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OVERVIEW OF CHINA'S SMART DEVICE MARKET

China's consumer smart device market shows clear product category segmentation, with distinct competitive dynamics for each category based on its stage of development.

For mainstream products such as smartphones, tablets, PCs, and smart wearables, growth is primarily driven by replacement demand, given their high market penetration. As hardware configurations become more standardized, user experience has emerged as the key factor influencing replacement decisions. Consequently, the focus of market competition is shifting from basic functionality to AI capabilities where smart device manufacturers are increasing their investment.

Emerging smart devices, such as smart glasses, are now in a high-growth phase with ecosystems and usage patterns under development. Next-generation devices, such as embodied robotics and other forms of Physical AI, are in the early stages of commercialization. Although their technical solutions, business models and application scenarios are still being validated, they show significant medium- to long-term growth potential.

Smart Device Interaction Frameworks

Consumer smart devices rely on two complementary interaction frameworks to provide seamless and intelligent user experience.

Language-Based Interaction

Language-based interaction uses linguistic symbols, such as natural language or code. Large language models (LLMs) have made this a standard feature on most smart devices. This type of interaction is most effective when users have clear and expressible intentions.

Perceptual Interaction

Perceptual interaction, on the other hand, uses non-linguistic physical signals as inputs. A smart device captures, combines, and analyzes signals from various sources, such as vision, non-semantic sound, and motion, in real time to understand the state of device users and the surrounding environment.

Perceptual interaction has two main advantages. First, it expands a smart device's ability to perceive and understand the physical world, enabling the interpretation of user states and environmental changes in real time. Second, it allows a device to proactively identify and respond to a user's unspoken intentions. For instance, a user can simply point at an object, and a device will recognize the gesture and take action without a voice command. These capabilities complement language-based interaction when a user's intent is unclear or not explicitly stated.

Industry Development Trends: Evolving Towards Physical AI by Virtue of Perceptual Interaction

AI is currently moving from digital systems into the physical world. While LLMs are widely adopted, the next frontier for AI will go beyond language to real-time perception of physical environments, interpretation of states, and proactive decision-making. As a result, smart devices will evolve into "Physical AI," which can be built and trained to seamlessly interact with their surroundings in the real world.

Language-based interaction is primarily for interpreting user intents through symbols, but it has inherent limitations in physical-world applications because it cannot directly perceive the physical environment or real-time variables. Perceptual interaction, by contrast, enables smart devices to capture and integrate spatial information, behavioural patterns and sensor data from the physical environment. To provide complete services in the physical world, a perceptual interaction system is needed to gather and merge such environmental data, thereby overcoming the limitations of language-based interaction. Together, these two systems provide the technical foundation for Physical AI.

CHINA'S PERCEPTUAL INTERACTION SOLUTIONS MARKET

Pain Points of Current Perceptual Interaction Solutions

Perceptual interaction solutions use algorithms on smart devices to interpret user states and environmental information through single or multiple modes of perception (such as vision, sound, and optics). However, as user scenarios become more complex, current systems are insufficient and face several major challenges:

- **Inaccurate intent recognition from single-modal inputs:** Interactions that rely on a single mode of perception convey limited information. Without combining data from multiple sources, single-modal perception systems can only respond to explicit commands, often failing to recognize the user's latent intent.

- **Poor performance in complex environments:** Single-modal perception systems fail to overcome the challenge by leveraging other perception modalities for calibration or accuracy enhancement, and therefore are often unreliable in challenging conditions like low light, obstruction, noisy background, or other physical limitations.

- **Lack of proactive services:** Most device interactions are passive and command-based. They cannot infer user intents or provide preemptive services without deliberate instructions from users.

Comparison of Technology Pathways

The industry is pursuing two distinct technology pathways, each with its own architecture, capabilities, and potential for commercial scaling.

Pathway One: Modular Stacking (Current Pathway Adopted by Mainstream Vendors)

This development paradigm is built upon isolated, task-specific algorithms, such as visual recognition. While effective in addressing individual scenario, the approach lacks a unified intelligence layer, requiring substantial re-engineering whenever it is extended to new applications. Consequently, this paradigm leads to high development costs, prolonged deployment cycles and inherently constrained scalability. As the number and complexity of application scenarios increase, R&D expenditure rises correspondingly. Furthermore, modular stacking architectures struggle to coordinate different functions, such as sharing data across different perception modules or enabling seamless transitions between functions.

Pathway Two: Unified Foundation Model (Innovative Multi-modal Interaction)

This approach uses a unified perceptual interaction model that can handle multiple modes of perception. By modeling user behavior, environmental context, and multi-modal sensor data together, the unified perceptual interaction model can recognize user intents across different scenarios and extend its capabilities to new use cases.

This approach has two key advantages. First, combining multiple modes of perception improves accuracy and reliability. Second, by using a unified system for encoding multi-modal data, existing capabilities can be rapidly extended into new scenarios. This leads to lower development costs at scale and creates a "data flywheel" effect, where more data lead to better training and faster expansion into new scenarios.

From the perspective of information processing, multi-modal interaction consists of three core layers: the input layer, the target recognition layer, and the output layer.

- The input layer supports the acquisition and processing of a wide range of signals, including visual, tactile, vibration, and other sensory data.

- The target recognition layer supports the identification and understanding of diverse target types, including human features, biometrics, behavioral patterns, and environmental objects.

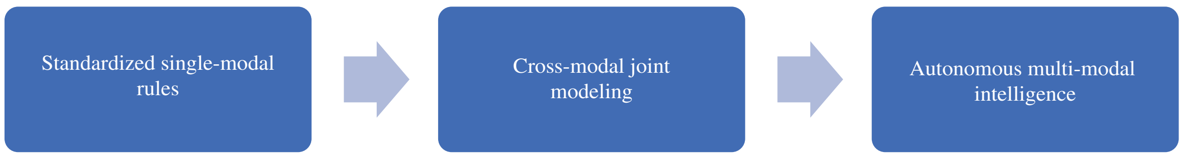
- The output layer supports the generation and delivery of diverse forms of output, including spatial keypoint localization, object detection, action recognition, and other intelligent interaction feedback.

Together, these three layers create a complete information-processing architecture for multi-modal interaction, allowing smart devices to evolve from passive responders to proactive and intelligent systems.

While the first pathway facilitates rapid deployment in specific scenarios, its structural limitations lead to increasing development costs and worse user experience over time. The second pathway, in contrast, requires a large upfront investment but creates a powerful "data flywheel" effect that becomes more effective as it is used in more scenarios. Therefore, the unified foundation model approach is the only sustainable way to achieve comprehensive coverage across all scenarios and smart devices.

Stages of Technology Evolution

Perceptual interaction technology is evolving through three stages: from single-modal, rule-based perception to cross-modal joint modeling, and finally to intelligent multi-modal systems powered by unified cognitive models.



Source: Frost & Sullivan, expert interviews

The first stage uses single-modal sensor signals, such as optical, electrical or acoustic signals, together with rule-based algorithms or task-specific machine learning models for basic recognition in predefined use cases, such as biometric authentication on smartphones. This approach is mature, but it is limited to specific scenarios and has little contextual awareness. The second stage combines data from multiple sensors as joint inputs, which improves overall performance and expands application scenarios by leveraging complementary information across modalities. For example, smart glasses might gather and analyze data collected from various sensors to more accurately understand users' intention, enabling existing interaction functions to perform better. However, these systems still have limited learning capabilities and mostly rely on users to initiate interactions. The third stage uses a foundation model as its cognitive core, moving beyond simple environmental perception to understand intents, interpret physical context and provide proactive, context-aware assistance. For example, smart glasses may combine gaze, gesture, voice or lip movement, and spatial understanding to identify what the user is paying attention to and overlay relevant information or guidance at the right moment, without waiting for an explicit command. This stage represents two key shifts: from user-initiated interaction to proactive, system-driven services, and from rule-based to cognition-driven decision-making.

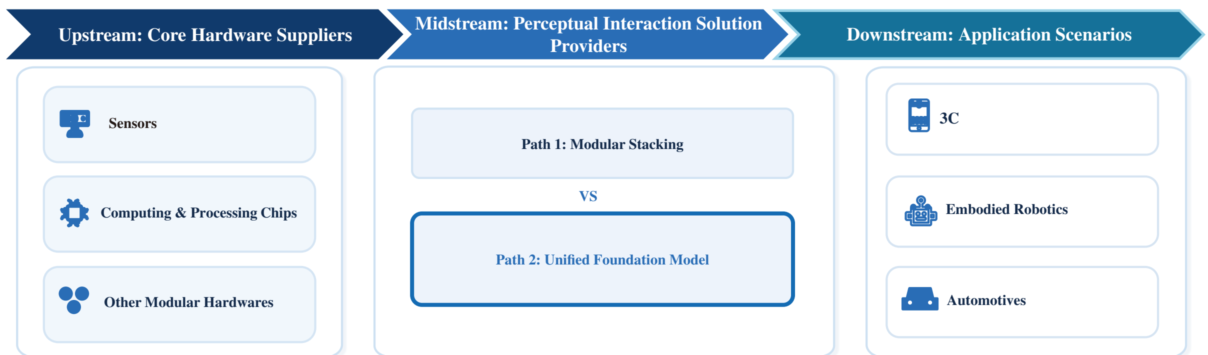
Industry Chain and Value Distribution

The perceptual interaction solutions industry chain comprises three main segments: upstream core hardware supply, midstream perceptual interaction solution providers, and downstream smart device application scenarios. The core value distribution across this industry chain is undergoing a structural shift.

Smart device manufacturers dominate the value chain. Sensor and chip manufacturers primarily provided hardware, and the algorithm layer was either bundled with hardware sales or licensed as a standard function. This was because the key competitive differences in perceptual interaction were at the hardware level, such as sensor precision and chip performance in the past.

As foundation models become more important, competition in perceptual interaction is shifting from hardware to the algorithm and model layer. Solution providers that can offer perceptual interaction foundation models and coordinated software-hardware systems are no longer just supporting players in the hardware supply chain. They are now core technology providers that define what is possible in perceptual interaction. In practice, these providers design and optimize the entire perceptual interaction system, from chip architecture and sensor configuration to data transmission and on-device collaboration. Such structural shift results in lower power consumption, better multi-modal collaboration and performance, resulting in improvements in user experience.

Industry Chain of Perceptual Interaction Solutions

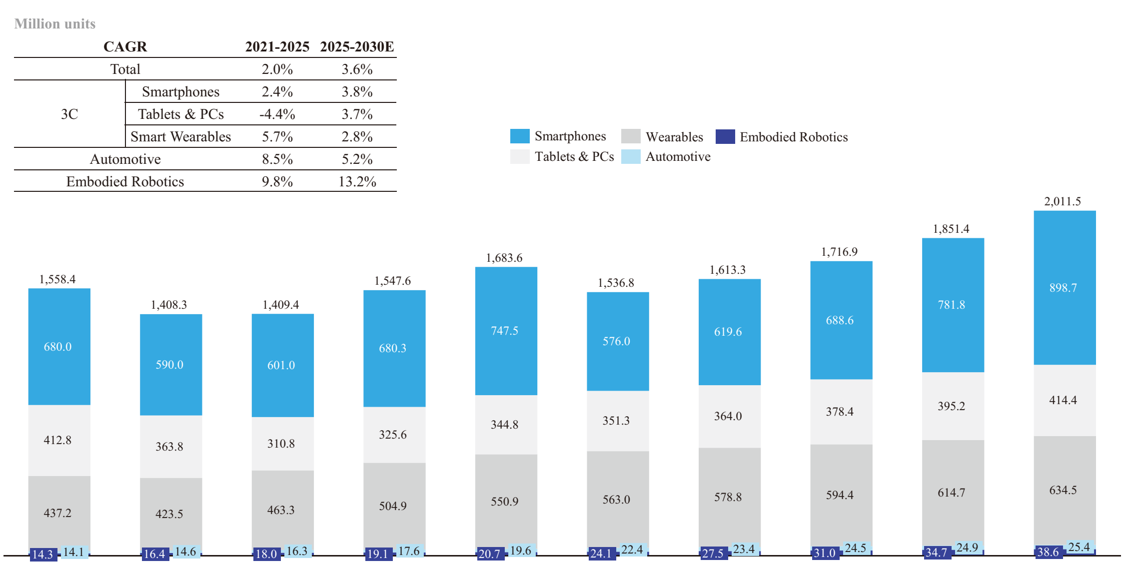


Source: Frost & Sullivan, expert interviews

Market Size of China's Perceptual Interaction Solutions Market

Perceptual interaction applications are categorized into three main areas based on their commercial maturity and application: 3C products, embodied robotics and automotive. The 3C segment is the most mature, with stable applications and steady market growth. Growth is mainly driven by emerging categories like smart glasses, which have a growing demand for real-time perceptual interaction. Embodied robotics is the next stage of industrial development. In the automotive sector, smart cockpits have over 70% penetration in passenger vehicles, but current applications mainly relate to gesture and facial recognition. In the era of Physical AI, embodied robotics will be the ideal platform for deploying perceptual interaction capabilities, and their growth potential is expected to exceed that of the automotive and 3C segments.

Factory Shipments of Smart Devices by Product Types in China, 2021-2030E



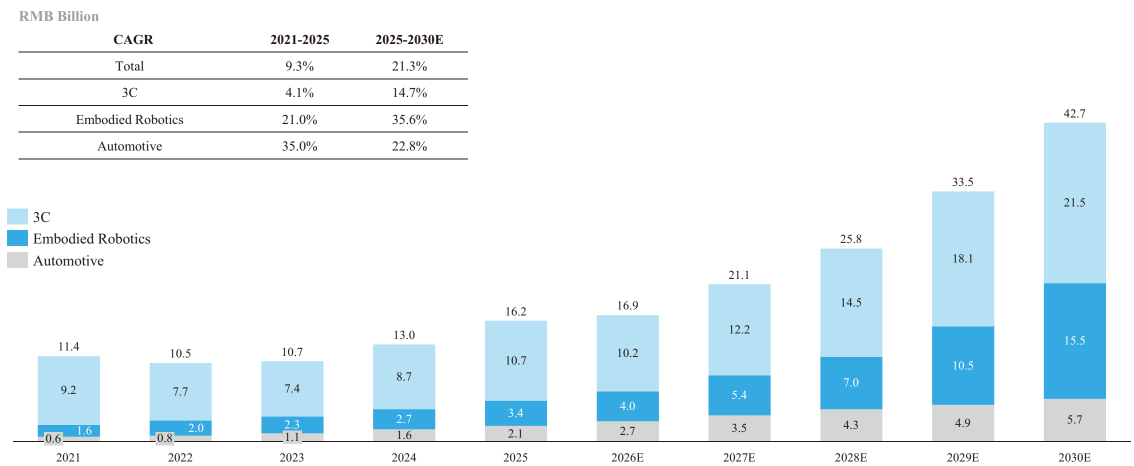
Source: Frost & Sullivan, IDC

Notes:

(1) The market size above represents factory shipment volume in China and excludes smart devices with iOS operating system, which primarily use proprietary technologies and do not incorporate third-party solutions.

(2) The market size of embodied robotics covers all categories of embodied robots, such as humanoid and household embodied robots.

Market Size of China's Perceptual Interaction Solutions Market, by Revenue, 2021-2030E



Source: Frost & Sullivan, annual reports from listing companies

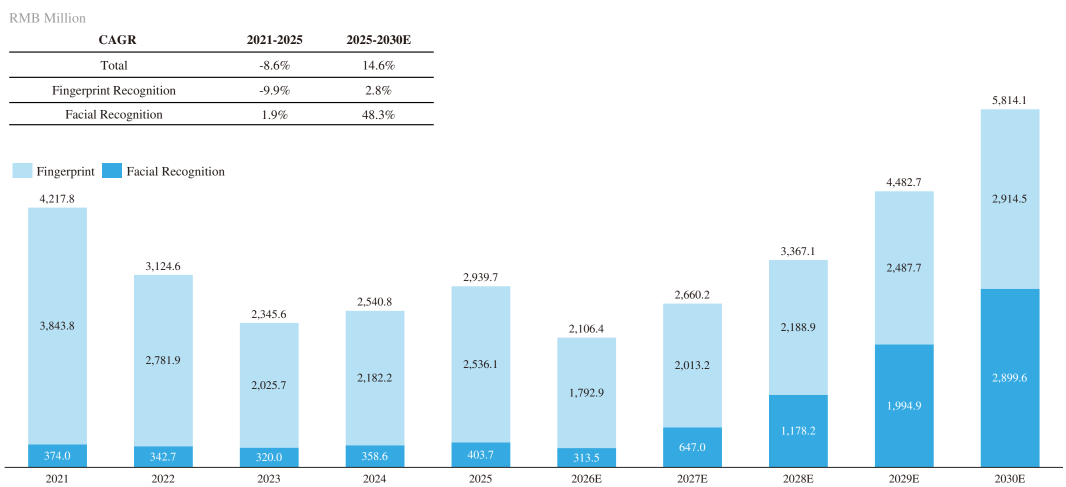
3C Smart Devices Segment

3C smart devices, including smartphones, tablets, laptops, PCs, and various smart wearables, are already widely used and represent the most commercially mature and broadly deployed applications for perceptual interaction technologies. Growth in this segment is driven by two factors: the upgrade of existing technologies and the expansion into new product categories. On one hand, in segments with mature technology and widespread adoption, such as smartphone biometric recognition, growth is driven by the shift to higher-value solutions such as ultrasonic fingerprint recognition and contactless AI biometric recognition. On the other hand, the increasing adoption of perceptual interaction technologies in emerging smart devices, especially smart glasses, constitutes the primary source of new market growth.

Within the overall market of 3C smart devices, biometric recognition stands out as a key sub-segment where perceptual interaction technologies are widely deployed. The smartphone biometric recognition market is primarily divided into facial recognition and fingerprint recognition technologies. Within the facial recognition segment, future growth is expected to be driven by contactless AI-powered biometric solutions. Current 3D facial recognition systems rely on costly depth-sensing components, such as ToF modules, limiting adoption largely to premium smartphone models. As demand grows for enhanced security, convenience, and adaptability, the industry is increasingly shifting toward multi-modal biometric solutions that integrate multiple authentication methods, including facial and palm-vein recognition. Large-scale deployment of multi-modal biometric solutions is expected to start in 2027, and the facial recognition market is projected to grow at a CAGR of 48.3% from 2025 to 2030, reaching RMB2.9 billion. The fingerprint recognition market is segmented by technology and price. Capacitive solutions are common in mid- to low-end and side-mounted recognition applications, supported by their cost advantages and mature technology. Optical solutions are the standard for under-display fingerprint sensors, benefiting from the rising adoption of OLED screens. Ultrasonic solutions, which offer 3D imaging and better security, are increasingly used in high-end smartphones. These technologies are not mutually exclusive but rather coexist long-term, providing tiered coverage across different price ranges based on smart device positioning, cost structure, and application scenarios.

The market size of smartphone biometric recognition is closely tied to smartphone shipment volumes, as fingerprint sensors are standard components across all device tiers. The market size of smartphone biometric recognition decreased from RMB4,217.8 million in 2021 to RMB2,345.6 million in 2023, driven by the global semiconductor supply shortage. Capacity constraints, pandemic disruptions, and geopolitical stockpiling reduced smartphone shipments, which lowered demand for onboard perceptual interaction solutions. Similarly, the industry is expected to see another contraction in 2026 as the AI-driven memory chip shortage diverts foundry capacity and storage supply away from consumer electronics, pressuring smartphone volumes and component demand downstream. Looking ahead, the market size of smartphone biometric recognition is projected to recover to RMB5,814.1 million by 2030, representing a CAGR of 14.6% from 2025 to 2030, driven by the expansion of higher-ASP solutions from flagship models into the broader high-end tier.

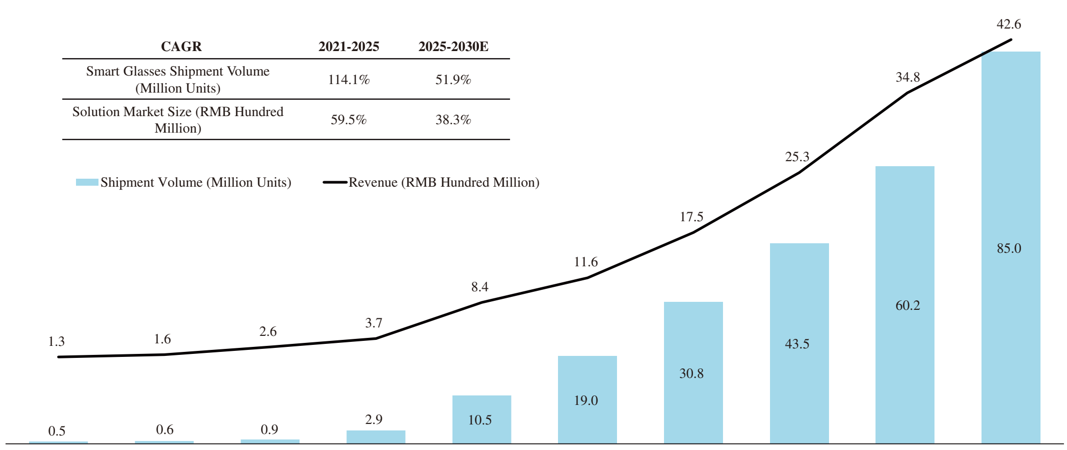
Market Size of China's Smartphone Biometric Recognition Segment of the Perceptual Interaction Solutions Market, by Revenue, 2021-2030E



Source: Frost & Sullivan, annual reports from listing companies

Emerging 3C smart devices such as smart glasses are the main driver of growth in the 3C market. These devices are associated with broader, more complex, and interaction-intensive scenarios, which typically integrate a greater number of perceptual interaction modules than the average of 3C market. As a result, the increase in the value of modules installed per device, coupled with growing shipment volumes, is expected to drive the continued expansion of smart glasses segment of the perceptual interaction solutions market.

Market Size of China's Smart Glasses Segment of the Perceptual Interaction Solutions Market, by Revenue, 2021-2030E

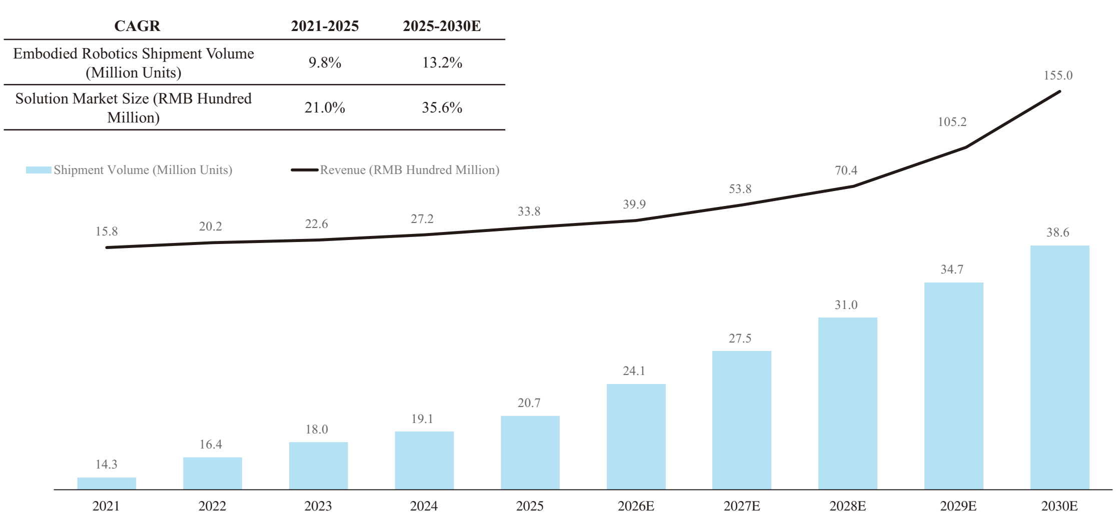


Source: Frost & Sullivan, expert interviews

Embodied Robotics Segment

Currently, integrated software-hardware solutions, such as visuo-tactile fusion modules and spatial perception modules, are to be adopted by embodied robotics manufacturers, with some leading manufacturers commencing small-batch validation. The capabilities being developed at this early stage, including understanding user intents, perceiving the environment, and achieving task goals through autonomous decision-making, represent the core direction for future perceptual interaction models. As the production of embodied robots increases, so will the demand for visuo-tactile modules. The mass production of embodied robots with dexterous hands will also create significant market opportunities for perceptual interaction. With advances in multi-modal foundation models, edge computing, and low-power sensors, this market segment is expected to grow rapidly and become a key driver of the perceptual interaction industry.

Market Size of China's Embodied Robotics Segment of the Perceptual Interaction Solutions Market, by Revenue, 2021-2030E



CAGR	2021-2025	2025-2030E
Embodied Robotics Shipment Volume (Million Units)	9.8%	13.2%
Solution Market Size (RMB Hundred Million)	21.0%	35.6%

Source: Frost & Sullivan, expert interviews

Note: The market size of embodied robotics covers all categories of embodied robots, such as humanoid and household embodied robots.

Automotive Segment

While smart cockpits have a relatively high penetration rate in automotive scenarios, their perceptual interaction capabilities are still in the early stages of development. Most in-car systems currently rely on single capabilities like gesture and facial recognition. In the future, as technologies like eye-tracking, Driver Monitoring Systems (DMS), Occupant Monitoring Systems (OMS), and multi-modal fusion become more common in smart cockpits, the market will move towards more advanced and integrated solutions.

Market Drivers and Future Trends of China’s Perceptual Interaction Solutions Market

Growing on-device computing power and model efficiency are enabling broader adoption: The growing use of neural processing units (NPUs) in consumer chips provides the hardware support needed for complex model computations. The Transformer architecture enables multi-modal perception by processing data from different sources, such as visual, voice, touch and motion signals, within a single model. This reduces the number of models needed on a device and lowers computing costs. The maturation of model compression techniques, such as quantization and distillation, further supports wider adoption by reducing model size and inference costs. These advances are making it possible to bring features that were once only available on high-end devices to mid-range and lower-priced ones, which expands the market for perceptual interaction solutions.

Emerging smart device categories are demanding advanced perceptual capabilities: The number of cases of perceptual interaction solutions in new smart device categories is growing. Smart glasses, for example, rely on visual and other multi-modal information to understand the environment and interact in real time due to their first-person perspective and hands-free design. This creates a need for more advanced perceptual capabilities like eye-tracking, gesture recognition, and intent prediction. As new types of devices create more complex requirements for perceptual interaction, these capabilities are becoming a key competitive factor rather than just a way to differentiate a product.

Shift in competitive focus from hardware to software-defined experiences: The competition in smart device market is shifting towards software-defined experiences rather than hardware specifications. This is changing the role of perceptual interaction solution providers in the industry. As perceptual interaction becomes more important to user experience, some device manufacturers are making it a key part of their strategy. This is leading to more integration of software and hardware in the supply chain. As a result, perceptual interaction solutions have evolved from a supporting function into a core component. Solution providers that can offer algorithms, integrated hardware and software, and cross-platform deployment are likely to gain stronger bargaining power.

Rising smart device penetration is driving demand for cross-device collaboration: As the adoption of smart devices continues to increase, users are interacting with a growing number of connected devices across different scenarios. This trend is driving the demand for seamless coordination, and information sharing across devices. As a result, the increasing complexity of cross-device interactions requires different smart devices to collaborate with each other and to deliver better user experience.

COMPETITIVE LANDSCAPE

The perceptual interaction solutions industry in China is generally fragmented, but the level of concentration varies by segments. The smartphone biometric recognition segment is relatively concentrated, with a few leading players. However, in emerging segments like perceptual interaction for smart glasses, no dominant player has emerged yet.

This competitive landscape reflects the structural complexity of the perceptual interaction industry. The technology chain is long, spanning sensors, algorithms, chips, and system integration, with each layer requiring deep specialization. As a result, building vertically integrated capabilities across the value chain demands a wide range of expertise and resources, creating high barriers to entry. Most players have developed strengths in specific segments, but few possess the cross-functional integration capabilities needed to deliver comprehensive solutions across the entire value chain.

Competitive Landscape in Smartphone Biometric Recognition Segment

Smartphone biometric recognition is one of the most mature and largest segments of the perceptual interaction market, with the top five providers accounting for over 80% of market share within smartphone biometric recognition industry. Despite this concentration, the leading players use notably different technological approaches. Most major competitors still rely on algorithms in a single scenario or modular-stacking architecture. The Company, by contrast, has developed a differentiated approach which uses a unified perceptual interaction model.

Our Company is currently the only one in China's perceptual interaction market with the perceptual interaction foundation model. Our unified model architecture allows us to extend our capabilities to fingerprints, faces, multi-modal applications, and emerging smart devices in a cost-effective way.

In 2025, the Company was the second largest player in China's smartphone biometric recognition solutions market, with a 14.5% market share by revenue and a 24.1% market share by shipment volume. Notably, from 2023 to 2025, while the overall industry experienced slow growth due to technology transitions and price changes, our related business revenue grew at a CAGR of 44.4%, nearly three times the growth rate of the next fastest-growing competitor among the top five, which grew at approximately 15%.

Top 5 Smartphone Biometric Recognition Solutions Providers in China by Revenue and Growth, 2025

Rank	Company	Related Business Revenue (RMB million)	Market Share	Related Business Revenue CAGR (2023–2025)
1 . . .	Company A	~1,450.0	49.3%	4.1%
2 . . .	**The Group**	**426.0**	**14.5%**	**44.4%**
3 . . .	Company B	224.8	7.6%	5.1%
4 . . .	Company C	196.1	6.7%	~15.0%
5 . . .	Company D	80.5	2.7%	~1.5%
. . . .	**Top 5**	2,377.4	80.8%	

Source: Frost & Sullivan, annual reports from listing companies

Note:

(1) Revenue and CAGR above exclude revenue from iOS-based products.

Top 5 Smartphone Biometric Recognition Solutions Providers in China by Shipment Volume, 2025

Rank	Company	Shipment Volume (million units)	Market Share
1 . . .	Company A	325.4	42.8%
2 . . .	**The Group**	**183.5**	**24.1%**
3 . . .	Company B	117.7	15.5%
4 . . .	Company C	100.8	13.2%
5 . . .	Company D	4.0	0.5%
. . . .	**Top 5**	731.4	96.1%

Source: Frost & Sullivan, annual reports from listing companies

Notes:

(1) Shipment volume above is calculated based on chip shipments, excluding shipment related to iOS-based products.

(2) Company A was founded in 2002 and is headquartered in Shenzhen. It is listed on the Shanghai Stock Exchange. The company primarily focuses on fingerprint sensors, touch controller IC, and other semiconductor solutions for smart devices.

(3) Company B was founded in 2011 and is headquartered in Shanghai. It is a subsidiary of a publicly listed company. The company primarily focuses on biometric identification technologies, including fingerprint sensing chips, and biometric security solutions for smart devices.

(4) Company C was founded in 2007 and is headquartered in Taiwan. It is listed on the Taipei Exchange. The company primarily focuses on biometric authentication technologies, including fingerprint sensors, biometric security solutions and related IC design services.

(5) Company D was founded in 1985 and is headquartered in California. It is listed on the Nasdaq Stock Market. The company primarily focuses on wireless communication technologies, semiconductor platforms, and chip solutions.

Entry Barriers

Foundation model barriers: First, a first-mover advantage emerges as the development of such models requires sustained, large-scale R&D investment and substantial optimization over time, resulting in high upfront costs and technological barriers for new entrants. Second, the flywheel effect is formed: more user data and feedback leading to better understanding of user intents and lower costs for expansion into new scenarios. This reinforces incumbents' advantages and is difficult for new entrants to replicate.

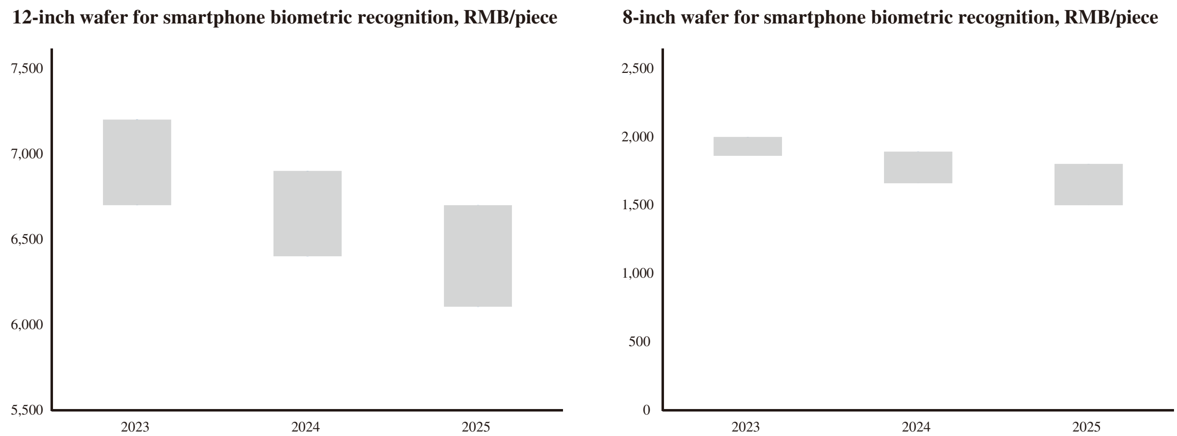
Software-hardware integration barriers: The widespread deployment of perceptual interaction capabilities requires deep integration between algorithms and hardware, as system performance is jointly determined by sensor characteristics, chip architecture, and algorithm efficiency. Key metrics such as accuracy, latency, and power consumption are interdependent and must be optimized at the system level rather than in isolation. As a result, building high-performance perceptual interaction systems requires deep ecosystem collaboration, creating significant entry barriers for new entrants.

Engineering delivery barriers: The commercial success of perceptual interaction solutions depends on the ability to deliver integrated software-hardware solutions at scale in a cost-efficient way. This requires engineering capabilities to convert technologies into deliverable products and solutions. Established players can achieve large-scale deployment through a unified technology foundation, enabling lower marginal costs and creating barriers for new entrants.

ANALYSIS OF RAW MATERIAL PRICES

Wafer is the primary upstream raw material for smartphone biometric recognition. From 2023 to 2025, wafer procurement costs for fingerprint chips decreased steadily, pressured by ongoing foundry capacity expansion and weak smartphone fingerprint demand. 12-inch wafer ASPs fell 4%–6% annually, reflecting persistent oversupply in standard logic capacity. 8-inch wafer ASPs experienced steeper erosion as demand for low-end capacitive fingerprint solutions contracted. By late 2025, the downward cycle began to stabilize as foundry utilization rates improved, leaving limited headroom for further price concessions. The chart below illustrates trends in the price range of wafers for fingerprint chips from 2023 to 2025.

Wafer Price Index in China, 2023–2025



Source: Frost & Sullivan

SOURCE OF INFORMATION

We have commissioned Frost & Sullivan, an independent market research and consulting company, to conduct an analysis of, and to prepare a report on the perceptual interaction solutions market in China. The report prepared by Frost & Sullivan for us is referred to in this document as the Frost & Sullivan Report. A total fee of RMB600,000 was paid to Frost & Sullivan for the preparation of the report, which we believe reflects market rates for reports of this type.

Frost & Sullivan is a global consulting company founded in 1961 in New York and has over 40 global offices with more than 2,000 industry consultants, market research analysts, technology analysts and economists. The Frost & Sullivan Report was prepared through both primary and secondary research obtained from various sources using intelligence collection methodologies. Primary research involved discussing the status of the industry with certain leading industry participants across the industry value chain and conducting interviews with relevant parties to obtain objective and factual data and prospective predictions. Secondary research involved information integration of data and publication from publicly available sources, including official data and announcements from government agencies, company reports, independent research reports and data based on Frost & Sullivan's own data base.

In compiling and preparing the Frost & Sullivan Report, Frost & Sullivan has adopted the following assumptions: (i) the social, economic and political environment in the world and China is likely to remain stable in the forecast period; and (ii) industry key drivers are likely to drive the growth of the perceptual interaction solutions market in China in the forecast period. All statistics are based on the information available as at the date of the Frost & Sullivan Report.