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PRESS INFORMATION

Audi AI

Audi AI – with intelligence and empathy

Extensively networked, automated and electrified – these characteristics define the Audi of the future. Audi AI will soon be the cipher for a variety of innovative systems which will relieve strain on the driver and simultaneously also offer him or her new possibilities to use the time spent in the car. To this end, Audi AI also uses strategies and technologies from the field of artificial intelligence and machine learning. This thus puts the brand ahead of its competitors.

Audi AI systems are capable of learning and thinking, whilst also being proactive and personal. Thanks to Audi AI, models bearing the four rings will be both intelligent and empathetic. They will be able to continually interact with their surroundings and the vehicle occupants, and thus adapt themselves in a better way than ever before to the individual requirements of those on-board.

Freedom on the road
Audi AI will pick up on the many years of experience which the brand has accumulated in concept cars featuring piloted driving. The new label will see innovative and intelligent electronic systems and technologies from Audi bundled together. Audi AI will create new forms of freedom for drivers and passengers by reducing the complexity of their interaction with the vehicle and with other road users. Various elements of artificial intelligence will also play a leading role in this – both in the development of new, intelligent and empathetic systems, as well as during their subsequent use. In order to do this, Audi is evaluating various approaches to and methods of machine learning.

Research on the highway
In 2009 already, a piloted Audi TTS drew the four rings on the frozen salt lake in Utah (USA) as a visible sign of the company's decade-long research. A year later, a driverless Audi TT drove up Pikes Peak in Colorado (USA).

In 2013, Audi was the first car manufacturer worldwide to obtain a testing license for the US states of California and Nevada. In January 2015, the Audi A7 piloted driving concept research vehicle drove 900 kilometers on the highway from Stanford to Las Vegas. And in May 2015, a driverless Audi was on the road in the dense urban traffic of Shanghai (China) – one of the most complex situations ever.

At what point is the development of the intelligent automobile today? Ultrasound and radar sensors, laser scanners, camera-based systems, a high-performance processor for data processing and a rapid internet connection via the mobile phone network are all features which the new Audi A8 has on-board. The rule-based application of driving assistance systems such as the active lane assist, the adaptive cruise control (ACC) or the predictive efficiency assistant has already made driving safer, more comfortable and more efficient in the past years.

The car looks to the future

Audi AI is now introducing the next step: the large amounts of driving data gathered by the various assistance systems will soon be able to be processed much more quickly and they will be usable and comparable in almost real-time with the data of other road users. The fully networked vehicle will take a much more distant look into the future than with systems previously used, and that is thanks to Audi AI. In short: the car of the future will gain the possibility to make prognoses.

In the new Audi A8, the Audi AI traffic jam pilot will be the first system in the world to be presented, which allows for highly automated driving at level 3. Level 3 means: in certain situations, the car takes over the task of driving. During this time, the driver no longer has to permanently survey all processes – contrary to level 2. The driver needs merely to be in a position to take back control once he or she is requested to do so. The new Audi AI traffic jam pilot is a technological milestone which was preceded by many years of research and development work.

Vehicle intelligence and interaction intelligence

Vehicle intelligence is a key component of Audi AI: that’s because intelligent assistance systems and technologies will lead the way to the fully autonomous vehicle. The Audi AI traffic jam pilot in the new Audi A8 is an example of how vehicle intelligence looks today. A comprehensive collection of sensors takes in the surroundings. The data from these is then computed in the central vehicle assistance control unit (zFAS) which celebrates its premiere in the new Audi A8. This continually delivers a map of the surroundings and is supported by means of a second data fusion in the radar control unit. The new Audi A8 is the first series-production automobile in the world to fulfill the technical requirements to drive upon request in a highly automated manner in traffic situations.

On the path to fully automated driving functions and the vision of autonomous driving, the car of the future will offer much more. Besides continually improved vehicle intelligence, interaction intelligence will also grow.

In the future, thanks to Audi AI, the car will feature a completely new characteristic: empathy towards vehicle occupants. The intelligent systems and technologies turn the car into a thinking, empathetic assistant which surpasses its initially intended purpose. Audi AI allows the vehicles of the future to anticipate the wishes of the driver or passengers in a situationally appropriate way, and thus to proactively support them in all situations. Furthermore, they can suggest a service and book it for the passengers autonomously, very much like a personal concierge. Thus, Audi AI creates new freedom and a new type of premium experience.

In a nutshell, Audi AI stands for the comprehensive and responsible interplay of innovative technologies which are seamlessly networked with the infrastructure and with other road users. The Audi of the future will continually learn new things and develop its capabilities even further. In this way, the technology adapts itself to the individual needs of people.

The individual components of Audi AI change our interaction with automobiles and improve the quality of our stay on-board. The car will become more and more a “third living space” alongside our homes and workplaces. Individual customer benefits are Audi’s main focus, as too is the clear relation to mobility. The advantages of Audi AI for the customer are clearly defined: the intelligent systems and technologies focus on time, safety, efficiency and individual adaptability.

Advantage 1: Time

Functions such as the new Audi AI traffic jam pilot or piloted parking are just the beginning. Audi AI makes it possible for the driver of the future to create a completely different type of stay on-board the fully-connected vehicle than was previously possible. Slowly but surely, he/she will be able to release the steering wheel and, instead, connect with the vehicle in a completely new way. The driver gains time as the autonomously driving vehicle takes over routine tasks such as parking or even driving through the car wash.

Time savings and comfort gains
The infotainment functions are continually expanding, with the ever-increasing internet speed making it possible to share large quantities of data during the journey. Simultaneously, the integration of communications media in the vehicle continues to advance. They allow people to work inside the vehicle, for example, taking part in a video conference. The driver has more time and more choice as to how he/she wishes to use the time aboard the vehicle. But the car of the future doesn’t just offer great potential for saving time and improving comfort while on the road, in specially designated areas, so-called “Audi AI zones”, an Audi will soon be able to complete tasks autonomously while the driver works or enjoys some leisure time.

Audi AI Zone:
The driver parks the Audi in a designated area (the handover zone). From there, the car drives on its own and un-manned to a multistory parking garage with various services on offer, such as a car wash, a package station, a gas station, or – in the case of an electric vehicle – a charging post. Thanks to Audi AI, the car can look after all of these things itself. Connected with its surroundings, the intelligent Audi can even locate a parking space itself before precisely parking in it. At the desired time, the vehicle is positioned back in the handover zone, ready for its next journey. The driver can follow the actions of the vehicle at any time using an app, to which he/she can also add new services.

The time savings and associated comfort gains from which Audi customers benefit during their visit to an Audi AI zone can soon become a reality. The development of a standardized interface for connecting various smart devices, as well as web-based integration of vehicle-specific apps will soon be mature enough for series production. The Audi of the future will thus become part of the internet of things, seamlessly and smartly integrating itself within the world of its user.

25th HOUR:
Modern cars use car-to-x technology to avoid traffic jams and other annoying waits. What's more, piloted driving will, in the future, also assist drivers during their journey. Freed of the requirement to steer, the driver has free hands and a clear head for other things – and that for around an hour per day on average.

But what about when all cars navigate around the town without the driver having to do anything? How does a premium brand differentiate itself in such a case? As part of the project entitled "25th HOUR", Audi will turn its customers into great time management specialists. This sees individual preferences being in central focus. The interior adapts itself so that the user can enjoy the best possible relaxation, make the most of family and friends or even complete a bit of work. Together with the Fraunhofer Institute for Industrial Engineering (IAO), Audi is currently investigating how digital signals, light moods and auditive stimuli in the car affect the human organism, for example in relation to stress levels or concentration. Findings from this are intended to inspire interior and usability designers in turning the car of the future into a picture perfect workplace.

Advantage 2: Safety

Currently, driver error accounts for up to 90 percent of all road accidents. In the future, Audi AI will prevent dangerous situations which cause accidents from arising in the first place. In order to make autonomous driving possible even in difficult traffic situations in the future, further methods and approaches will be required. These range from rule-based systems right up to elements from artificial intelligence. The development of a vehicle capable of avoiding accidents is the top priority at Audi.

Advantage 3: Efficiency

Extensively networked and piloted vehicles use space and energy more efficiently, which brings about both ecological and economical benefits. Using car-to-x technology (intelligent networking of road users and the infrastructure), the vehicle can, for example avoid traffic jams and calculate optimum diversions. Alongside personal customer benefit and energy savings, piloted driving delivers a further economical dimension: heavily frequented roads are subject to sustainably less strain thanks to targeted guidance of traffic flows.

Advantage 4: Customization

By means of Audi AI, the vehicle gets to know its occupants and their habits personally. Man and machine communicate with one another in order to create trust and to facilitate the smooth running of the daily routine. “Audi Fit Driver” keeps an eye on the driver’s health condition, while the personal, intelligent assistant (PIA) gets to know the driver and, thanks to intelligent algorithms, can independently and adaptively interact with him/her.

Audi AI – the technology

zFAS – computing power, networking and data processing

The core of the systems which Audi is developing for piloted driving is the central driver assistance system control unit (zFAS). The mastermind makes its debut in the new Audi A8.

Until now, driver assistance systems were managed by spatially isolated control units. Audi will be the first automobile manufacturer to bundle these in a central domain architecture. To this extent, the function portfolio, the required sensors, electronic hardware and the software architecture have been combined into a single central system. Right from the outset, full attention was paid to this, and especially to the safety concept.

As a result of the vast sensor information bundled in the zFAS, it computes an entire model of the vehicle surroundings at lightning speed and provides this information to all assistance systems. It is thus also the central interface for all functions of piloted driving.

Despite compact package dimensions, it offers high computing power – the prerequisite for which are powerful electronic modular components. The zFAS – roughly as big as a tablet – is a high-tech computing center. Audi developed the zFAS with an international leading team of technology partners. It integrates high-performance chips – the Tegra K1 from NVIDIA, the Aurix from Infineon, and the Cyclon V from Altera – which are supplemented by the EyeQ3 processor from Mobileye, the world leader in image processing algorithms for the automobile industry. Its modular concept makes the zFAS flexibly scalable and thus future-proof.

Artificial intelligence and machine learning
Artificial intelligence will soon make it possible for piloted vehicles to react appropriately in highly complex situations, similar to the way in which a human driver would, or perhaps even better. As a sub-branch of information technology, artificial intelligence looks at equipping machines with similar capabilities to those of human beings. This might be achievable, for example, using machine learning.

Machine learning is therefore a pre-requisite for artificial intelligence. The basis for this comes from mathematics and statistics. In the most complex of situations, algorithms will independently find patterns and rules – and will make decisions based on these. In the not-too-distant past, research in the field of artificial neural networks (i.e. the imitation of signal connections within the human brain) made major progress. Deep learning emulates networks of the brain on a computer. This requires enormous computing power and a broad base of data.

In intelligent and piloted vehicles, there will be numerous use cases for machine learning in the future. Thus Audi is evaluating different methods – for example supervised learning or deep reinforcement learning – with the aim of finding the optimal approach for each of these use cases. To this end, Audi is working closely with top businesses from the software field, as well as with leading universities.

Object and environment recognition
One of the most important fields of application of machine learning is currently object and environment recognition. In the Audi A4, A5, Q5 and Q7 models, object recognition has already been implemented in series production with the help of supervised learning. For this purpose, a trained system is used: the learning process is thus complete before the car goes into production.

Even in the new Audi A8, supervised learning is used for object recognition. Image processing developed by our technology partner Mobileye is based, among other things, on the deep learning method. This involves deep neural networks being trained using various data sets. In this way, the neural network learns to classify a diverse range of objects – as cars, as cyclists, as pedestrians. The data retrieved as part of this process is then made available to the final version of the driver assistance system software as well as to that of piloted driving.

Thanks to this process, the new Audi A8 therefore also detects free spaces, i.e. spaces in which it can drive. This is a major requirement for the new Audi AI traffic jam pilot.

Preliminary development projects at Audi

Audi Q2 deep learning concept:
At NIPS (Conference and Workshop on **N**eural **I**nformation **P**rocessing **S**ystems) held in Barcelona in December 2016, Audi used a scale model to demonstrate for the first time how a car can develop intelligent parking strategies. On a 3 x 3-meter *(9.8 x 9.8 ft)* field, the Audi Q2 deep learning concept autonomously searches for a suitable parking space in the form of a metal frame and then parks in it.

The model car (scale 1:8) gained the ability to park autonomously by means of deep reinforcement learning. As part of this process, the system essentially learns through trial and error. To begin, the car selects its direction of travel at random. An algorithm identifies the successful actions, thus continually refining the parking strategy. So in the end the system is able to solve even difficult problems autonomously.

The model car's sensor technology consists of two mono cameras, one facing forward and the other towards the rear, along with ten ultrasonic sensors positioned at points all around the model. A central on-board computer converts their data into control signals for steering and the electric motor. On the driving area, the model car first determines its position relative to the parking space. As soon as this is recognized, the system calculates how it can safely drive to its destination. The model car maneuvers, steers and drives forward or in reverse, depending on the situation.

The "Audi Q2 deep learning concept" is a pre-development project of Audi Electronics Venture (AEV), an AUDI AG subsidiary.

Audi Q7 deep learning concept:
A use case for machine learning in 1:1 scale was presented by Audi in January 2017 at the Consumer Electronics Show (CES) in Las Vegas. On a specially established, adaptable open-air track, the Audi Q7 deep learning concept used a front camera with two-megapixel resolution for orientation. This then communicated with an NVIDIA Drive PX 2 computer unit which subsequently initiated the highly precise steering movement itself. The high-performance controller was specially engineered for piloted driving applications.

Serving as the core of the software are deep neural networks that experts from Audi and NVIDIA have trained specifically for autonomous driving and recognition of dynamic traffic control signals. At the beginning, the Audi Q7 deep learning concept made several laps of the track with a driver behind the wheel and additional training cameras in order to get to know the route. The system established a correlation between the driver's reactions and the occurrences detected by the cameras. As a result, the car understands external signals such as a temporary traffic light, can interpret them and deal with them as the situation requires.

The biggest difference between the Audi Q2 deep learning concept and the Audi Q7 deep learning concept is the method used for machine learning. While the 1:8 scale model car learns how to park through trial and error (deep reinforcement learning), during the training runs, the network of the Audi Q7 deep learning concept receives concrete, relevant data – in other words, it learns from a human driver (supervised learning). Both projects are important aspects in researching the topic of artificial intelligence at Audi and illustrate the bandwidth of this approach. Audi also evaluates and trials various types of machine learning in order to implement the technologies in a targeted manner as part of new applications in the field of autonomous driving and personalization.

Car-to-x technology

See more than with the human eye or the infra-red camera – car-to-x technology expands the horizon of the established vehicle sensors based on radars, cameras and ultrasound, by supplementing these with information obtained from far away and outside of the field of vision of the driver. In this way, dangerous situations can be recognized even earlier and accidents can be avoided. Real-time communication between cars and the road infrastructure today already offers us improved safety, comfort and efficiency. With the A8, Audi will be the first manufacturer to introduce the powerful LTE Advanced mobile transmission standard.

“Traffic light information”:
The first highly-networked standard function of the car-to-x module is called “Time-to-Green”. In the Audi virtual cockpit or the head-up display, the driver sees whether the next traffic light will be green upon arrival there (within the legally permitted speed). If this is not the case, a countdown starts until the next green phase. The driver can therefore move his/her foot off the gas pedal in good time. In the future, it would also be conceivable that Audi e-tron models rolling towards a red traffic light use more of the braking energy for charging the battery. At a red light, car-to-x technology will soon make it possible for a column of vehicles to start off almost simultaneously when the light turns green. The through-flow of vehicles during each green phase should thus drastically improve.

Car drivers drive in a more forward-thinking manner thanks to this traffic light information. And that has a positive effect on traffic flow. In the future, traffic light information will, for example, also be coupled with an intelligent navigation system and will be usable in conjunction with new drive concepts. A row of green lights would thus be possible in the optimum route plan.

“On Street Parking”:
A further car-to-x service is the parking space search function, which Audi has developed under the project name “On Street Parking”. Cars equipped with car-to-x technology automatically report when they enter and leave a parking spot to the servers in the cloud. The application registers parking maneuvers based on various parameters, such as control signals of the engine, gear changes, steering angle and speed.

Using the information supplied by ultrasonic sensors or a camera, in future the system will also be able to identify vacant parking spaces while on the move. It calculates the number of free parking spaces on the side of the road based on statistical models that consider factors such as the time of day. The service shows the driver in real time the probability of finding a free parking space, making it easier to find a spot, particularly in city centers. Unnecessary time spent searching for a parking space is thus saved and that also reduces traffic on the road.

At the same time, emissions in major cities could be effectively reduced. In today's rush hour, hundreds of cars often spend up to 30 minutes driving around residential areas looking for a parking space, but in the future, free parking spaces on the side of the road and in parking garages will be reliably shown to the driver. The driver therefore benefits from a direct journey to the location. A simple example calculation shows how much fuel and gaseous emissions could be saved by this process: an average passenger car consumes more than five liters of fuel every 100 kilometers *(1.3 US gal per 62.1 mi)* in urban traffic. This is the distance which some drivers cover in urban areas each month simply looking for a parking space. Thus, overall, each car consumes more than 50 liters *(13.2 US gal)* of fuel each year – that's an entire tank of fuel.

Voice control

The next stage of voice control can be seen in a hybrid concept. It answers questions from the driver in two ways. On the one hand, it uses knowledge about the user's preferences saved in the vehicle, while on the other hand it calls up knowledge from the cloud. What's more, the driver can formulate his/her questions or instructions freely – the self-teaching dialog manager reacts, asks questions itself where needed, or provides a list of possible selection options. In dialog with the system, the driver can switch between menu areas. For example, he/she can call a contact from the address book and have the navigation system adopt the address as the destination for route guidance. Using the destination search, the new hybrid voice control also includes media, climate control, as well as some telephone functions and some Audi connect services. In Europe, these work across borders.

Audi Fit Driver

Today already, every Audi is equipped with the latest technology and offers top-level comfort and safety. As a private place of retreat and all-round networked space, a car isn't just an ideal place for monitoring fitness levels, rather it can also actively improve the health and well-being of the driver. The Audi Fit Driver project turns the car into an empathetic assistant. In many situations, it knows what the driver needs.

The number of users of so-called wearables – fitness bands or smartwatches – continues to grow. These wrist-bound devices monitor vital parameters such as the pulse or skin temperature. In future development stages, the data of these wearables will be combinable with that of the vehicle sensors. This will then allow reliable statements to be made about the current condition of the driver, to which the car can then individually adapt. If the up-coming Audi Fit Driver detects, for example, increased stress or fatigue, the vehicle systems adapt themselves accordingly in a relaxing, a vitalizing or a protective manner. Thanks to intelligent algorithms, the system gets to know the driver better and better.

For the first time, Audi Fit Driver will allow for stress to be actively diminished and concentration increased, all whilst in the vehicle. If the system notices high stress on the driver, this can be reduced by means of a special breathing technique. The instructions for this are shown in the Audi virtual cockpit display as so-called Bio-Feedback, similar to how it works in top-level sports. Additionally, a voice over the loudspeakers guides the driver through the exercise. Whether it be relaxing breathing exercises, energizing seat massage functions to the beat of the music, special climate control functions, adaptive infotainment measures or perfectly-suited interior lighting moods: the aim of Audi Fit Driver is to create a driving experience which is optimally suited to the respective condition of the driver, which allows him/her to leave the vehicle at the destination feeling more relaxed than when he/she got in.

In a later expansion stage, Audi Fit Driver could incorporate assistance and safety systems, as well as future systems for piloted driving. In extreme situations, an Audi could initiate a piloted emergency stop and issue an emergency call using the eCall system.

Empathetic technology and gamification

The “Klara” and “Bonnie” concept studies are both based on the Audi A1 but couldn’t be more different to one another. While “Klara” features breathing bodywork and provides us with an insight into possible advances in exterior design, “Bonnie” is all about the innovative design of the interior. Both concepts share the idea of using empathetic technology or playful elements (gamification) to build up trust between man and machine – an important and basic pre-requisite for piloted driving.

Klara concept car

Being able to trust a car can best be achieved through creating empathy, whereby people near a car feel that the car is permanently keeping an eye on them and reacting in a sensitive way towards them. The “Klara – The Living One” concept study provides surprising answers to the question as to how an Audi may develop in the space of ten, twenty or thirty years: a high-tech automobile which shows emotion and which could thus become a personal friend or assistant.

At first glance, “Klara” looks like a regular Audi A1, but looks can be deceiving. Upon closer inspection, you can see that the car appears to take breaths of air in regularly spaced periods. In order for the bodywork to be able to carry out these breathing movements, 39 electric adjustment motors are at work under the metalwork. Thanks to a sensitive set of sensors, “Klara” reacts interactively and subjectively to its surroundings. If a person approaches who the vehicle perceives as friendly, it greets them by flashing its lights. But Klara is also capable of showing discontentment by growling.

For future series-production applications at Audi, particularly interesting is feedback on how “Klara” uses her empathetic reactions to establish a communication level between driver and car – and even create trust between man and machine.

Bonnie concept car

Numerous new options for personalization and interior ideas are presented by the “Bonnie” interior concept car. The driver and passengers can, for example, create drum noises by rhythmically tapping on certain surfaces in the cockpit, or they can use an app to adapt the LED ambient lighting to the color of their T-shirt or nail polish.

With the innovative lighting concept in the interior, “Bonnie” shows the possibilities that digitization in lighting design can open up and how the interior will, in future, be much more personlizable. This new type of personalization offers the advantage that drivers and passengers feel particularly good. Anyone can change the interior lighting color at any time to suit their favorite color. If a person uses multiple vehicles, for example as in car sharing, the person’s favorite color can be carried with them from vehicle to vehicle. Thus, each vehicle feels like his/her own car. The same applies if several people – for example a family – share one vehicle.

Besides personlizable LED ambient lighting, “Bonnie” offers other ideas for illumination: surface lights instead of the familiar ceiling-mounted grab handles, air vents and loudspeakers illuminated from the inside, a particularly bright light for the footwell and luggage compartment, as well as a carpet of light for the immediate vehicle surrounding.

The sports seats make use of sustainable materials which feel like real suede. The start button is integrated into the shift lever knob and the shift point display in the flat-bottomed steering wheel. A smartphone and a tablet stowage tray highlight the target customers of this concept study: young professionals and young-at-heart over-50s who always have their mobile devices with them. A handbag holder in front of the front-passenger seat prevents handbags from slipping forward in the footwell upon braking. For heavily-used training shoes, there is a sort of dirt bucket under the double floor of the luggage compartment. The lid embedded in the luggage compartment floor extends the stowage height, for example for transporting potted plants or larger bunches of flowers.

A thrilling entertainment feature of “Bonnie” is the “Drumbase” function. Piezo sensors in the steering wheel, the air vents and in the lid of the glove compartment precisely register drumming by the driver and passengers, while a computer turns them into drum noises.

It almost sounds as if a real drum kit is on-board the Audi A1. This playful approach ensures a new type of possibility to while away the time on-board. Similar gamification gadgets may, in future, also be interesting in piloted vehicles.

Personal intelligent assistant (PIA)

The best operating concept is the one which is ideally adapted to the driver, the one which relieves him/her of as many actions as possible and which autonomously carries out routine operational inputs – PIA, the personal intelligent assistant, follows precisely this principle. Using artificial intelligence methods, PIA combines data intelligently with one another – data from the car, data about the driver, about the current or up-coming traffic situation, as well as data from the internet. Among other things, PIA responds to voice inputs and, thanks to intelligent algorithms, it can interact with the user independently and adaptively.

PIA looks at the activities of the driver and, based on them, gets to know his/her typical behavior. This opens it up to use for a broad range of possible applications: navigation, selection of music, selection of the desired Audi connect service, climate control, suggestion of a parking space or maintaining the regular distance to vehicles traveling in front on the motorway. Based on the knowledge ascertained through machine learning, PIA adapts the car's functions to the behavior and needs of the driver and can actively make recommendations.

A server in the secure Audi cloud hosts and processes the PIA data. Customers can view and manage these data at any time via their myAudi account. These can then be deleted or modified, for example in the event of moving house. What's more, they can be automatically transferred to other cars. The car identifies the individual user, loads the right user profile, and PIA then adapts the car and its interactive behavior accordingly.

Audi Electronics Venture GmbH (AEV), an Audi subsidiary, has overall responsibility for the PIA predevelopment project. Initial elements could make their way into production before the end of this decade and then gradually expand to create a perfect, tactful driver's assistant.

Data protection/privacy

Audi treats data protection as a high priority. Audi fully complies with the respective national laws governing personal data, data protection and privacy rights. The brand follows clear principles in handling the personal data of customers.