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Road vehicles — Ergonomic aspects of human vehicle interactions — Taxonomy for the classification of adaptive interactive vehicle systems

Véhicules routiers — Aspects ergonomiques des interactions homme-véhicule — Taxonomie pour la classification des systèmes interactifs adaptatifs pour véhicules

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 39, *Ergonomics*.

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Introduction

With increasing technical feasibility of artificial intelligence (AI), more companies are integrating AI-based adaptivity and personalization into vehicle systems to adapt their behavior and/or content to the needs or expectations of individual users or groups of users. This enables vehicle systems to match individual user preferences and assist and ease execution of non-driving related functions. For the driving context, this offers the potential to reduce workload and distraction by helping users to handle large amounts of information within road vehicles. Nevertheless, there is no uniform classification for the capacities and characteristics of the type of adaptivity for vehicle systems.

This may lead to several risks of misunderstandings and unmatched expectations for different stakeholders as well as for the end user. If the type of the adaptivity is not clear to the end user, it can lead to uncertainty and a lack of transparency, predictability, algorithmic awareness, and understanding of the vehicle system's capacities and limits. Developers as well as the manufacturers as stakeholders also bear the risks of misunderstandings or unmatched expectations within all phases of the development process (ISO/IEC/IEEE 29148).

The ISO 8235 was developed to classify vehicle functions regarding their type of adaptivity and parameters used to achieve the adaptations.

Standardizing the types of adaptation of vehicle systems serves the following purposes:

a) enables end users to assess the extent and limitations of adaptation specified by the manufacturers, suppliers and researchers,

b) provides an unambiguous framework for the specification of adaptive vehicle systems and the technical differentiation of the respective types of adaptivity in the requirement phase,

c) provides clarity and transparency in communication on the topic of adaptive vehicle systems for manufacturers, suppliers as well as researchers,

d) reduces uncertainty about the capacity and limitations associated with non-transparent black box technology solutions for the manufacturers,

e) prevents misunderstandings and deviating expectations between development partners of adaptive vehicle systems and therefore,

f) prevents unnecessary effort, duplicate work and costs in the development and evaluation of adaptive vehicle systems.

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Road vehicles — Ergonomic aspects of human vehicle interactions — Taxonomy for the classification of adaptive interactive vehicle systems

1 Scope

This document provides a taxonomy to classify the type of adaptivity within vehicle systems. The taxonomy includes five types ranging from no adaptation (type 0) to adaptations based on interpreted user characteristics and context data (type 4). This document provides definitions of the five types of adaptation and explains adaptation in a consistent and coherent manner. By offering definitions and descriptions of the five types, this document can be used to classify the adaptivity within vehicle systems according to the types.

This document is intended to be applied to all components of vehicle systems that the driver and/or other occupants interact with either while driving or while parked. This includes vehicle information systems, communication systems, for example, navigation systems or mobile devices connected to the vehicle infrastructure, traffic and travel information (TTI) systems, as well as vehicle comfort systems, for example, climate control, massage, or ambient lighting. The taxonomy is also applicable to third-party software provided by third-party suppliers that is displayed and/or operated in the vehicle.

The taxonomy can also be applied to interactive exterior elements, like windscreen wipers or pedestrian communication devices and non-driving-related functions that are novel to future vehicles in the context of automated driving, such as playing a video.

The information and communication vehicle systems described in this document exclude driving-operation or driving-assistance systems. Consequently, safety-related functions governed by Automotive Safety Integrity Level (ASIL) specifications (ISO 26262) are not addressed. Implementation and validation of data collection/detection are also beyond the scope. Additionally, priority handling, as well as varying legal regulations across countries, are not covered in the taxonomy.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
adaptable vehicle system
interactive system within a vehicle that can change its behaviour and/or content triggered by configurations from the user

[SOURCE: Reference [8]]

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3.2
adaptation
proactive changes in the system behaviour and/or content based on user configurations, pre-defined rules or self-learned system rules

3.3
adaptive vehicle system
interactive system within a vehicle that can proactively change its behaviour and/or content triggered by certain events without intervention from the user

Note 1 to entry: Adapted from Reference [7].

3.4
black box
idealized mechanism that accepts inputs and produces outputs, but is designed such that an observer cannot see inside the box or determine exactly what is happening inside that box

Note 1 to entry: This term can be contrasted with *glass box* (3.13).

[SOURCE: ISO/IEC 18031:2011, 3.6]

3.5
context data
influencing factors from both, the general context of use as well as situational factors and conditions resulting from the surrounding environment

3.6
data processing
manner in which real time inputs are analysed by the system to decide on the suitable reaction and/or *adaptation* (3.2)

3.7
enhanced data
data that has been processed to enhance its quality, accuracy, or relevance

Note 1 to entry: This involves cleaning, filtering, combining data from multiple sources and adding contextual information before storage.

3.8
exterior element
element outside the vehicle with the function of taking on different states

3.9
individualization
modification of interaction and presentation of information to suit individual capabilities, needs and preferences of users

[SOURCE: ISO 9241-129:2010, 3.3, modified — "preferences" was added to the definition.]

3.10
non-driving related function
secondary (3.15), or *tertiary task* (3.17) the user can execute inside a vehicle that is not related to the *primary driving task* (3.12)

3.11
preference
predilection of a user pertaining to a vehicle system

Note 1 to entry: This includes the user's tastes, likes and dislikes with respect to the vehicle system and its properties.

[SOURCE: ISO/IEC TR 15938-8:2002, 2.2.2.41, modified — The original term was user preferences, in the definition predilection replaces preference and the note to entry was originally part of the definition.]

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3.12
primary driving task
activity that the driver undertakes to maintain longitudinal and lateral vehicle control within the traffic environment

[SOURCE: ISO 17287:2003, 3.2.17]

3.13
priority
relative importance of two or more messages which determines their ranking in a time sequence or emphasis of presentation

[SOURCE: ISO 16951:2021, 3.10]

3.14
real-time learning
process of using live data input to continuously improve the vehicle system algorithms based on continuous learning

3.15
secondary task
function that increases the safety for the driver, the car and the environment

EXAMPLE Setting turning signals or activating the windshield wipers.

[SOURCE: Reference [9]]

3.16
stakeholder
person or organisation that may influence a decision or activity, may be influenced by it, or may have the impression of being influenced by it

Note 1 to entry: Stakeholders may include: users, purchasers, system owners or managers, and persons indirectly influenced by the operation of a system, product or service.

Note 2 to entry: Different stakeholders may have different needs, requirements and/or expectations.

[SOURCE: ISO 9241-11:2018, 3.1.9, modified — Affect(ed) was replaced by influence(d).]

3.17
tertiary task
any function regarding entertainment and information systems

[SOURCE: Reference [9]]

3.18
trait
temporal stable and cross-situational consistent characteristics of the user's personality

[SOURCE: Reference [10]]

3.19
user identification
identification of user groups, such as family members sharing the same car key, and the identification of numerical identifiers, such as 1, 2, 3, etc., that users can utilize independently, is not limited to the identification of individuals by methods such as facial recognition

3.20
user interface
all components of an interactive system (software or hardware) that provide information and controls for the user to accomplish specific tasks with the interactive system

[SOURCE: ISO 9241-129:2010, 3.9]

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4 Application

The taxonomy can be applied to classify systems or components within vehicle systems based on their type of adaptivity. As Figure 1 illustrates, vehicle systems are a comprehensive assembly consisting of several components. Each of these vehicle systems, for example, an infotainment system is further subdivided into several subsystems, e.g. a navigation system. Within each subsystem, various functions are organized, such as the destination input function or route guidance function within a navigation system.

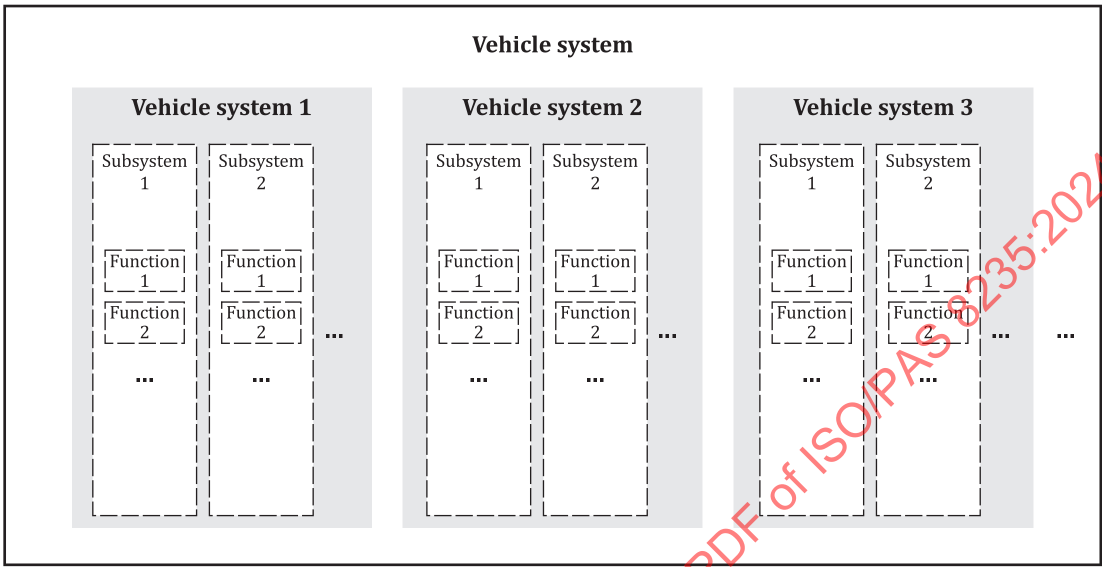

Figure 1 — Conceptual architecture of vehicle systems

The taxonomy is intended for application to all components of vehicle systems, classifying the type of adaptation to the driver and/or other vehicle occupants, either while driving, standstill or being parked. The taxonomy can also be applied to interactive exterior elements, like windscreen wipers or pedestrian communication devices and non-driving-related functions that are novel to future vehicles in the context of automated driving, such as playing a video. Functions provided by third-party suppliers are also included in the intended application.

When specifying the adaptivity type for a vehicle system, the documentation shall transparently state the relevant component, tailored to the appropriate target audience, e.g. for developers in the technical specification or for end users in the product description.

If the classified vehicle system includes multiple components, the documentation shall provide a clear description indicating the relevant component and whether other components of the vehicle system have a different adaptivity type. This transparency ensures a relatable application of the taxonomy and enables the classified adaptivity types of vehicle systems to be comparable.

To define the adaptivity type of a vehicle system, the taxonomy is applied to the required data and data processing, as shown in Clause 5. More than one type can be applied to one vehicle system and its components, and combinations of types are possible.

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5 Classification of the type of adaptivity for vehicle systems

5.1 General

Vehicle systems are classified into five types of adaptation ranging from type 0 with no adaptation, to type 4 as the highest type of adaptation. Vehicle systems at higher adaptation types exhibit more advanced data processing capabilities, including the ability to learn from observing user interactions.

In 5.2 to 5.6, each adaptation type is characterized by a general description, the necessary data and data processing requirements, and an illustrative data flow accompanied by a conceptual architecture.

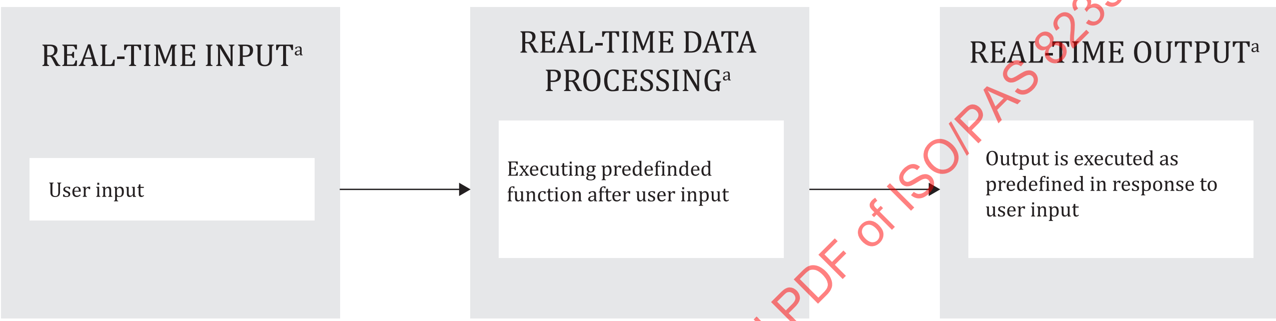
Additionally, Annex A contains a decision tree to conveniently classify adaptive vehicle systems into the appropriate types for all stakeholders and end users.

5.2 Type 0 – no adaptation

5.2.1 General description

As depicted in Figure 2, a type 0 vehicle system utilizes real-time user input via various modalities, such as speech, touch, or gesture, to execute commands initiated by the user, triggering predefined real-time output on the predefined device accordingly. The system operates on explicit user actions for activating or deactivating specific functions via their chosen input modality. Importantly, at this type, no data or configurations are stored—neither functions nor settings are retained.

This type defines a vehicle system with no adaptation, necessitating users to explicitly activate or deactivate each function individually. This system behaviour applies universally to all users.



a Data flow can be onboard and/or online.

Figure 2 — Conceptual data flow of type 0 - no adaptation

5.2.2 Example

The user presses the button "relax mode" (real-time input). The vehicle system processes this input as the predefined command to initiate the "relax mode" (real-time data processing), and the "relax mode" begins (real-time output).

5.3 Type 1 – saved adaptation

5.3.1 General description

As illustrated in Figure 3, type 1 defines an adaptable vehicle system that allows users to manually save one or more individual settings or preferences for specific functions. Activation of these previously saved preferences can occur by user identification which can either be manually by the user, upon the user's registration within the vehicle, or automatically by the vehicle system when the vehicle recognizes the user, e.g. via a personalized key or Bluetooth profile from the user's telephone. Additionally, activation can occur by user input without concrete user identification to save and retrieve settings, such as pressing a button for a seat memory function that relies on numbered buttons. The real-time output will be displayed or executed as previously saved by the user.

It is essential to emphasize that the range of possible adaptations, along with their respective setting options, is predetermined by the development team and cannot be altered by the user.

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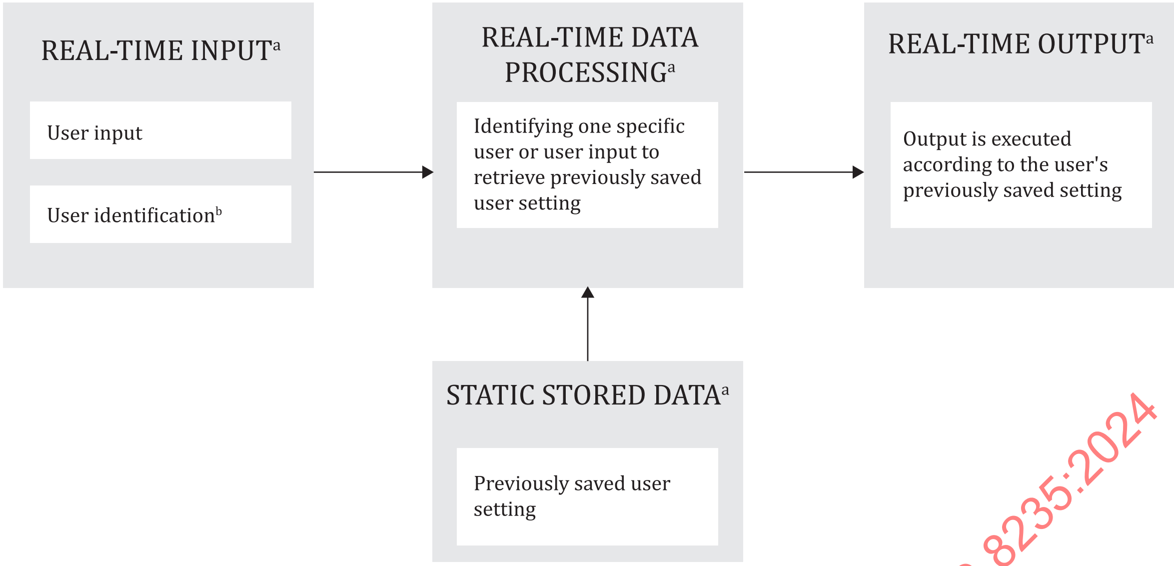

a Data flow can be onboard and/or online.

b Optional and not required.

Figure 3 — Conceptual data flow of type 1 - saved adaptation

5.3.2 Example

A user saves the "relax mode" as the default setting, and the adaptive vehicle system stores this personal preference, associating it with the user's specific profile (static stored data). The activation of this function “relax mode” takes place in real-time (real-time output) when the user enters the vehicle (real-time input), and the adaptive vehicle system identifies and activates the user's personalized "relax mode" setting (real-time data processing).

5.4 Type 2 – predefined adaptation

5.4.1 General description

As shown in Figure 4, the type 2 adaptive vehicle system operates on real-time data, incorporating user input and context data. This system executes predefined adaptations by detecting predetermined triggers based on real-time input and context data, and then applying if-then rules established by developers. The real-time output, whether displayed or executed, is also predefined by the developers. These adaptations are initiated by the adaptive vehicle system and applied to all users or predefined user groups. These user groups may be differentiated by a predetermined vehicle system configuration, such as diverse world regions or language settings.

The adaptation conditions, governed by fixed if-then rules, remain unchanged during the period of use or until the next software update occurs. Importantly, the initiation of updates is undertaken by the developers themselves and not autonomously by the vehicle system.

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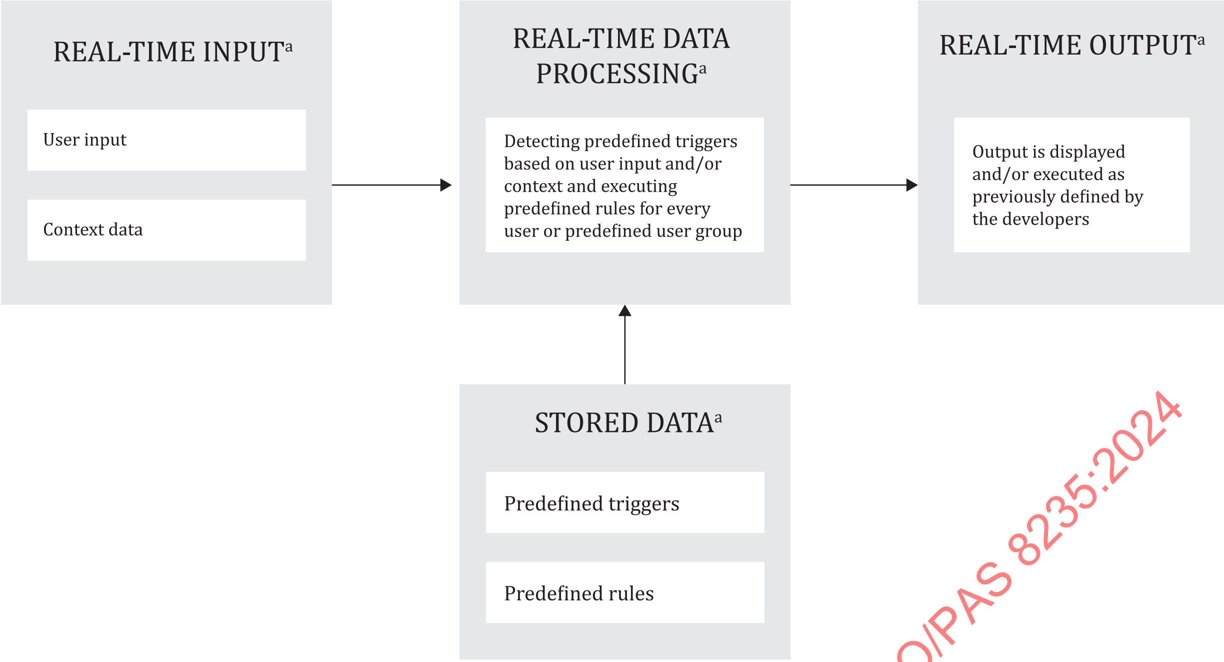

a Data flow can be onboard and/or online.

Figure 4 — Conceptual data flow of type 2 - predefined adaptation

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5.4.2 Example

The adaptive vehicle system has stored the predefined adaptation "recommend the relax mode" within the predetermined real-time user input “activate auto pilot” and context "traffic jam" (static stored data). Upon detection of the predefined user input "auto pilot activated" and the context "traffic jam" by the adaptive vehicle system in real-time (real-time input), the predefined adaptation "recommend the relax mode" is promptly executed by the adaptive vehicle system (real time data processing and real-time output). This execution applies universally to all users.

5.5 Type 3 – Adaption based on real-time learning

5.5.1 General description

As Figure 5 shows, the type 3 adaptive vehicle system engages in real-time data processing, encompassing user input, user identification and context data. Utilizing machine learning algorithms, the system adapts dynamically to the unique profile of a specific user through real-time observations, continuously adjusting based on continuous learning.

The system effectively employs this adaptive learning process to discern patterns in user behaviour and preferences, saving valuable insights into the user interaction history. This data, along with user personal preferences and context data, are systematically stored and enhanced, potentially including pre-processed data, filtered data, data fusion and aligned data. Over time, the system refines its understanding of the user's preferences and needs, steadily adapting the learned data accordingly, thus contributing to a comprehensive user interaction history and personal preferences repository. This continuous learning, depicted in Figure 5 by the circle around "real-time and over-time data processing" and "adaptive stored data," illustrates the perpetual nature of the process.

Notably, the learning process is versatile, allowing adaptation based on either collective data from a group of users or individually collected data. The choice between these approaches is contingent upon the addressed functions and the required type of individualization. This information guides the generation of appropriate system responses. Whether displayed on a graphical user interface (GUI) or implemented

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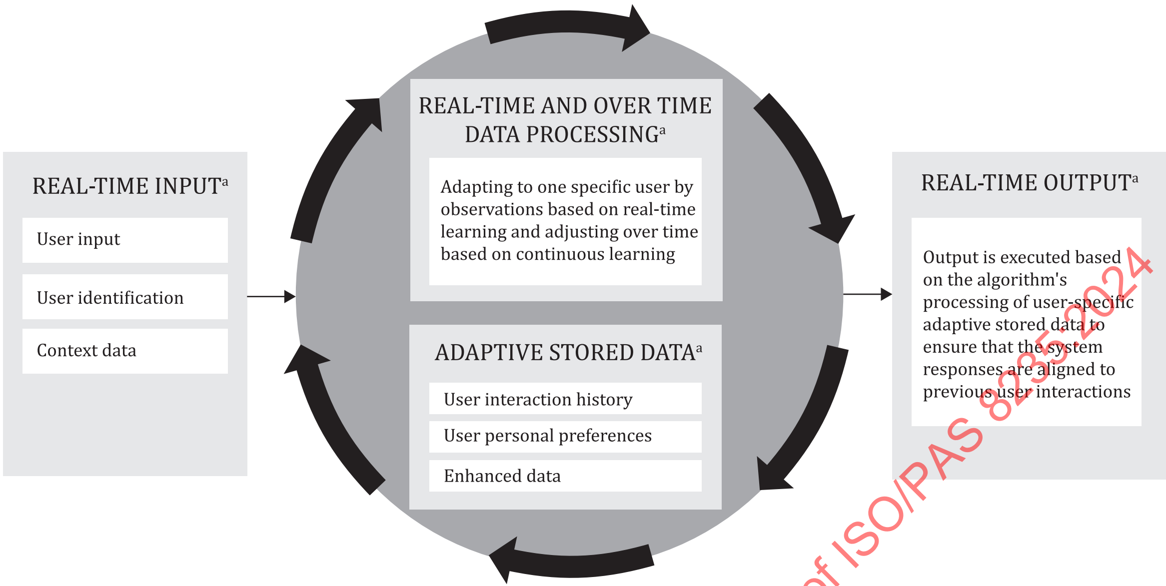
through actuators, these responses are tailored to meet the specific needs and preferences of the individual user. The output depends on the algorithm's processing of the specific user and the user-specific adaptive stored data, incorporating past interactions to ensure that the system responses are aligned to previous user interactions.



[a] Data flow can be onboard and/or online.

Figure 5 — Conceptual data flow of type 3 - adaption based on real-time learning

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5.5.2 Example

The type 3 adaptive vehicle system observes over time that an individual user activates the function “relax mode” in the context driving home from work (real-time input). After learning (real-time and over time data processing and adaptive stored data), the adaptive vehicle system recommends or activates the “relax mode” (real-time output) as soon as the same context “driving home from work”, is detected. Furthermore, the vehicle system learns continuously and adjusts over time if the specific user changes the behaviour (real-time and over time data processing).

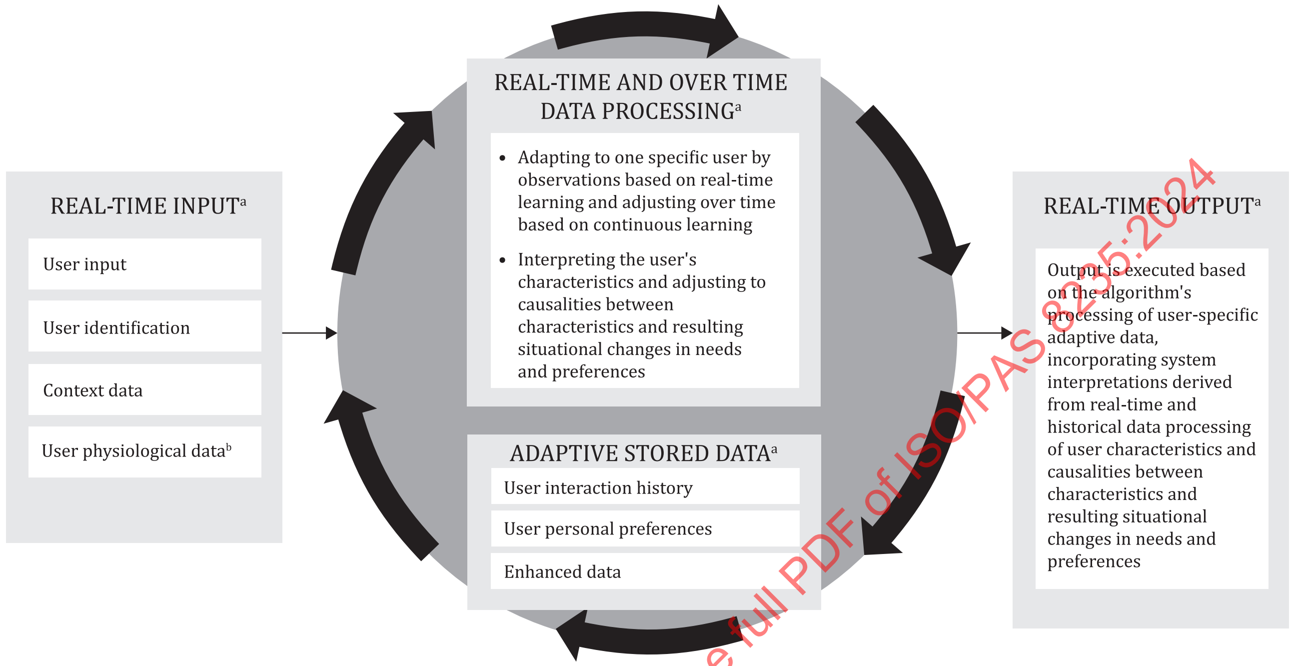
5.6 Type 4 – Adaptation based on real-time learning and interpretations

5.6.1 General description

Expanding upon the capabilities of type 3, type 4 exemplifies a heightened dimension of the adaptive vehicle system. As Figure 6 illustrates, type 4 incorporates specific user characteristics in addition to type 3 functions. The adaptive vehicle system employs algorithms to discern patterns and relationships between various data points, particularly focusing on the user's states, inputs and contextual cues. Through continuous learning, the system refines its understanding of user characteristics, including physical states, for example, fatigue, and/or emotional states, for example, happiness detected through devices like smartwatches or camera-based emotion detection or interpreted based on a lookup table, and user traits, e.g. extroversion derived from system interpretations. The adaptive vehicle system establishes connections between these states and the resulting changes in situational needs and preferences.

This dynamic adaptation is fuelled by the system's ability to interpret complex causalities, learning from the relationships between user characteristics and the corresponding alterations in preferences and requirements. The system utilizes stored data, including user interaction history, personal preferences, and contextual information, to refine its responses adaptively over time. As depicted in Figure 6, the circles surrounding "real-time and over-time data processing" and "adaptive stored data" illustrate the perpetual nature of this continuous learning process. Equipped with sophisticated algorithms, the adaptive system utilizes the learned data to anticipate and respond to novel situations autonomously. This advanced adaptivity goes beyond type 3 learning algorithms by proactively anticipating and responding to new situations.

The output of this adaptive system is manifested through the output device, such as a graphical user interface (GUI) or actuator. The system generates responses tailored to the real-time needs of the user and aligned with historical user interactions and preferences in the context of the user's characteristics.



a Data flow can be onboard and/or online.

b Optional and not required.

Figure 6 — Conceptual data flow of type 4 - adaptation based on real-time learning and interpretations

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5.6.2 Example

The type 4 adaptive vehicle system observes and interprets, over time, that an individual user activates the "relax mode" when the interpreted user characteristic is "angry," detected through various user inputs (real-time input and real-time and over time data processing). These inputs include driving behaviour, user physiological data such as heart rate, facial expression detection, and body temperature, and context data like calendar information with meeting start time, ETA of the navigation system. After learning from the user's interactions (adaptive stored data and real-time and over time data processing), the vehicle system recommends or activates the function as soon as the same user characteristic "angry" is detected (real-time output). This can occur in previously observed situations as well as in new situations.

Furthermore, the adaptive vehicle system continuously learns and adjusts over time if the specific user changes their behaviour, or the situational needs and preferences change based on the interpreted user characteristic (real-time and over time data processing).

5.7 Summary

This document presents a taxonomy for classifying adaptive vehicle systems according to five types of adaptation. The types range from type 0 (no adaptation) to type 4 (adaptation based on real-time learnings and interpretations). The taxonomy can be applied to classify a vehicle system, subsystem or function. The main classification criteria are input data, stored data and data processing. Table 1 presents an overview how systems are assigned to the types of adaptation depending on real-time input data, stored data and data

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processing. While low types of adaptation require few types of data and simple forms of data processing, high types of adaptations require data from various sources and complex processing strategies, incorporating algorithms for real-time learning, learning over time, and interpretations of non-observable information.

Table 1 — Summary of the required data and data processing for adaptive vehicle systems (type 0-4)

Required data and data processing		**Type 0** No adaptation	**Type 1** Saved adaptation	**Type 2** Predefined adaptation	**Type 3** Adaption based on real-time learning	**Type 4** Adaptation based on real-time learning and interpretations of user states
Real-time input data	User input					
	User identification					
	Context data					
	User physiological data					
Stored data	Previously saved user setting					
	Predefined triggers & rules					
	User interaction history					
	User personal preferences					
	Enhanced data					
Data processing	Executing predefined function directly in response to user input					
	Identifying one specific user or user input to retrieve previously saved user setting					
	Detecting predefined triggers based on user input and/or context and executing predefined rules for every user or predefined user group					
	Adapting to one specific user by observations based on real-time learning and adjusting over time based on continuous learning					
	Interpreting the user's characteristics and adjusting to causalities between characteristics and resulting situational changes in needs and preferences					

NOTE Shaded cells indicate that the respective elements of real-time input data, stored data and data processing are required to meet the prerequisites for enabling the corresponding type of adaptability.

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Annex A
(informative)

A.1 Decision tree to classify the type of adaptivity for vehicle systems

A decision tree, as shown in Figure A.1, has been developed to conveniently classify adaptive vehicle systems into the appropriate types for all stakeholders and end users. This classification is based on the required data processing, summarized in Table 1.

To use the decision tree, start by verifying if the component or function employs the specified data processing from left to right. Based on your answer (yes or no), proceed to the next decision node accordingly. The type of adaptivity will be identifiable once the final node is reached.

The necessary information for classification can be obtained through system interaction or a search or both.

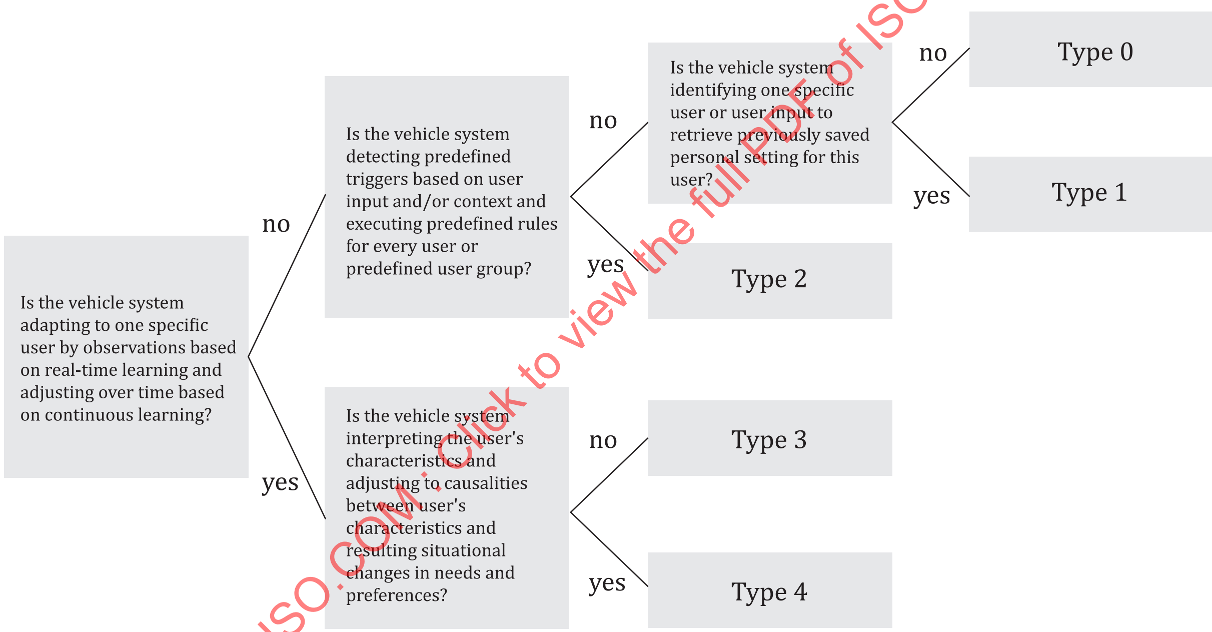

Figure A.1 — Decision tree to classify vehicle systems, subsystem or function

In the following subclauses, five example functions are described and classified step by step into the corresponding type of adaptivity with the help of the decision tree.

A.1.1 Example function 1

A.1.1.1 Description of example function 1

The user presses the button "relax mode" (real-time input) and the "relax mode" begins (real-time output).

A.1.1.2 Using the decision tree to classify example function 1

Table A.1 shows the usage of the decision tree with the questions, answers, and the result for example function 1.

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Table A.1 — Step-by-step instructions for classifying the adaptivity type for example function 1 using the decision tree

Step	Question	Answer and explanation	Result
1	Is the vehicle system adapting to one specific user by observations based on real-time learning and adjusting over time based on continuous learning?	No, the vehicle system responds only to the button press (relax mode) by the user and does not adapt to specific users through real-time learning or continuous adjustments over time in this scenario.	Procced to next question that follows “no”.
2	Is the vehicle system detecting predefined triggers based on user input and/or context and executing predefined rules for every user or predefined user group?	No, the vehicle system behaviour remains consistent regardless of the context. It is not detecting predefined triggers based on user input and/or context and executing predefined rules for every user or predefined user group.	Procced to next question that follows “no”.
3	Is the vehicle system identifying one specific user or user input to retrieve previously saved personal setting for this user?	No, the vehicle system responds only to the button press (relax mode) by the user and does not involve identifying a specific user or user input to activate previously saved personal settings for a specific user.	**“no” leads to final result = type 0**

A.1.2 Example function 2

A.1.2.1 Description of example function 2

A user saves the "relax mode" as the default setting, and the adaptive vehicle system stores this personal preference, associating it with the user's specific profile (static stored data). The activation of this function “relax mode” takes place in real-time (real-time output) when the user enters the vehicle (real-time input), and the adaptive vehicle system identifies and activates the user's personalized "relax mode" setting (real-time data processing).

A.1.2.2 Using the decision tree to classify example function 2

Table A.2 shows the usage of the decision tree with the questions, answers, and the result for example function 2.

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Table A.2 — Step-by-step instructions for classifying the adaptivity type for example function 2 using the decision tree

Step	Question	Answer and explanation	Result
1	Is the vehicle system adapting to one specific user by observations based on real-time learning and adjusting over time based on continuous learning?	No, the vehicle system retrieves a previously saved setting (saving and activating the relax mode) and does not adapt to specific users through real-time learning or continuous adjustments over time in this scenario.	Procced to next question that follows “no”.
2	Is the vehicle system detecting predefined triggers based on user input and/or context and executing predefined rules for every user or predefined user group?	No, the vehicle system retrieves a previously saved setting (saving and activating the relax mode). It is not detecting predefined triggers based on user input and/or context and executing predefined rules for every user or predefined user group.	Procced to next question that follows “no”.
3	Is the vehicle system identifying one specific user or user input to retrieve previously saved personal setting for this user?	Yes, the vehicle system identifies the user (user enters the vehicle) and activates the previously saved setting for this user (relax mode).	**“yes” leads to final result = type 1**

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A.1.3 Example function 3

A.1.3.1 Description of example function 3

The system has stored the predefined adaptation "recommend the relax mode" within the predetermined real-time user input “activate auto pilot” and context "traffic jam" (static stored data). Upon detection of the predefined user input "auto pilot activated" and the context "traffic jam" by the adaptive vehicle system in real-time (real-time input), the predefined adaptation "recommend the relax mode" is promptly executed by the adaptive vehicle system (real time data processing and real-time output). This execution applies universally to all users.

A.1.3.2 Using the decision tree to classify example function 3

Table A.3 shows the usage of the decision tree with the questions, answers, and the result for example function 3.

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