natural disasters
6	SMA Sunny Boy Storage	Autonomous operation, provides power for critical devices	Lacks integration with other Smart Home systems	Provides energy support but does not adapt to severe catastrophic situations

Taking natural disasters into account when designing smart homes is a critical aspect of ensuring the safety of residents and the integrity of the building. Recent studies show that dynamic natural phenomena such as severe storms, earthquakes, floods, and temperature fluctuations have a significant impact on the operation of smart homes. Works published in 2022-2024 describe how these natural factors can cause power supply failures [10], affect the structural stability of buildings, and disrupt the operation of sensor networks [11].

Below is a table of damage caused to smart homes by natural disasters, Table 2. According to the latest data, the greatest damage is observed during earthquakes and floods, as these phenomena not only affect structural elements but also disrupt the operation of networks and automated systems [12, 13].

Table 2. damage to the Smart Home from the impact of dynamic natural phenomena and disasters according to data from 2022-2024

№	Type of Natural Phenomenon or Disaster	Main Damages in Smart Homes	Causes of Damage	Examples (2022–2024)	Percentage of Damage (2022–2024)
1	Floods	Damage to electronics, control system short-circuits, power outages	Water infiltration into critical system components	Flood in Germany (2023), damage to electronics in Rhine River homes	35%
2	Earthquakes	Structural damage, sensor failures, power cable breaks	Insufficient resistance to vibrations and structural damage	Earthquake in Turkey (2023), safety system failures in 25% of homes	25%
3	Hurricanes	Power supply disruptions, damage to antennas, ventilation, and solar panels	High wind speed, trees falling on equipment	Hurricane Fiona in the USA (2022), power systems damaged in Florida	40%
4	Heavy Snowfalls	Solar panel breakdowns, sensor icing, heating system failures	Snow accumulation on critical house components	Snowstorms in Canada (2023), heating failures in 18% of homes	18%
5	Wildfires	Sensor burns, safety system damage, loss of energy independence	High temperatures, fire spreading to houses	California wildfires (2022), destruction of components in 60% of affected homes	60%
6	Temperature Fluctuations	Sensor failures and climate control system malfunctions	Insufficient protection against extreme temperatures	Heatwave in Europe (2022), 20% of homes with air conditioning failures	20%

An analysis of existing research in the field of developing adaptive models for smart homes reveals several significant gaps that limit their effectiveness in real-world conditions. First, most modern models do not provide sufficient resistance to sudden natural disasters such as earthquakes, storms, or floods, which calls into question their ability to operate in extreme situations. Another significant problem is the lack of integrated alarm systems that would respond quickly to danger and alert residents. Also, the lack of algorithms with a high level of adaptability and the ability to quickly restore systems after catastrophic events complicates the practical application of such models in crisis conditions. In addition, scientific research is often limited to predictable scenarios of changes in external conditions, without taking into account dynamic factors that can unexpectedly change the characteristics of the environment, which further complicates the adaptation of Smart Homes to real threats.

Therefore, developing models capable of withstanding natural disasters is crucial for ensuring human safety and protecting vital infrastructure. Such models allow for more accurate prediction of potential risks, which in turn facilitates effective planning of preventive measures aimed at preventing destruction. This not only reduces economic losses, but also facilitates the recovery process after catastrophic events, ensuring stability and speed of system recovery in emergency situations.

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