SOAFEE

Evolution direction & Multidimensional analysis of SDV

Industry observation and sharing

Teng Zhaozhi, ASIC
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CSIP Linux 应用及发行版开发者
Canonical 认证 Ubuntu Builder
Debian Edu 社区开发者
PMI 认证 PMP 项目管理师
CCF 开源发展委员会执委
国家 Linux 标准工作组成员
Linux基金会 LFAPAC 开源布道者
OpenSDV 汽车软件开源社区技术生态总监
中国科协“科创中国”开源技术传播委员会委员
木兰开源社区知识产权委员会委员

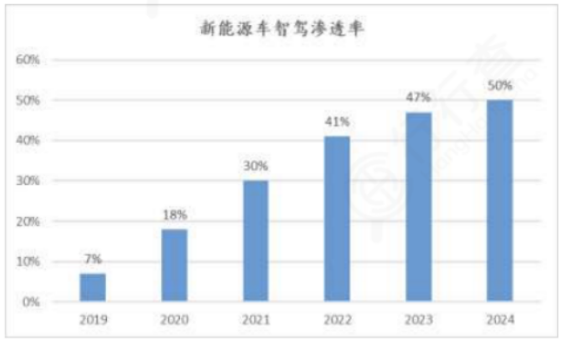
Smart car intelligence increment is relatively stable

Increment of output value of 【Car-Road-Cloud】 integrated intelligent connected car industry

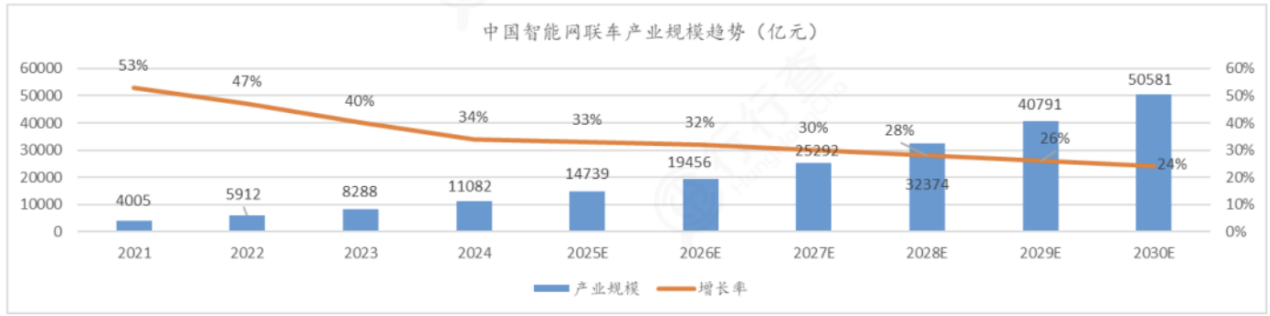
"Intelligent vehicle" is mainly defined here as a vehicle model with intelligent networking function or L2 and above automatic driving capability.

■ 中国乘用车销量整体增幅趋于平稳，新能源车销量快速增长，渗透率从2019年的5%增长至2024年的48%，涨幅显著

■ 新能源车智驾渗透率大幅增长，从2019年的7%增长至2024年的50%，涨幅显著



■ 智能驾驶带动的市场空间巨大，2024年国内智能网联汽车产业规模11,082亿元，增速达34%，预计到2030年市场规模有望突破5万亿元人民币



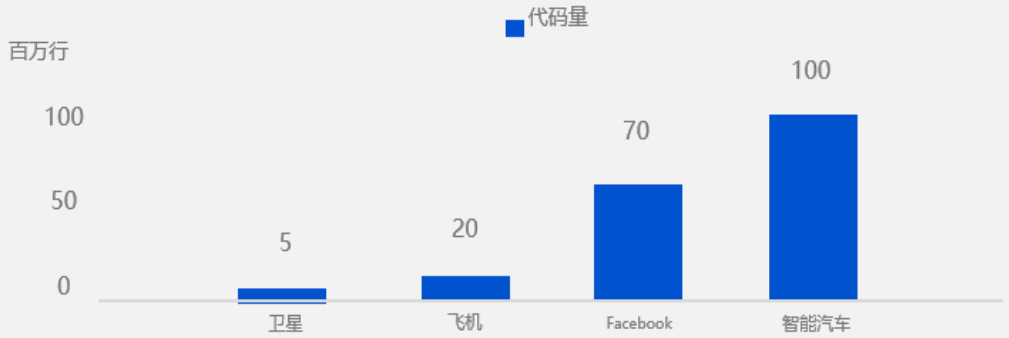
数据来源：《中国智能驾驶商业化白皮书》、浙商证券产业研究院

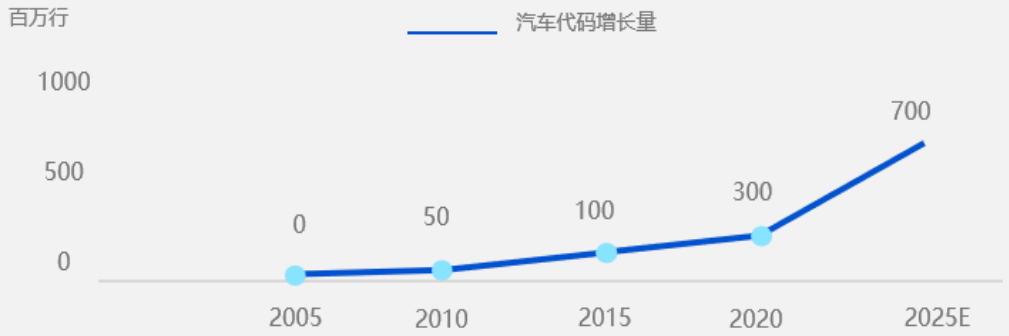
As the terminal of intelligent networking, the global growth scale of automobiles is expected to be 80 million in 2025, with 78.5 million vehicles up to now, of which 24.9 million are sold in China. It shows that the leading position of intelligent models in the global automobile market has been preliminarily established.

How software affects cars value

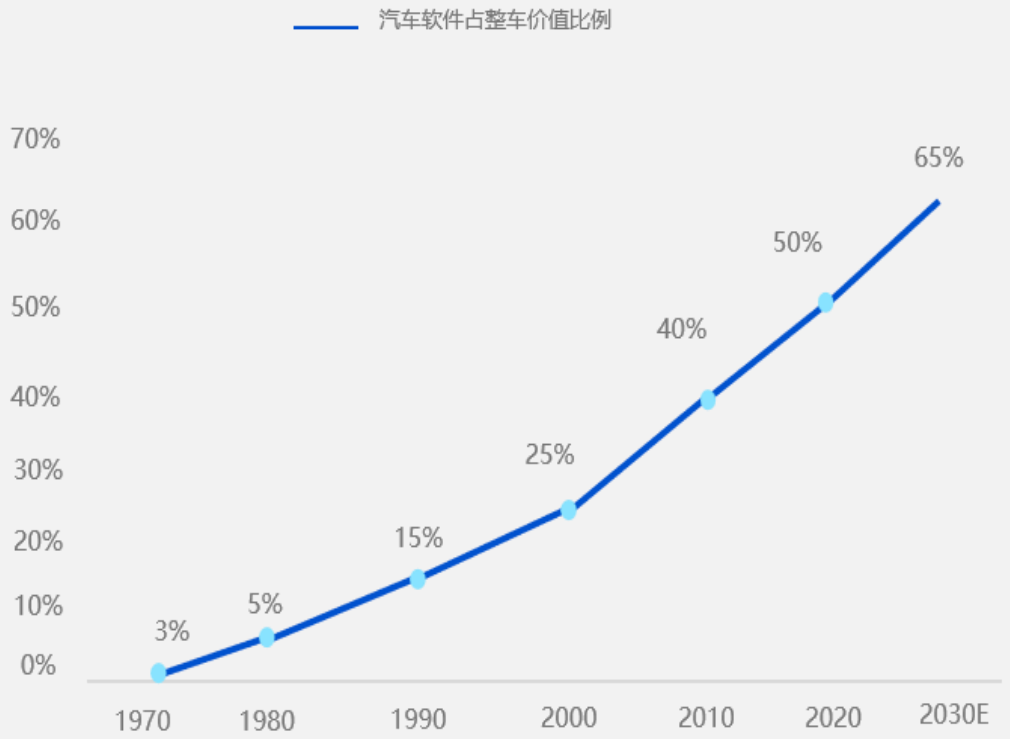
A big role in automobile value

Number of software codes in Cars





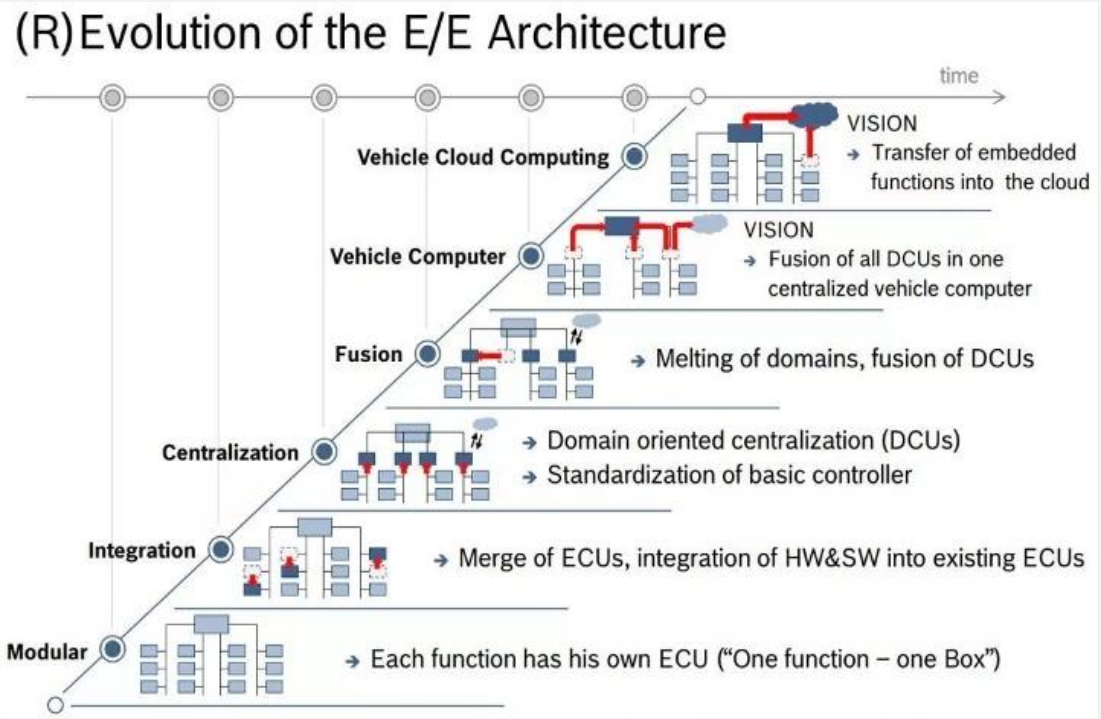
Proportion of automobile software in vehicle value



来源：亿欧智库，东北证券

How software affects cars tech

Evolution Paradigm of EE Architecture and System Software



Led by semiconductor industry

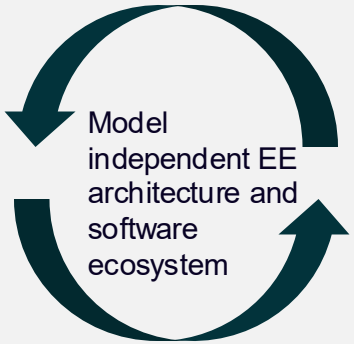
- Leading semiconductor enterprises actively promote the design of advanced driving assistance system (ADAS)/automatic driving and some standards in the field of information and entertainment, that is, standards specifically applicable to certain hardware, and occupy a dominant position in the relationship with OEMs and primary suppliers
- OEMs have created their own standard system with smaller semiconductor, thereby driving all semiconductor enterprises to adjust to the same standard

Ecosystem led by technology enterprises

- Technology companies develop middleware independent of hardware (such as a complete set of Android based systems), occupy a favorable competitive position in the value chain by providing an open source platform, and use their advantages in data driven services/functions and other fields to expand their share in the profit pool

Ecosystem led by OEMs

- OEMs(mostly emerging hosts, factories or tier1) introduce open source architecture and middleware to expand their own scale (cooperate with other hosts), or sell solutions /functions based on it.
- As OEMs face greater cost pressure, the ecosystem led by OEMs will rise rapidly



Software Defined Vehicle (SDV) has arrived

The technical architecture, business model, supplier ecology, etc. are facing changes

Technology

OEMs are adopting more centralized and efficient computing architecture, separating hardware and software, simplifying system structure, and making software update and management more efficient and flexible. Standardized interfaces must be established between technical layers, especially between hardware and software layers. Non differentiated domains can be the preferred candidate for open source solutions.

Supplier ecology

An enterprise adopting an open architecture can avoid being bound by a single manufacturer, and can choose the most appropriate technical solutions to promote functional differentiation and enhance competitiveness. It can improve system compatibility and interoperability. Automobile manufacturers need complex talents. Cooperation with the supplier ecosystem can help automobile manufacturers narrow the gap.

Business model

It is expected that by 2035, 51% of the revenue will be self sustainable digital services and software subscriptions, such as advanced connectivity, vehicle subscriptions, software defined function upgrades, enhanced travel experience and automatic driving, according to the consensus of both auto executives and suppliers. At present, this ratio is only 15%.

SDV has arrived

74% of auto industry executives said that cars in 2035 will rely on software definition and AI drive.

Automobile manufacturers will significantly increase the R&D budget of software definition products from 21% at present to 58% in 2035.

75% of auto industry executives said that by 2035, software defined experience will become the core of brand value.

Source: IBM Institute of Business Value, Oxford Institute of Economics, Car 2035: The Way to Success in the Software Definition Era

Auto software embraces the future of open source

The history .

- 项目

- 社区组织

In 2009, the predecessor of COVESA (The Connected Vehicle Systems Alliance), GENIVI Alliance, was established. GENIVI provides open source software based on Linux, and is committed to providing various open source vehicle infotainment system technology solutions for the automotive industry.

In 2014, the Linux Foundation released the first open vehicle infotainment (IVI) software specification: the open source AGL (Automotive Grade Linux) specification version 1.0. The AGL open source project is committed to building an open source platform for internal use of networked vehicles based on Linux.

In 2017, Baidu released the Apollo open source project, which aims to help industry partners quickly build a self driving system of their own;

In 2018, AWF (Autoware Foundation) was founded and organized to develop Autoware series open source automatic driving projects;

In 2019, the Linux Foundation launched the ELISA open source project, committed to developing the Safety Linux operating system with the goal of functional security level ASIL-B.

In 2022, Bosch, Microsoft and other enterprises announced the establishment of the Eclipse SDV Working Group to provide open source automotive software for the automotive industry;

In 2022, the Institute of Software of the Chinese Academy of Sciences led the establishment of OpenSDV to promote the development of basic automotive software through open source;

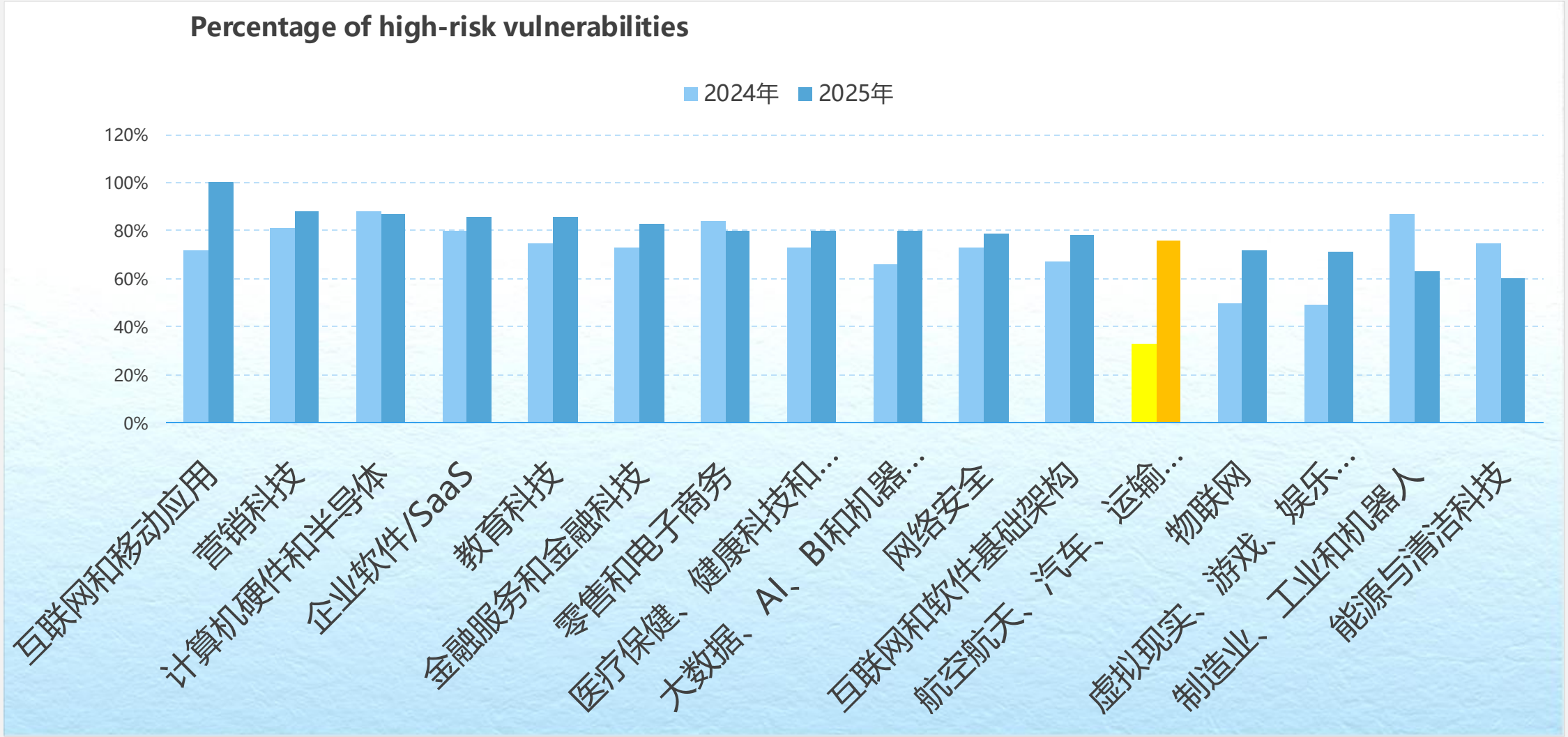
In 2023, five leading automotive electronic chip companies, including Bosch and Qualcomm, jointly invest to establish Quintauris, a company focusing on the automotive field based on RISC-V architecture;

In 2023, the Chinese Society of Automotive Engineering, the Chinese Computer Society and the National Intelligent Connected Vehicle Innovation Center will jointly build a joint laboratory of vehicle operating system and ubiquitous operating system, and develop the open source baseline version of vehicle operating system;

In 2023, China Automobile Industry Association, Open Atom Open Source Foundation, Puhua Basic Software and other vehicle and chip enterprises jointly launched the "Open Source Program of China's Automotive Operating System"

Is Open-Source a silver bullet?

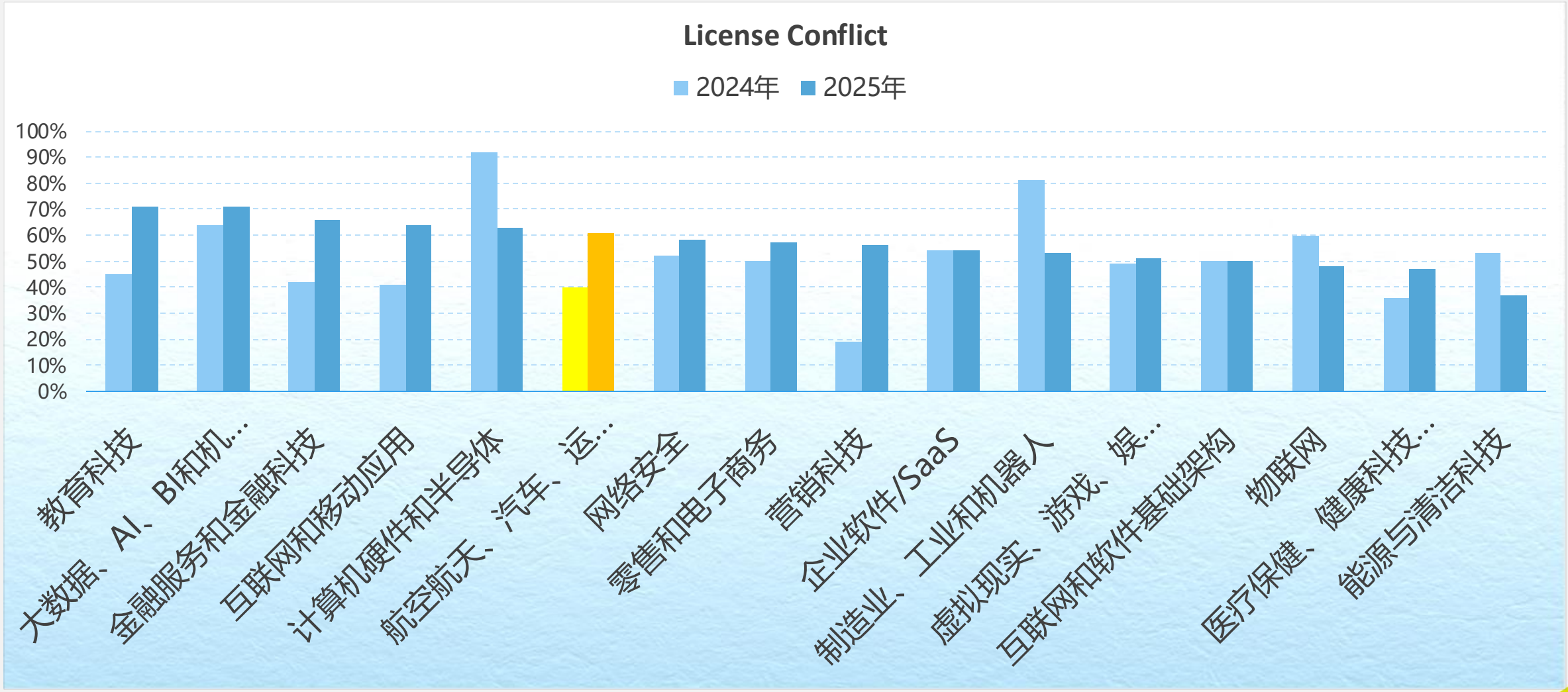
Security security and security



Data source: Synopsys《2024年开源安全和风险分析报告OSSRA》

Is Open-Source a silver bullet?

Compliance Compliance and Compliance



Data source: Synopsys《2024年开源安全和风险分析报告OSSRA》

Is Open-Source a silver bullet?

AI Large model empower intelligent vehicle

LLM	Show case
Step Video-T2V Step Audio	Step Video T2V can be used for automatic driving model training data synthesis. For example, Geely optimizes Step Video T2V based on real driving video data, which can be turned into an automatic driving data synthesizer. Geely Starry AI big model is exploring to convert these rich synthetic scenes into automatic driving training data. Step Audio can be used for intelligent passenger car interaction. For example, the GEELY STAR Rui AI large model can significantly improve the response speed of voice commands, as well as the emotional understanding and expression ability in the interaction process under the enabling of the step audio large model interaction function.
Deepseek	More than 20 auto companies announced access to DeepSeek, including Geely, Geekrypton, Chery, BYD, Great Wall, Zero Race, Landu, Dongfeng, Dongfeng Nissan, Zhiji, Chang'an, SAIC GM, GAC, BAIC Jihu Smart、 Jiangqi, FAW Hongqi, FAW Pentium, SAIC Baojun, Ideals, etc. cover independent car enterprises, new forces, joint venture car enterprises. At present, the application of DeepSeek in the automotive field mainly focuses on the intelligent cockpit, which is used to improve the capabilities of voice interaction, perception and decision-making in the vehicle cockpit. From the perspective of technology realization path, automobile enterprises mainly adopt three access modes: direct model access (such as Dongfeng), multi model joint collaborative deployment (such as Zhiji), model deep integration and distillation training (such as Geely and Ideal). In addition, DeepSeek takes the lead in cost reduction, performance improvement and other aspects, and is expected to enable assisted driving from multiple perspectives of data, algorithm and computing power.
Qwen	Smart cabins of Xiaopeng, Jikrypton, ZeroRun, Zhiji, BMW and other cars have been connected to Tongyi Qianwen. For example, Zhiji IM AIOS ecological cockpit introduces "big model+AI Agent" into the intelligent cockpit. On the access of the underlying model, it selects the multi model fusion composed of Tongyi Qianwen, DeepSeek, etc. By virtue of the distillation technology, it can provide different strong performance support for different scenarios, such as ensuring reasoning efficiency and low energy consumption at the same time; Based on Tongyi Qianwen, BMW and Alibaba jointly developed AI engine to improve intelligent interactive experience.
MiniCPM	Based on the MiniCPM end side large model drive, the wall smart launched the small steel gun super assistant cpmGO, an intelligent cockpit product, which has cooperated with Chang'an Mazda, Shanghai Volkswagen, Great Wall and other car manufacturers. CpmGO is the industry's first intelligent assistant driven by a pure end side large model. It is fast, quasi stable, purely local, and full scene. It can achieve millisecond response, 100% data without leaving the vehicle, and no fear of weak network disconnection.

SDV 2025

Participation and contribution

Geely: On February 18, 2025, Geely Automobile Group and Step Star jointly opened two large multi-mode models of Step Step series - Step Video T2V video generation model and Step Audio voice model.

Dongfeng: On March 25, 2025, Dongfeng Motor announced the release of the industry's largest end-to-end automated driving open source data set covering 1.25 million sets of high-quality data. The data set is led by Dongfeng Motor Group Co., Ltd. and jointly released by China Automobile Industry Association, China Auto Chuangzhi Technology Co., Ltd., Chongqing Chang'an Automobile Co., Ltd. and China FAW Group Co., Ltd. On April 23, 2025, Dongfeng Motor announced the release of the open-source domestic vehicle operating system Tianyuan OS to provide the underlying software platform for the passenger vehicle and commercial vehicle fields. It has become the first open source project of the AUTOSEMO automotive operating system open source community established on April 25.

Ideal: On March 27, 2025, Li Xiang, the chairman and CEO of Ideal Auto, announced at the annual meeting of Zhongguancun Forum that Ideal Auto would become the first auto enterprise in the world to open source its auto operating system, and would open source the auto operating system Ideal Star Ring OS, including car control operating system, intelligent driving operating system, communication middleware, virtualization platform and other core components.

Chery: On April 10, 2025, Chery Automobile released the open source plan of hybrid technology, and promoted the academic research of automobile hybrid technology by building a full chain incubation system of "open source, technology research and talent education". On May 12, 2025, Kaiyang Laboratory signed a contract with Nanyang Technological University of Singapore, and the first overseas collaborative innovation center of Chery's global open source plan was launched.

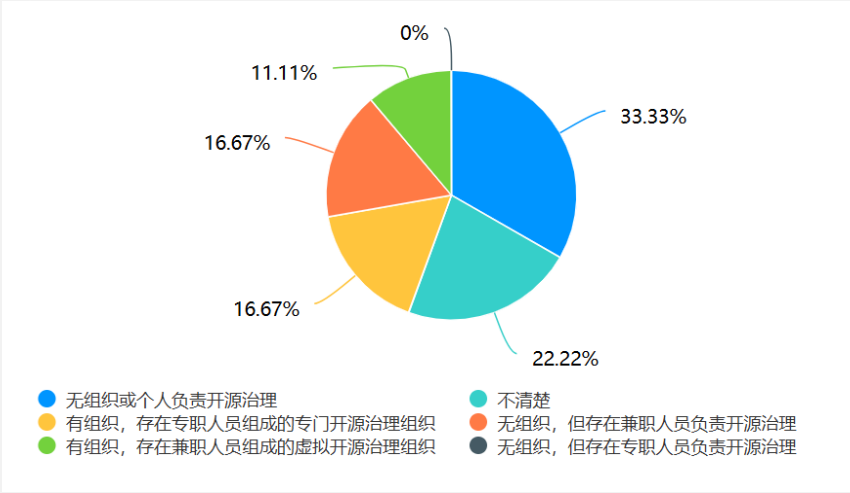
Lotus: On April 23, 2025, Lianhua Auto announced that it would open the chassis technology to the whole industry, opening its chassis database that has been meticulously accumulated for 77 years, which covers the test and development data of various Lianhua sports cars under extreme conditions.

Dark Blue: On May 22, 2025, Dark Blue Auto announced the opening of two core patent clusters, including the key technology patent cluster of electric vehicle power battery safety that won the second prize of the National Science and Technology Progress Award, and the patent cluster of micronucleus high-frequency pulse heating technology that won the gold medal of China's intellectual property patent.

OpenSDV – Research in China

Overview of open-source governance mechanism

Among the sample enterprises, more than 60% have open source software related management systems, and nearly 50% have carried out open source governance related training and open source compliance related work. Among them, automobile manufacturers, chip manufacturers, and sample enterprises with automobile basic software and automobile cockpit domain software business account for a higher proportion.



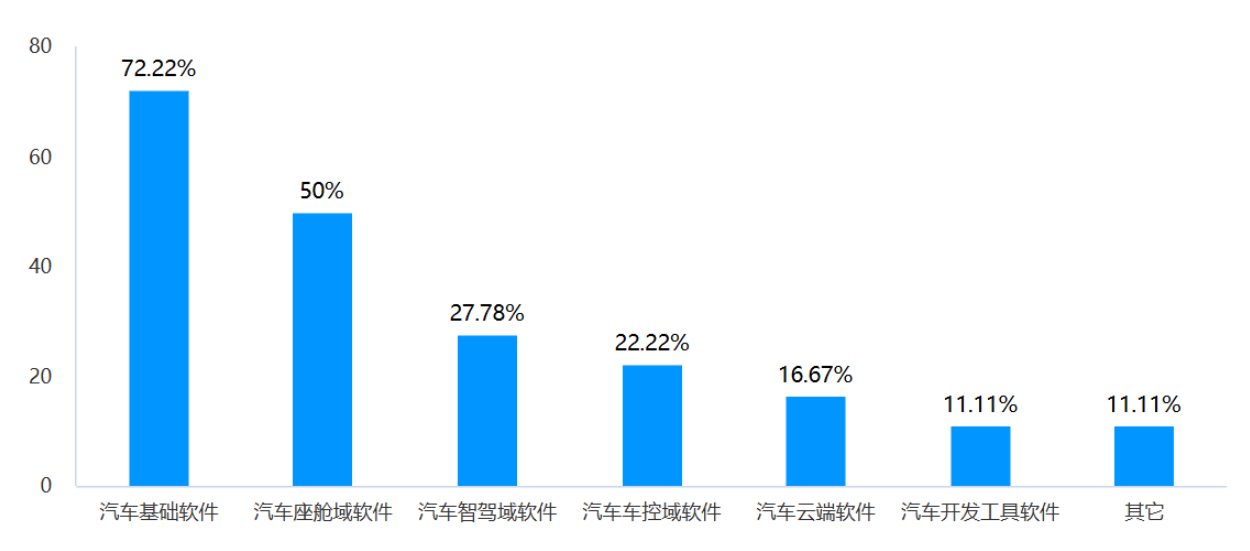
Nearly 50% of the sample enterprises have full-time or part-time personnel responsible for open source governance, and nearly 30% have organizations responsible for open source governance. Among them, the head of the open source governance organization of some enterprises will reach the CEO level in the highest position in the enterprise, and the number of part-time staff responsible for open source governance of some enterprises will reach nearly 20. Among the sample enterprises, automobile manufacturers, chip manufacturers, as well as the sample enterprises with automobile basic software and automobile cockpit domain software business, the proportion of full-time or part-time personnel responsible for open source governance is higher. For the sample enterprises with full-time or part-time personnel responsible for open source governance, the departments that introduce and use open source software for management are mainly responsible according to their responsibilities or are uniformly responsible by specialized organizations.

Less than 30% of the sample enterprises have built open source software management platforms. The proportion of automobile manufacturers in the sample enterprises, as well as the sample enterprises with basic automobile software and intelligent driving software business, who have built open source software management platforms is higher. In addition, few open source organizations/communities cooperate with or participate in the contribution of sample enterprises, and few sample enterprises carry out certification related to open source governance.

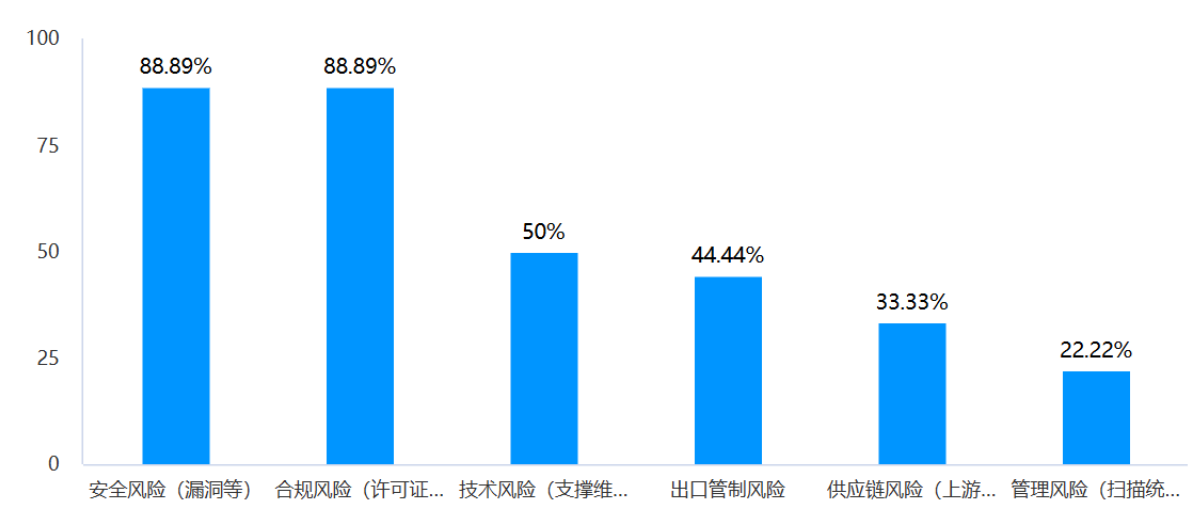
OpenSDV – Research in China

Background of open-source governance

Enterprise use of open source components



Open source governance focused by enterprises



At least 2/3 of the sample enterprises have scanned the open source components used, and the open source software used by the sample enterprises is mainly concentrated in basic automotive software and automotive cockpit domain software, involving various types.

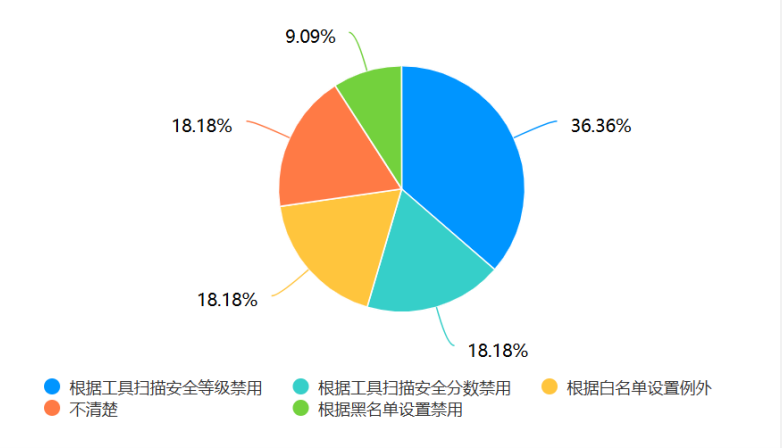
The sample enterprises are relatively popular at the level of open source compliance awareness. The most concerned open source risks focus on security risks and compliance risks. The concerned open source governance cases involve SBOM, open source licenses and other aspects.

OpenSDV – Research in China

Governance mechanism for enterprises to introduce and use open-source software

Among the sample enterprises with open source software related management systems, more than half of them disable the management strategy of introducing and using open source software based on tool scanning, and less than 30% manage it by setting blacklist or whitelist.

More than 70% of the sample enterprises with open source software related management systems have special requirements for the introduction and use of open source software under certain licenses, such as GPL, but the introduction and use of open source software are not completely prohibited. Among them, a larger proportion of automobile chip manufacturers and sample enterprises with automobile cockpit domain software and automobile basic software business will have special requirements.



In the sample enterprises with open source software related management systems, the stock of open source software that has been introduced and used before the open source governance work is generally subject to unified management, such as scanning and re reviewing or self-development and replacement.

OpenSDV – Research in China

Corporate governance mechanism for O&M and contribution to open-source software

The sample enterprises usually assign special personnel to be responsible for the continuous maintenance of the open source software used, dynamically track the vulnerability, version, license and other information, and pay attention to the open collaboration with external suppliers and the open source community.

The frequency of version updates of open source software used by sample enterprises will be set in combination with project conditions (such as software types), customer needs and other factors, including regular (such as weekly, semi annual), irregular (such as before release), and no longer updated (such as commercial delivery); The update frequency is not necessarily synchronized with the community version.

The sample enterprise may not use some open source software (version), and upgrade or replace it for many reasons, such as not meeting functional requirements, having security compliance risks, and stopping updating.

The license agreements selected by sample enterprises for external open source include mainstream open source software licenses such as MIT, GPL 2.0, Apache 2.0, and will require contributors to sign DCO agreements (mainly suppliers) or CLA agreements (mainly automobile enterprises).

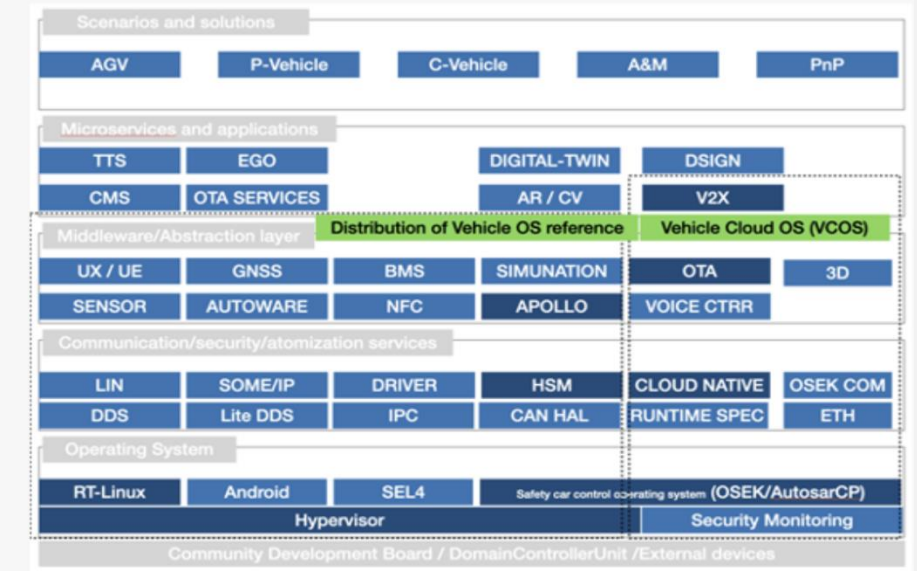
OpenSDV

Operating system team

According to the work plan of the operating system team for standard work and release.:

The distribution of the federated operating system and Performance test method of intelligent driving operating system has officially started:

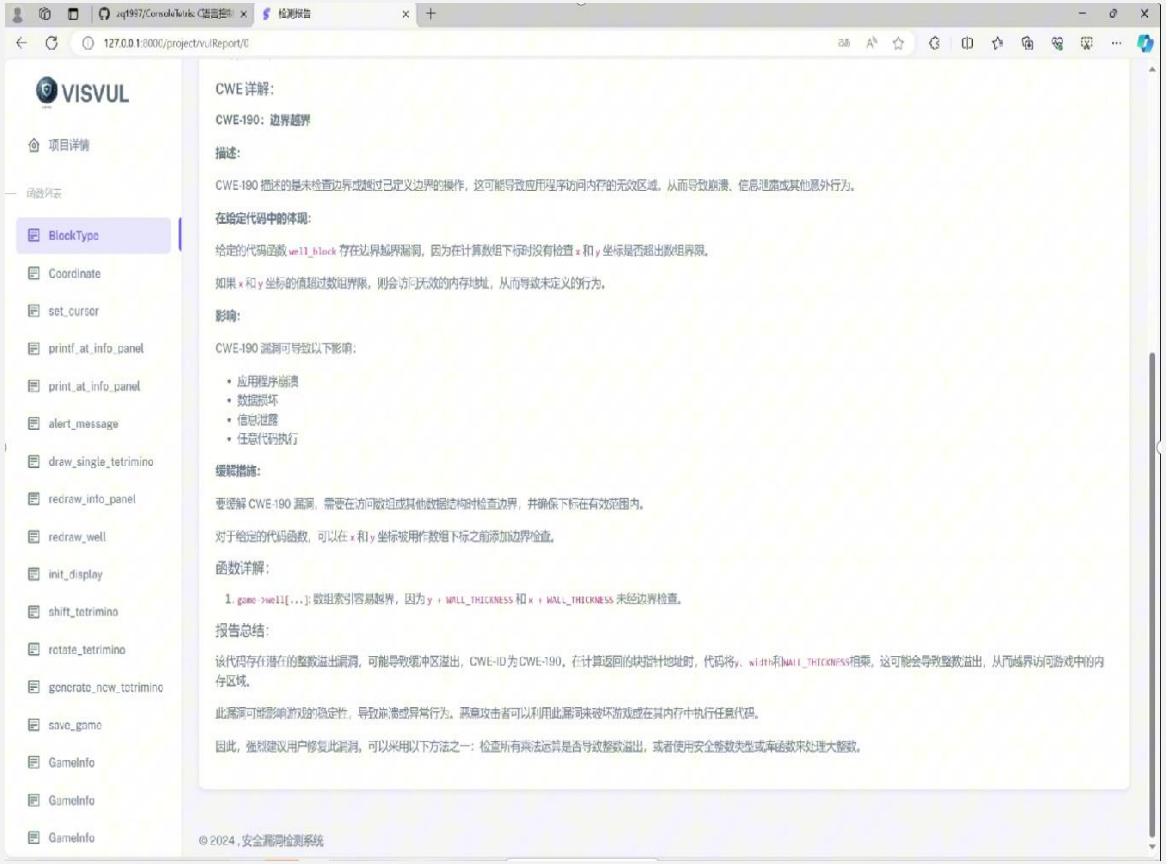
According to the opinions of participating units, the first project is the community release of Smart Drive operating system. The project kick-off meeting was held on April 17, 2024, and about 20 π member units of the working group attended the kick-off meeting, at which the version release plan and the division of labor of the participating units were basically defined. The follow-up working group meets on a biweekly basis. In addition, many other companies participated in the recruitment:
Sponsors: Chang'an Technology, Guoke Foundation Stone, Black Sesame Intelligence, and Guochuang Center;
Initial member units: Software Institute of the Chinese Academy of Sciences, Desai Siwei, SAIC General Institute of Innovation Research and Development, Great Wall Motors, and Software Innovation Center of China Science and Technology Automobile;
Additional member units: Chongqing University, Valeo, Yitu Technology, Zhongke Chuangda, Dongfeng Technology Research Institute Elektrobit、Celus, Zero Run Technology, Huayang Group, Xi'an University of Posts and Telecommunications, Anmou Technology, Linux Foundation Asia Pacific Region, Beihang Computer College



OpenSDV

Prototype System for Vulnerability Detection and Repair Based on Code Large Language Models

Vulnerability Detection



Vulnerability Repair

汽车核心软件研发重大专项 - 开源高可信车载实时操作系统项目

OpenSDV

Section 1: C/C++ Open-Source Vulnerability Database

- Constructed a fine-grained code vulnerability database
- **271,977** function-level open-source C/C++ code samples
- **60,234** code security vulnerability records
- **91** diverse types of security vulnerabilities (CWEs)

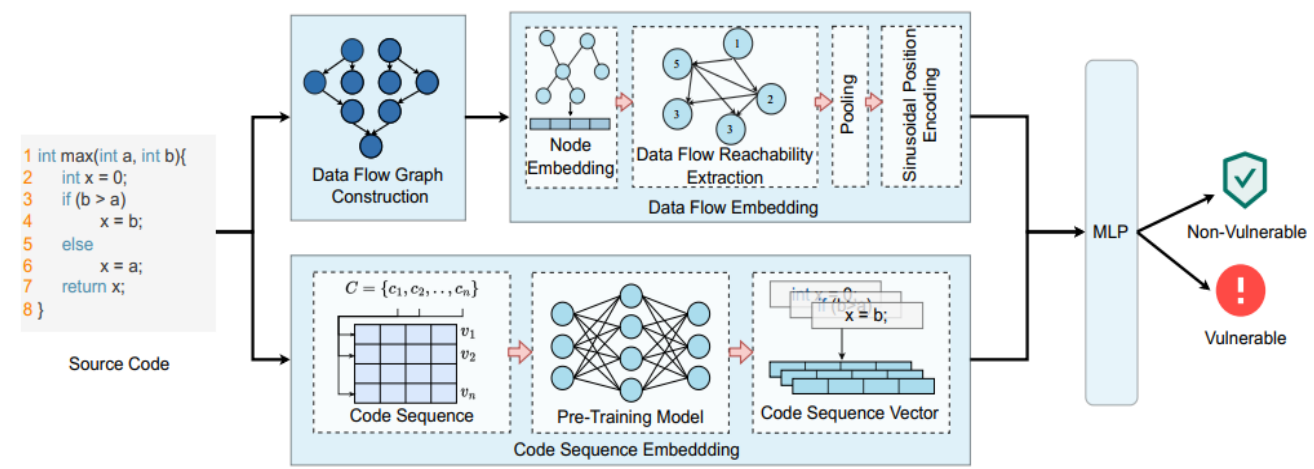
CSV中的列名	特征	描述
access_complexity	访问复杂性	反映利用软件特性漏洞的攻击复杂性
authentication_required	身份验证要求	如果利用漏洞需要身份验证
availability_impact	可用性影响	反映成功利用漏洞可能对软件可用性的影响
commit_id	提交ID	代码仓库中的提交ID，表示一个最小版本
commit_message	提交信息	开发者的提交信息
confidentiality_impact	保密性影响	成功利用误用漏洞对保密性的潜在影响
cwe_id	CVE ID	常见弱点枚举ID
cve_id	CVE 页面	通用漏洞和暴露ID
cve_page	CVE 页面链接	CVE详情页面链接
cve_summary	CVE 摘要	CVE的概要信息
score	CVSS得分	软件漏洞严重性的相对评分
files_changed	修改文件	所有改变的文件和对应的补丁
integrity_impact	完整性影响	成功利用漏洞可能对完整性的潜在影响
version_after_fix	修复后的最小版本	修复后的最小版本ID
version_before_fix	修复前的最小版本	修复前的最小版本ID
lang	编程语言	项目编程语言
project	项目	项目名称
publish_date	发布日期	CVE的发布日期
ref_link	参考链接	CVE页面的参考链接
update_date	更新日期	CVE的更新日期
vulnerability_classification	漏洞分类	漏洞类型

Availab	CVE ID	CVE Page	CWE ID	Comp	Confide	Integrity
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	(Null)	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial
Partial	CVE-2015	https://ww	CWE-2	Low	Partial	Partial

OpenSDV

Section 2: C/C++ Open-Source Vulnerability Database

- **Motivation:** Traditional static tools lack flexibility due to manual rules; code LLMs miss vulnerability patterns due to absent code dependency information.
- **Contribution:** Proposed a vulnerability detection method combining data flow graphs and code LLMs.



Dataset	Devign				Reveal			
Model	Accurancy	F1	Precision	Recall	Accuracy	F1	Precision	Recall
CodeBERT	0.6332	0.471	0.698	0.3554	0.9085	0.3659	0.6122	0.2609
GraphCodeBERT	0.6384	0.4822	**0.7044**	0.3665	0.9156	0.4074	0.7021	0.287
UniXcoder	0.6369	0.5466	0.6409	0.4765	0.9094	0.408	0.6017	0.3087
CodeT5	0.6336	0.5988	0.6024	0.5952	0.9265	0.4698	0.7048	**0.3524**
CodeBERT+DFEPT	0.6475	0.5523	0.6162	0.5004	0.9125	0.3801	0.6703	0.2652
GraphCodeBERT+DFEPT	0.6296	0.5645	0.6137	0.5227	0.9265	0.4261	**0.7654**	0.2952
UniXcoder+DFEPT	**0.6497**	0.5726	0.6514	0.5108	0.9182	0.4464	0.7075	0.3261
CodeT5+DFEPT	0.6453	**0.6122**	0.615	**0.6096**	**0.9292**	**0.479**	0.7475	**0.3524**

Dataset	Devign				Reveal			
Model	Accuracy	F1	Precision	Recall	Accuracy	F1	Precision	Recall
CodeBERT	0.6332	0.471	0.698	0.3554	0.9085	0.3659	0.6122	0.2609
GraphCodeBERT	0.6384	0.4822	**0.7044**	0.3665	0.9156	0.4074	0.7021	0.287
UniXcoder	0.6369	0.5466	0.6409	0.4765	0.9094	0.408	0.6017	0.3087
CodeT5	0.6336	0.5988	0.6024	0.5952	0.9265	0.4698	0.7048	0.3524
ReGVD	0.6285	0.5955	0.5957	0.5952	0.9015	0.3946	0.5214	0.3174
VulBERTa	0.6413	0.6045	0.6124	0.5968	0.8646	0.4597	0.3853	**0.5696**
CSGVD	0.6446	0.6039	0.6187	0.5899	0.9008	0.3297	0.5114	0.2432
DFEPT	**0.6453**	**0.6122**	0.615	**0.6096**	**0.9292**	**0.479**	**0.7475**	0.3524

	Model	Accuracy	F1	Precision	Recall
Devign	DFEPT w/o GNN	0.6369	0.5466	0.6409	0.4765
	DFEPT w/o pre-trained Model	0.5458	0.2929	0.514	0.2048
	DFEPT w/o Sin. Encoding	0.6417	0.5305	**0.6663**	0.4406
	DFEPT	**0.6497**	**0.5726**	0.6514	**0.5108**
Reveal	DFEPT w/o GNN	0.9094	0.408	0.6017	0.3087
	DFEPT w/o pre-trained Model	0.8989	0.0417	0.5	0.0217
	DFEPT w/o Sin. Encoding	0.9164	0.4412	0.6818	0.3261
	DFEPT	**0.9182**	**0.4464**	**0.7075**	**0.3261**

OpenSDV

Other works

类别	成果
牵头/参与各类标准、许可证编写	OpenSDV与AUTOSEMO成功组织召开智能驾驶操作系统性能测试方法团标编写
	作为技术牵头，开展《开放原子开放硬件许可证》编写
	中国互联网协会团体标准《软件安全开发能力评估技术规范》参编
	中国互联网协会团体标准《软件供应链安全要求》参编
	中国知识产权研究会《专利池管理规范》《专利池运营规范》参编
	中国信通院《软件物料清单（SBOM）发展洞察报告（2023年）》参编
	中国信通院《开源人工智能大模型应用指南1.0》参编
牵头白/蓝皮书汽车方向内容编写	COPU《2023中国开源发展蓝皮书》汽车行业内容牵头编写
	COPU 《2024中国开源发展现状》蓝皮书汽车行业内容牵头编写
开展重点调研活动	组织开展两期粤港澳汽车产业链企业调研行活动，走访十余家车企及产业链企业
	国家知识产权局专利开源课题组来访调研交流
社区/工作组	中国科学院软件所AGIROS开源社区共建单位
	国家工业信息安全发展研究中心软件物料清单（SBOM）工作组成员单位

社区公众号

SOAFEE

Thank You

社区运营 Leon