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The Trans-Cognitive Vehicle (TCV)

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Abstract: **Current systems that help cars and trucks run like Intelligent Transportation Systems and Advanced Driver Assistance Systems mostly react to things after they happen. They really don't think about how people think and feel when they are driving on roads. This study is about the Neuro-Adaptive Synthetic Co-Pilot, an idea that brings people and machines together in a special way. The Neuro-Adaptive Synthetic Co-Pilot uses a lot of kinds of information like what is happening inside the car, how the person is moving their phone, what the person's feet are doing and how complicated the roads are. All this information helps create a "Digital Symbiont" that works with the person. The Neuro-Adaptive Synthetic Co-Pilot is different from automated systems because it uses special tools to understand what people are doing and can explain why it is doing something. The Neuro-Adaptive Synthetic Co-Pilot looks at information from people driving and uses new computer programs to understand how each person drives. It can find problems like when there are many signs on the road, when people get tired and when people drive strangely. The Neuro-Adaptive Synthetic Co-Pilot can do this with high accuracy, 98.84%. This study shows how we can make a system where cars and people work together well so that there are no accidents. The car would not just be a machine. A partner that helps the person driving.**

Keywords: *Human-Machine Symbiosis, Neuro-Adaptive Systems, Explainable Artificial Intelligence (XAI), Multi-Modal Sensor Fusion, Behavioral DNA Profiling, Intelligent Transportation Systems (ITS), Predictive Cognitive Modeling, Cyber-Physical Infrastructure Safety.*

INTRODUCTION

The world of cars is having a problem these days. We are getting closer to cars that can drive themselves. For now, we have cars that can do some things on their own like help with steering or braking. This is causing an issue: people are not paying attention to the road as much as they used

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to and we do not know what they will do. A lot of people die in car accidents every year over 1.35 million and most of these accidents happen because people are tired not paying attention or just not being careful.

The systems that are supposed to help with driving called ADAS are not working well. They can make things worse because they do things without explaining why which can confuse the driver. To fix this problem we came up with something called the Neuro-Adaptive Synthetic Co-Pilot. This is a change in how we think about cars. Of just being a tool the car becomes a partner that helps the driver.

Our new idea is to use a lot of information to understand how each person drives. We look at what's happening inside the car like, how fast it's going and what's happening outside the car like if there are a lot of cars or pedestrians around then we also look at information about the drivers like how they're feeling or if they are using their phone. By using all this information, we can tell what is normal for each driver and what is not. We use computer programs to learn about each driver's style and to tell if someone else is driving the car. We also try to figure out if the driver is getting stressed or overwhelmed by things like many signs on the road.

This research puts together a lot of ideas to create a system that works with the driver not just drives the car or helps with driving. We want to make sure that the driver trusts the system, so we use something called Explainable AI to make sure the driver knows why the system is doing something. This way the driver and the car can work together safely and well. The Neuro-Adaptive Synthetic Co-Pilot is like a partner that helps the driver and makes driving safer.

THE ONTOLOGICAL SHIFT: FROM TOOL TO SYMBIONT

The history of keeping people safe in cars has been about adding things to the car to help in case of an accident, like seatbelts and airbags. In the century we started using computer programs to help prevent accidents, which are called ADAS. But both of these ways of thinking have a problem: they think of the person driving and the car as two separate things.

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The NASCP idea is that the car needs to be like a partner to the person driving, which we call a "Digital Symbiont". We looked at a lot of data from studies of how people drive in life like the UDRIVE study. From this data we saw that driving is like a back and forth of control between the person and the car, which we call "Transfers of Control". Our goal is to make the car work with the person in a way that's clear and easy to understand, not like a mysterious box that just does things on its own, which is what we mean by Transparent Cooperative Logic.

MULTI-MODAL DATA FUSION: THE "HOLISTIC PERCEPTION" STACK

To understand a human, the machine must sense what the human senses—and what they feel.



The NASCP Architectural Framework: Integration of Multi-modal Data Fusion with the Trans-Cognitive Symbiosis Learning Loop for Explainable AI(XAI) Interventions and assessment of cognitive load by Kohonen Self Organizing Map Clustering in Real-time.

Internal Biometrics and Gesture Anticipation

The old systems just wait for you to turn the steering wheel. Nascp uses Computer Vision to look at your foot and figure out if you are going to brake. It can tell you are going to break 133 milliseconds before you even touch the pedal. This is what we call the "Pre-Act" phase. It works with other things like: Modified Capsule Networks which are really good at seeing what you are doing even if it is dark. For example, it can see if you are reaching for your phone or fixing your hair. Spatial Attention Mechanisms which help the computer focus on the things that're important for safety.

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The Ubiquitous Sensor Mesh

This is like a network of sensors that're already in your car and phone. We do not need any equipment like lidars. We use: The sensors in your smartphone like the accelerometer and gyroscope to see if you are getting tired or stressed. The OBD-II which is like a computer in your car, tells us what is going on with the engine. It tells us things, like how fast the car's going and how much fuel it is using. This helps us see if you are driving aggressively.

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PROPOSED SYSTEM ARCHITECTURE: THE NASCP LEARNING LOOP

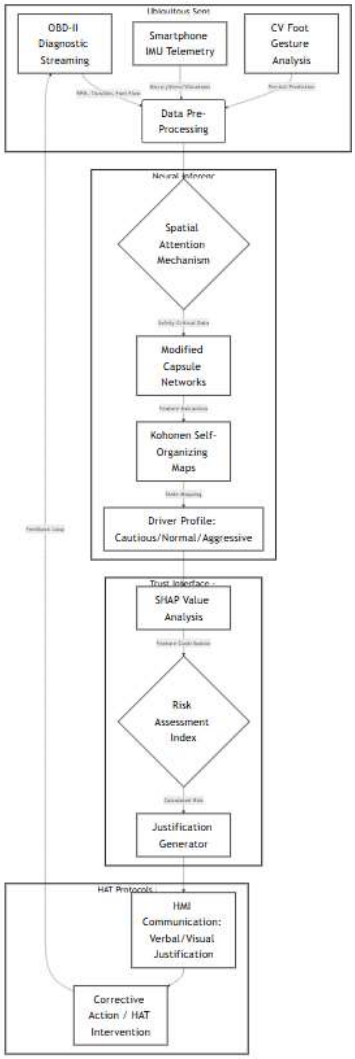

Fig1: System Architecture

The Neuro-Adaptive Synthetic Co-Pilot system is set up in a way that it can change and adapt in time. This is different from driver assistance systems that just do things in a straight line. The Neuro-Adaptive Synthetic Co-Pilot system uses a framework that helps it understand what is happening, think about what it means, explain what it is doing and then take action. This helps the Neuro-Adaptive Synthetic Co-Pilot system work well with people and creates a partnership between the Neuro-Adaptive Synthetic Co-Pilot system and the person using it.

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A. Data Acquisition and Pre-Processing

The base of the NASCP is its Ubiquitous Sensing Mesh. The NASCP has a few parts that work together: One part is the In-Vehicle Stream. This is where the NASCP gets data from the car's computer like how fast the engine is running, how hard the driver is pressing the gas pedal and how much load the engine is under. The NASCP checks this data often to see if a car is being driven roughly or if its engine is under a lot of stress.

The NASCP also has this thing called the Human-Centric Stream. The NASCP uses the driver's smartphone for this. It helps the NASCP see how the drivers are driving. The Human-Centric Stream can even tell when the driver is holding the steering wheel in a way that's not normal. This can mean the driver is getting very tired or really stressed out. The NASCP does this by feeling the vibrations in the steering wheel. The Human-Centric Stream is a part of the NASCP.

The NASCP has another part that is the Anticipatory Stream. This is where the NASCP uses a computer system to look at what the driver is doing with their feet. It can even tell when the driver is about to press the brake pedal before they actually do it. NASCP uses this information to try to stay one step. The NASCP and its Ubiquitous Sensing Mesh are always working together to make driving safer.

B. The Neural Inference Engine

At the heart of the system Modified Capsule Networks or CapsNet for short look at lots of kinds of information that are coming in. The system has something called Spatial Attention. This means it can pick out what is important and ignore the rest like noise in the environment. It focuses on things that're really important for safety such as where the driver is looking and where they have their feet. The system also uses something called Clustering via SOM. This is like a map that is always being updated. It is called the Kohonen Self-Organizing Map or SOM. This map takes all the information that is coming in and turns it into a picture that shows what the driver is doing right now. This picture can show if the driver is being Cautious, Normal or Aggressive. Modified Capsule Networks or CapsNet use this information to understand the driver.

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C. The Trust Interface (XAI Layer)

The SHAP Analysis layer figures out how much each sensor input affects the risk assessment before anything is done to fix it. The system does more than just hit the brakes when it detects a threat. It also gives a reason for doing like a message saying, "Braking due to trailing vehicle speed".

This helps the driver understand what the Artificial Intelligence is thinking, which is important because it stops the driver from doing something that might not be the idea, like what happens with automation systems that do not explain things clearly. The SHAP Analysis layer and the justification that the system provides are key to making sure the driver and Artificial Intelligence are on the page, which is what Mental Model Alignment is all about.

BEHAVIORAL DNA: CONTINUOUS IDENTITY AND RISK PROFILING

The NASCP system has a security layer that looks at how someone drives a car. This is like an identifier, like a fingerprint, that is just, for them. They call this a Biometric Driving Profile. The NASCP system watches how a person drives and uses this information to figure out what kind of driver they are. It looks at twenty things about the way they drive. Then it uses something called Kohonen Self-Organizing Maps to help understand all this information. The NASCP system puts the driver into one of three groups: a driver, an Aggressive driver or just a driver. This helps keep people safe. The NASCP system checks to make sure the person driving the car is really the person who is supposed to be driving it. The NASCP system can even help prevent things from happening. For example, it can stop someone from taking a car that does not belong to them. The NASCP system does this by noticing if someone is driving in a way that's not normal for the NASCP system to see from them.

The NASCP system has a feature called Deep Risk Assessment. It uses Deep Neural Networks to come up with a Risk Index. This Risk Index is a number that helps us understand if a driver is going to be a danger to themselves or others when they are driving in areas. The NASCP system uses this Risk Index to try to find out if a driver is having trouble before something bad

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happens. The NASCP system is trying to keep people safe. It does this by using the Cyber-Physical Security Layer and other things like Biometric Driving Profiles and Deep Risk Assessment. The NASCP system is always. Trying to prevent bad things from happening to people. The NASCP system and its Deep Risk Assessment are important, for keeping people safe when they are driving.

INFRASTRUCTURE PSYCHOLOGY: THE "OUT-CAR" PERSPECTIVE

The road can be tough to handle, which feels like a battle going on in your head. NASCP is a system that deals with stress from the environment. This stress is called Cognitive Load. The road has a lot of stress. NASCP helps manage that stress, on the road. It makes it easier to cope with. Cognitive Load is a challenge. NASCP is designed to handle it.

Sign. Attention Budgets

When there are many signs in the school areas it gets really confusing for the drivers. This is called "Sign Saturation". Drivers just stop paying attention to all the signs. NASCP helps with this by showing the most important information on a special display that you can see while driving.

Navigating the "Hybrid Era

Now we have lanes for self-driving cars that are very narrow, only 9 feet wide. When human drivers are in the lanes next to these lanes they have to think really hard to stay safe. NASCP helps these drivers by: Visual Guidance: Using lights in the road to help drivers stay in their late at night. NASCP looks at how different colors affect the way people think and feel. Complexity Quantification: Figuring out how hard it is to drive through an intersection. If it is too hard the computer takes over. If it is not too hard the computer just helps the driver. NASCP does this so that the road is a place for everyone.

EXPLAINABLE ARTIFICIAL INTELLIGENCE (XAI): THE TRUST ENGINE

The biggest problem with using AI is that it can be really hard to understand how it will make decisions. This is often called the "Black Box" where the NASCP is trying to fix this problem by

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using XGBoost and SHAP Value Analysis. When the system helps out it tells you why it's doing it. This is called justification. For example, the system might say: "I am applying the brakes. The reason is that the car behind us is getting close. You looked away, from the road for 2 seconds". The human driver needs to know what is happening. This helps them stay calm when the system takes over. Artificial Intelligence systems are very good at making decisions. If they do not tell the driver what they are doing it can be very confusing. NASCP wants to make this better by making the system easier to understand. The main goal of NASCP is to help the driver understand how the Artificial Intelligence system works, which can reduce reactions from the driver and make the driving experience better for the driver. Artificial Intelligence systems like this can make driving more fun for the human driver. The "Black Box" problem is an issue and NASCP is using tools, like XGBoost and SHAP Value Analysis to solve it and make Artificial Intelligence more user-friendly.

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HUMAN-AI TEAMING (HAT) PROTOCOLS: DYNAMIC TASK ALLOCATION

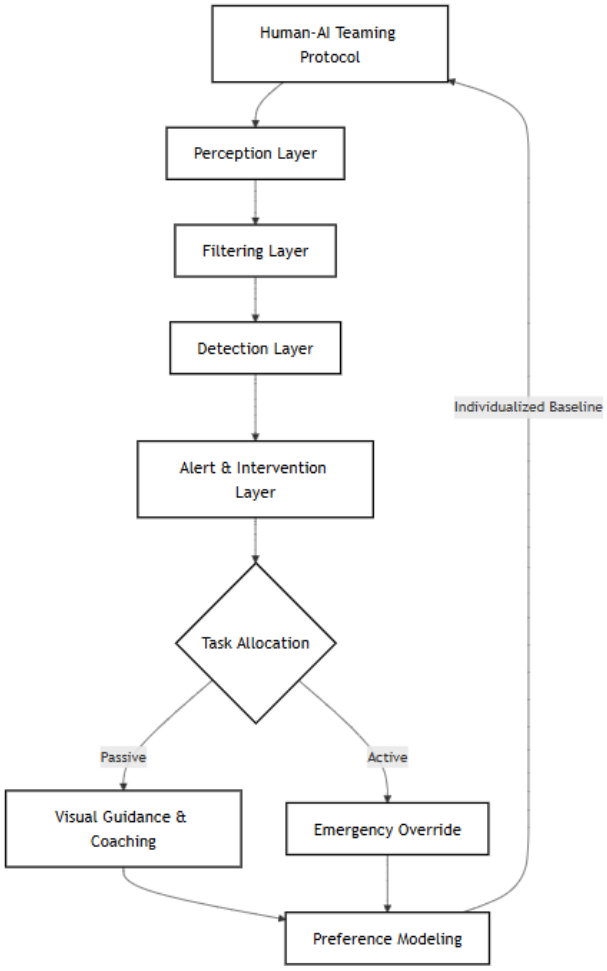

Fig. 2: Human-AI Teaming (HAT) Protocols

The NASCP system works in a way with four main parts. It can see what is happening, it can filter out what is not important, it can find problems and it can send out alerts. This is done so that when the system and the person are working together the person is not surprised when the system takes control.

A. Finding Out What People Like with HMIway

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The system uses a tool called HMIway to figure out what each person likes. The NASCP system gets to know the driver and learns if the driver likes it when the system helps a lot and does things early which is called a " sidecar" approach or if the driver likes it when the system does not interfere much, which is called a "performance-oriented" style. The NASCP system learns about the driver to make the experience better for the driver. The NASCP system is always learning about the driver and what the driver likes.

Bond of Trust: When the AI does things the way the driver normally does, the system starts to gain the trust of the driver. This trust is really important for the driver and the AI to work well together in the car. The Bond of Trust is what makes this work by making the driver feel comfortable with the AIs behavior, which's, like the driver's own style.

B. The Pre-Act Response Mechanism

One of the breakthroughs of the HAT protocol is that it uses a 133ms head start provided by gesture anticipation. The system can do braking. This means it can tell when a person is about to press the brake pedal. So, it can get the braking systems ready. Give a slight vibration. The system also helps in situations. For example at intersections or roundabouts, without traffic lights it uses Conflict Severity Indices. These indices help the system decide what to do. It can show guidance or take emergency action. The HAT protocol uses Conflict Severity Indices to decide on the course of action. The HAT protocol provides guidance or initiates an emergency override based on Conflict Severity Indices.

C. Automated Tutoring and Safety Scoring

The NASCP system is like a teacher, for the driver it is always there to help. The NASCP system looks at how the human driver is doing and compares it to a very safe way of driving, which is called Automated Driving Logic. The NASCP system provides the driver with tips and feedback so the human driver can become a safer driver and improve their Safety Score. This means the human driver will have accidents and problems. The NASCP system helps the driver in many ways. The human driver can get better at driving. The human driver can improve

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their Safety Score. This can help lower the cost of owning a car. The human driver may even get insurance because the human driver is a safer driver. The NASCP system is good for the driver.

HUMAN-AI TEAMING (HAT) PROTOCOLS

We are talking about the Framework. The Framework is an idea that has four parts: Perception, Filtering, Detection and Alert. The Framework is meant to be used in the world. We make the Framework personal with HMIway-env.

We use the HMIway-env simulation to teach the NASCP about what people like. The NASCP learns if a driver likes a co-pilot, that's careful or one that likes to go fast. This way the driver is happy with the system. The Framework and the NASCP are like a team. The NASCP is like a teacher that uses its rules to check how well a human is driving.

The NASCP gives the driver tips to make their driving safer. This happens over time. It helps to improve the human's safety score. The Safe SmartDrive Framework and the NASCP work together to make driving safer. They do this by using the Framework and the NASCP. The Framework is important. The NASCP is important too. The Framework and the NASCP make driving safer, for the driver.

MACRO-SCALE SAFETY AND ETHICS

Our system thinks about the people and the environment to make sure everyone is safe.

Demographic Sensitivity

We understand that your age and if you are a man or a woman can affect how likely you are to have an accident.

Environmental Resilience

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We use SHRP2 NDS data to make our sensors work better when the roads are slippery or the weather is bad. We want our system to be ready, for weather and slippery roads so that everyone who uses the roads is safe. Our system is designed to keep people safe. That is why we use Demographic Sensitivity and Environmental Resilience to make sure everyone is safe.

Complex Node Management

We use Conflict Severity Indices to help navigate areas like intersections without traffic lights and roundabouts where safety is a big concern and traffic accidents can happen easily with safety of the traffic system and the people in the traffic system, like the safety of the people who are driving and the safety of the people who are walking.

CONCLUSION: THE PATH TO ZERO

The Neuro-Adaptive Synthetic Co-Pilot or NASCP is a change for vehicles. They are not just machines anymore. We looked at different areas of research for the Neuro-Adaptive Synthetic Co-Pilot, including how to use deep neural networks to understand risk and how to make roads safer with special lights. We also studied how the color of road lights and the design of intersections affect people. All of this work has helped us create an idea of what transportation can be, which we call Neuro-Adaptive Synthetic Co-Pilot or NASCP and Trans-Cognitive Mobility.

What we found out is that we do not need to replace people with machines to make transportation safer. Instead, the Neuro-Adaptive Synthetic Co-Pilot or NASCP can help people by making up for what they cannot do. The Neuro-Adaptive Synthetic Co-Pilot or NASCP can anticipate what people will do before they do it which gives us extra time to react. The Neuro-Adaptive Synthetic Co-Pilot or NASCP can also explain how it makes decisions, which helps us trust it more. This is important for transportation systems, which have problems, with latency and trust. The Neuro-Adaptive Synthetic Co-Pilot or NASCP also includes a way to understand people's behavior, which helps keep the vehicle safe and secure.

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As we try to make transportation safer, the Neuro-Adaptive Synthetic Co-Pilot or NASCP framework is a solution. It is flexible and new. Focused on people. The Neuro-Adaptive Synthetic Co-Pilot or NASCP takes into account the needs of people of different ages and genders and it can handle bad weather. It can also combine data from sensors quickly. The Neuro-Adaptive Synthetic Co-Pilot or NASCP and the Trans-Cognitive Vehicle are not something that someone made they are a promise. This promise is that one day machines will know people well just like people know roads. The Neuro-Adaptive Synthetic Co-Pilot and the Trans-Cognitive Vehicle are going to make this happen. We have a plan, for the Neuro-Adaptive Synthetic Co-Pilot and the Trans-Cognitive Vehicle now we just need to make the plan work for the Neuro-Adaptive Synthetic Co-Pilot and the Trans-Cognitive Vehicle.

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