International Journal of Computer Science and Information Technology
ISSN: 3005-9682 (Print), ISSN: 3005-7140 (Online) | Volume 8, Number 6, Year 2026
DOI: https://doi.org/10.62051/ijcsit.v8n6.07
Journal homepage: https://wepub.org/index.php/IJCSIT/index

Practical Value and Optimization Directions of Sensor Intelligent Perception Scheme on STM32 Platform

Yuxiang Li

College of Control Science and Engineering, China University of Petroleum (East China), Qingdao, China

ABSTRACT

Analyze the practical value and optimisation directions of sensor intelligent perception schemes based on the STM32 platform in this paper. STM32 is not only a low-cost control chip but also suitable for implementing integrated sensing and local processing, as well as communication and lightweight intelligent decision-making in embedded systems, as this paper explores. Based on smart sensor theory, Internet of Things architecture, multisensor fusion studies and recent STM32 artificial intelligence tools, this essay explores the prospects of STM32-based schemes for real-time response, deployment flexibility, system integration and edge-side data utilization. The following are the general optimisation directions of such schemes: sensor selection, interface coordination, fusion algorithms, energy management, memory optimisation, edge AI deployment and reliability enhancement. Therefore, the value of STM32-based intelligent perception lies not only in hardware cost but also in the combined design of a sensing architecture, embedded computing resources and application-specific optimisation strategies.

KEYWORDS

STM32; Intelligent perception; Smart sensors; Sensor fusion; Embedded systems; Edge intelligence

1. INTRODUCTION

Smart perception by sensors is now one of the directions for embedded systems. For applications such as environmental observation, industrial control, smart homes, wearables, edge devices, etc., a signal collection unit is not necessary in the sensing module in practice. They need to perform local pre-processing, feature extraction, state recognition and rapid response in a resource-constrained environment more often. Therefore, a microcontroller will be used to build the perception module.

Among the general embedded systems, STM32 is relatively popular because of its good performance, many peripherals, low-power features and a rich development toolchain. Therefore, it is often used for sensor interfacing, real-time acquisition and local control, and is now also applied in lightweight intelligent devices. However, the actual value of STM32-based intelligent perception is not guaranteed by the choice of hardware. It is determined by the combined sensing architecture, software strategy and optimisation logic.

This paper studies the practical applications and optimisation paths for sensor intelligent perception schemes on the STM32 platform. STM32 should be considered a general-purpose control chip that can also perform edge computing and integrate sensing, computation and communication, etc. Based on the above, this paper introduces the concept of smart sensing, explores the practical value of STM32 perception schemes, and suggests future directions for optimisation in embedded systems at present.

2. CONCEPTUAL BACKGROUND OF SMART SENSING ON STM32

At the foundation of an intelligent perception scheme is the development trend of ordinary sensors into smart sensor systems. Meijer believes that smart sensor systems should combine sensing modules, interface circuits, signal-conditioning and calibration components, embedded processors, etc., into a coordinated system rather than a simple measurement chain [1]. This view can be directly applied to the STM32-based design because the STM32 platform usually serves as the processing and coordination core of a system that incorporates multiple discrete sensor modules for local intelligence.

Yurish also provided a related practical perspective by considering the design of a smart sensor system as the integration of sensing, interfacing, buses and system-level architecture [2]. It is required for STM32 applications that, in terms of the quality of intelligent perception, timing control, conversion accuracy, bus compatibility and organisation of embedded resources, all play a vital role alongside the sensor itself. An STM32-based scheme is more effective when the above components are integrated rather than added separately.

Gubbi and his colleagues have expanded the scope of application for this study by introducing the Internet of things, which is an interconnected network of sensing, communication and service-integrated objects [3]. Therefore, in this environment, the STM32 is no longer only for data acquisition. It is generally an edge node that collects signals, makes local decisions and then prepares the collected information for transmission or cooperation with the upper-level system.

Al-Fuqaha and others have also shown that Internet of Things systems are based on enabling technologies, protocols and application-oriented design choices [4]. This reason is that the STM32 intelligent perception scheme should not be judged solely on its local sensing capabilities. Its actual application will also be affected by the support for communication protocols, distributed architecture and application constraints.

Collectively, the above views show that STM32-based intelligent perception falls under the general category of smart sensors and edge-connected systems. For the platform to be more practical, it should be possible to perform coordinated sensing, embedded computing and task-oriented communication in a single constrained-but-flexible node.

It can also be seen that the perception scheme of STM32 should be analysed at the system level, not just at the component level. A high-tech sensor connected to a messy embedded system will not be an intelligent perception system by itself. Intelligence is the organisation of measurement, processing and response into a coherent embedded workflow. STM32 is thus suitable for this purpose because it can serve as the core that integrates sensing logic, timing logic and decision logic.

3. PRACTICAL VALUE OF STM32-BASED INTELLIGENT PERCEPTION SCHEMES

The first is system integration in practice. STM32 microcontrollers have many interfaces, timers, analogue modules and communication ports, so they can be used for various sensing tasks in an embedded system. In line with the logic of the smart sensor system proposed by Meijer and Yurish, measurement, conditioning, processing and coordination are considered as a whole system problem rather than separate hardware stages [1, 2].

A second practical purpose is edge-side real-time processing. Often, all the raw data from intelligent perception do not need to be sent to an upper-level system. Gubbi and his colleagues have described IoT environments that integrate sensing, communication and distributed computing for connected applications [3]. The following is supported on STM32 platforms: filtering, threshold judgment, feature extraction, local alarm generation, and control-loop feedback before cloud or gateway transmission.

A third practical purpose is support for multi-sensor fusion. Mendes and others have explored smart sensors and sensor fusion techniques for sports and biomedical applications to combine data from several sources [5]. Kong and others have been studying multiple-sensor measurement and data-fusion technology for production-process monitoring, paying attention to the integration of heterogeneous measurement data [6]. STM32 platforms are practically applicable here because of their diverse peripherals and interrupt-driven control; they can synchronize many sensors and perform lightweight fusion tasks in real time.

A fourth practical value is the extension of classical embedded control to edge intelligence. Sakr et al. have shown machine-learning inference on popular microcontrollers and specifically used STM X-CUBE-AI to implement artificial neural networks on STM32 Nucleo boards [7]. Merenda and others have studied edge machine learning for resource-constrained IoT devices and shown that inference can be carried out near the data source [8]. Based on the above studies, the STM32-based perception scheme can perform lightweight operations at the device level, such as pattern classification, anomaly detection and event inference.

The fifth is its ease of use. Reviews of multisensor data fusion in smart manufacturing documents various fusion methods for different monitoring and prognosis purposes [9], and the application requirements significantly affect system design. A recent STM32-based smart switch further shows that STM32 is used in small networked control systems that integrate embedded processing and Modbus RTU communication [10]. Therefore, STM32 is suitable for various applications in monitoring and automation, health and building management.

A sixth is the accessibility of development. Sakr and others have shown that the existing toolchain, STM X-CUBE-AI, can be used to implement neural network models on STM32 Nucleo boards [7]. Tool support for embedded developers can reduce the implementation gap between trained models and device-side inference. Therefore, the actual application will be limited by the availability of mature development tools and other hardware functions.

The seventh is modular scalability in practice. Because the STM32 platform offers many high- and low-end performance levels and packages, it is often possible to move an application from a simple node to a more powerful one with only minor changes to the software and interface. This can help engineers perform iterative optimisation and staged deployment of the product or system without a full redesign. Scalability in sensor intelligence schemes can reduce the cost of experimentation and enhance the feasibility of long-term maintenance.

According to the above data, the STM32 intelligent perception scheme is suitable for this purpose because it has sufficient processing power and numerous interfaces; at the same time, it is low-power and supports embedded intelligence. They help to convert sensing nodes into responsive, structured and application-ready edge units.

4. MAIN OPTIMIZATION DIRECTIONS

The first optimisation direction is sensor selection and interface matching. Literature on smart sensor design shows that the overall effectiveness of a system depends on the compatibility of the sensing principle, conditioning circuit, sampling path and embedded controller resources [1, 2]. On the STM32 platform, attention must be paid to ADC accuracy, communication buses such as I2C, SPI, UART or CAN, interrupt behaviour and timing requirements. A perception scheme cannot be considered intelligent if the sensing layer is unstable or incompatible with the MCU architecture.

The second optimization direction is multisensor fusion strategy. Mendes and his co-authors, as well as Kong and his group, believe that the quality of fusion depends on how heterogeneous signals are synchronised, filtered and interpreted [5-6]. STM32-based systems are therefore expected to address optimisation problems in sampling alignment, noise suppression, feature-level integration and decision-level fusion. Given the resource constraints of embedded systems, it may be more practical to use a less complex fusion level.

The third optimisation direction is communication and architecture coordination. Research on the Internet of things indicates that sensing nodes function within a large-scale protocol and service system rather than independently [3-4]. Therefore, the perception schemes of STM32 need to be improved to enable local sensing and stable packet transmission, gateway compatibility, latency control, and distributed collaboration. The quality of perception in practice is directly related to the System's connection level.

The fourth optimisation direction is memory and computation efficiency. The first problem of edge machine learning is resource limitations. Sakr et al. evaluate machine-learning inference on mainstream microcontrollers, such as STM32 Nucleo boards, and Merenda et al. review techniques for executing machine-learning models on resource-constrained edge devices [7, 8]. For STM32-based perception schemes, therefore, when selecting or deploying a lightweight model, its model size, memory footprint, inference latency and computational cost should be considered together.

The fifth optimisation direction is energy saving. Power budget directly limits the application scope and lifespan of some sensors in mobile and distributed node environments. STM32 platforms are generally selected because they have good low-power modes, but to realise actual power saving, software scheduling, wake-up strategies, duty cycling and peripheral management are required. Therefore, the intelligent perception scheme should also optimise energy-aware execution in addition to algorithmic accuracy.

The sixth optimisation direction is reliability and maintainability. Review of Smart Manufacturing Fusion Solutions indicates that there are diverse demands for data acquisition, preprocessing and fusion in industrial monitoring systems [9]. Therefore, the reliability requirements for STM32-based implementations include fault tolerance, calibration preservation, noise immunity, firmware upgrade mechanism and modular structure. STM32-based implementations will thus have better fault tolerance, calibration management, noise immunity, firmware upgrade logic and modularity. Optimisation is not complete if the system works well only in the lab.

The seventh direction of optimisation is the coordination of classical algorithms and lightweight AI. Many STM32 applications still use filtering, threshold logic and handcrafted features because they are interpretable and computationally simple. The new AI tools for STM32 have not removed this logic but have added another kind to the hybrid architecture. Strong optimisation in practice often involves combining the traditional signal-processing stage with a compact learned model so that only essential inference at the edge is performed by the MCU.

All of the above show that optimisation in STM32 is not achieved by adjusting single parameters. It is a combined design problem for sensing hardware, embedded software, fusion logic, communication structure, computational constraints and extended-life operation.

5. DEVELOPMENT TREND AND APPLICATION IMPLICATIONS

The actual path of STM32-based intelligent perception is deeper edge computing. With the spread of the Internet of Things (IoT), sensing nodes are expected to carry out local decision-making, event compression and context-aware responses in addition to data collection [3, 4]. Thus, STM32 is likely to be used as an edge-AI computing platform for sensing, rather than a traditional controller.

Another problem is that lightweight intelligence has gradually been developed. Research on machine learning for microcontrollers shows that resource-constrained devices can run light-weight inference workloads when models and deployment methods are adapted to hardware limitations [7, 8]. Therefore, the future perception scheme of STM32 will probably be a combination of classical control logic and compact neural networks, handcrafted features, and hybrid decision strategies.

Another problem is that universality and specialisation are not in harmony. Reviews of multisensor fusion show that high-value perception systems are generally optimised for specific scenarios, signal characteristics and decision requirements, and are not built as general-purpose platforms [5, 6, 9]. Therefore, the best STM32 intelligent perception scheme is rarely the most complicated one. It is the one with the most suitable architecture, sensing combination and embedded intelligence for the demands of the application.

Thus, a different kind of practical value is expected. Cost is still necessary, but it is no longer an adequate measure. A low-cost STM32 scheme will have better practical value if the design supports a fast local response, reduces unnecessary transmission, is stable in sensing, and is feasible under application constraints. Optimisation should always be in the interest of the aim of use, not only based on hardware specifications.

Finally, STM32-based intelligent perception has educational and industrial applications at the same time. The toolchain is relatively accessible, so the start of embedded AI research is easier, and the ecosystem has been developed sufficiently for real-world applications. The two functions can help explain why STM32 is still widely used in the development of actual sensor intelligence.

Therefore, the level of requirements for the construction conditions has been raised. Future STM32 perception systems will be judged less on the quantity of connected sensors and more on the quality of local intelligence they can provide under constrained circumstances. In other words, its actual applications will depend on whether the node can convert the raw sensing data into timely, reliable and scenario-aware decisions at a reasonable energy and memory cost.

6. CONCLUSION

Sensor intelligent perception schemes on the STM32 platform can offer practical value by integrating sensing, embedded computing, communication and lightweight intelligence in a deployable edge architecture. Their advantages are not only relatively low hardware costs but also the capacity for real-time processing, multi-sensor cooperation and application-oriented embedded decision-making.

This paper has proposed that the optimisation of STM32-based intelligent perception should focus on sensor matching, fusion strategy, communication design, computational efficiency, energy control and operational reliability. The above reasons will determine whether the perception system is only a technical structure or actually constitutes an intelligent system.

Therefore, the future development direction of STM32 intelligent perception should be to enhance system coordination and edge-side optimisation. A good Design of STM32 is not about building an expensive high-end platform; rather, it aims to provide energy-efficient and flexible intelligence within the constraints of embedded systems.

REFERENCES

[1] Meijer, G. C. M. (Ed.). (2008). Smart sensor systems. John Wiley & Sons.

[2] Yurish, S. Y. (2008). Smart sensors systems design. IEEE Sensors Council Tutorial.

[3] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7), 1645-1660.

[4] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. IEEE Communications Surveys & Tutorials, 17(4), 2347-2376.

[5] Mendes Jr., J. J. A., Vieira, M. E. M., Pires, M. B., & Stevan Jr., S. L. (2016). Sensor fusion and smart sensor in sports and biomedical applications. Sensors, 16(10), 1569.

[6] Kong, L., Peng, X., Chen, Y., Wang, P., & Xu, M. (2020). Multi-sensor measurement and data fusion technology for manufacturing process monitoring: A literature review. International Journal of Extreme Manufacturing, 2(2), 022001.

[7] Sakr, F., Bellotti, F., Berta, R., & De Gloria, A. (2020). Machine learning on mainstream microcontrollers. Sensors, 20(9), 2638.

[8] Merenda, M., Porcaro, C., & Iero, D. (2020). Edge machine learning for AI-enabled IoT devices: A review. Sensors, 20(9), 2533.

[9] Tsanousa, A., Bektsis, E., Kyriakopoulos, C., Gómez González, A. G., Leturiondo, U., Gialampoukidis, I., Karakostas, A., Vrochidis, S., & Kompatsiaris, I. (2022). A review of multisensor data fusion solutions in smart manufacturing: Systems and trends. Sensors, 22(5), 1734.

[10] Zagan, I., & Găitan, V. G. (2024). BIoT smart switch-embedded system based on STM32 and Modbus RTU—Concept, theory of operation and implementation. Buildings, 14(10), 3076.