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Smart Water Filling and Bottle Handling using STM32 and IoT

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Abstract

The smart water filling and bottle handling project using STM32 and IoT systems aims to modernize inventory management and production line control. This system uses wireless technology to automate inventory data collection and monitoring, reducing manual data entry and human error. The primary objective is optimizing production line efficiency by maintaining adequate stock levels in a warehouse with a wireless monitoring system. This will enhance the performance and reliability of the entire production line, reduce manufacturing lead time, and benefit the inventory management and manufacturing environment The microcontrollers that have been used are STM32 F3348-DISCO and ESP32 (WROOM) which can process the data from the sensor, collecting and communicating data while the internet of things (IoT) transmits information to a central database for real-time monitoring and analysis using the Blynk application. This project completed the filling process in 20 seconds and the closing process in 4 seconds, taking only 60 seconds to prepare one bottle. This approach will revolutionize the production line operations, ensuring efficiency, accuracy, and smooth data-driven management. Finally, the project can provide easier interaction for production staff.

1. Introduction

Small and medium enterprises (SMEs) are vital to Malaysia's economy and are key to the country's industrial development. They make up 93.8% of manufacturing companies, contribute 27.3% to total output, 25.8% to value-added production, hold 276.6% of fixed assets, and employ 38.9% of the workforce [1]. By 2020, the value of their products was expected to reach RM 120 billion. Despite their significant role, Malaysian SMEs' share of total exports is 20% lower than in other countries.

SMEs significantly contribute to GDP growth in Malaysia, increasing their share from 37.3% in 2016 to 38.9% in 2019[2], with key sectors including agriculture, construction, services, mining, and manufacturing. However, the COVID-19 pandemic has negatively impacted SME growth, and without easing restrictions, a decline is predicted. The expected growth target of 41% is uncertain, as 70% of SMEs do not sustain themselves within ten years. Although Industry 4.0 technologies can enhance production efficiency and competitiveness, their adoption among Malaysian SMEs, particularly in the manufacturing sector, is still low [3].

Production line issues are common in SMEs, with ineffective manual handling being a major problem. Manual manufacturing procedures can slow down production and increase the likelihood of errors. The reliance on manual labor can lead to mistakes and inconsistencies in final products and limit work speed and precision. To address these challenges, SMEs need to adopt automation solutions to reduce manual intervention and improve overall production line efficiency.

The efficiency of bottling systems can be improved by utilizing advanced technologies such as intelligent packaging bottle identification devices. This device incorporates features such as online identification, a weighing system, and image recognition to simplify the bottling process. Moreover, the application of monitoring sensors in complex manufacturing systems, including bottling lines, can detect errors early and improve overall performance [4].

Ensuring the quality of packaged products is very important. Proper sealing mechanisms and cleaning procedures are essential to prevent the carryover of aromas between different types of bottled beverages [8]. In addition, quality control measures, such as image processing to detect impurities in bottled water, can significantly improve product quality and consumer safety [5].

Automation plays an important role in modern bottling systems. Automated monitoring and control systems, such as those based on SCADA technology, can improve operational speed, production costs, and system reliability [6]. Furthermore, the use of a programmable logic controller (PLC) in the fluid mixing process can optimize the control mechanism in bottle-washing operations [7] . Environmental sustainability is another important aspect of bottling systems. Life cycle assessment of packaging products can provide insight into the environmental impact of the bottling process and guide sustainable practices [3].

A volumetric filler is a type of liquid-filling machine that fills containers with liquids [8]. Volumetric is a process of filling bottles by adjusting the height of the liquid, using level-controlled fillers. Current research has been focused on filling bottles using programmable logic controllers (PLC), bottle scheduling in the wine industry, automated liquid filling systems, and bottling scheduling problems.

The WARSCHUM acetone bottling line consists of a filling system, a capping system, and labeling system [9]. For filling systems, nozzles are installed at a certain distance from the filling station, and then conveying is done in star form, moving the bottles from the conveyor belt to the transfer station. When the bottle is filled, the bottle is not in contact with the conveyor belt.

Next, a simple, scalable, and economical automated liquid filling system has been developed in Ghana to address the challenges faced by SMEs in implementing automated systems in their beverage production. The system consists of a microcontroller, servo motor, submersible water pump, relay, LCD, and keypad. It is portable, user-friendly, and can fill twelve 250-mL bottles with water, sobolo (Hibiscus drink), and fruit juice within 21-30 seconds [10].

Production monitoring systems for bottling systems are essential to ensure efficiency, quality control, and compliance with standards. Utilizing technologies such as SCADA, IoT, PLC, RFID, and IoT-based microcontrollers can significantly improve monitoring capabilities in bottling environments [11], [12], [13], [14] These systems can provide real-time data regarding bottle filling levels, automate the liquid filling process, ensure safe supply chain management, and enable remote monitoring and alerts for timely intervention.

Understanding the production process, packaging materials, and transportation logistics is critical to making the right decisions to minimize your environmental impact. Implementing automated systems that can measure the volume of blood in bottles or monitor the stability and sensory quality of wine during transportation can improve product quality and safety measures [15], [16].

In conclusion, optimization of bottling systems involves a multidisciplinary approach that includes material science, automation, quality control, environmental considerations, and advanced technologies. By effectively integrating these aspects, the bottling process can be streamlined, thus ensuring efficiency, quality, and sustainability.

2. Methodology

Figure 1 shows the basic function flow chart and Figure 2 shows the Blynk IoT function. When the system starts, infrared sensor 1 is active, and the conveyor moves. The conveyor approaches the first infrared sensor. After sensor 1 identifies the bottle, the conveyor stops for 20 seconds to start filling, and the bottle enters the capping system. The capping process takes 4 seconds, including the placement of the stamp. Finally, the Blynk dashboard displays the counting process.

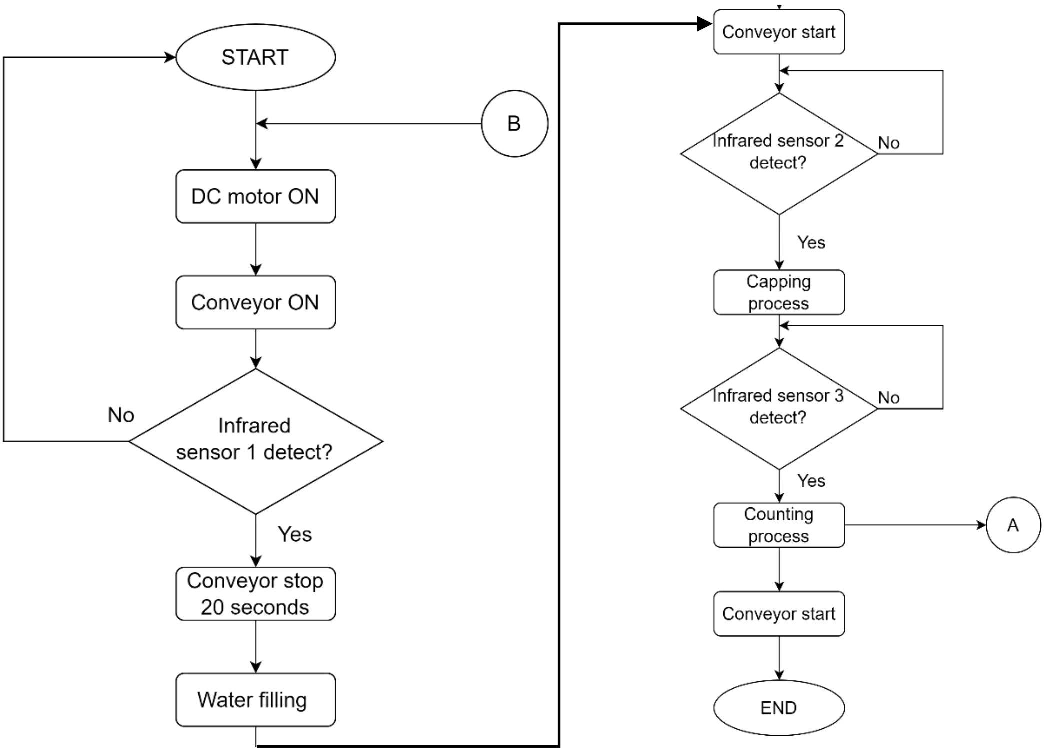

Fig 1: System Flowchart

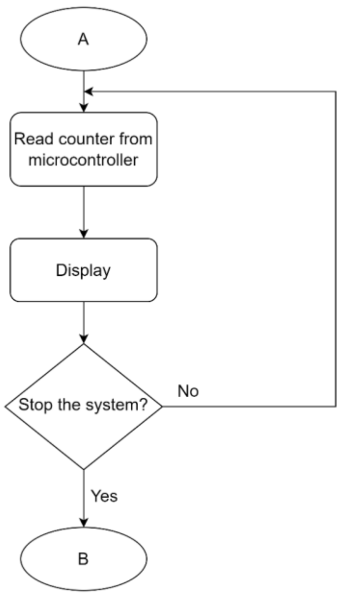

Fig 2: Blynk System Flowchart

Figure 3 illustrates the block diagram of the control system for this project. This system uses the STM32 F3348-DISCO. This project requires an infrared sensor to trigger the conveyor for filling, counting, and closing. This project uses infrared sensors. One for filling and another for capping. When infrared sensor 1 detects a bottle, the conveyor stops for 20 seconds for filling. After 20 seconds, the conveyor runs until infrared sensor 2 detects the bottle, stopping for 4 seconds to cap it. STM32 output sensor and DC motor. The DC motor will control the transmitter using its output signal. The sensor is active when the bottle is on the conveyor. Finally, after counting, the user can monitor using the Blynk app on a smartphone or tablet and stop or interrupt the system if not counting stock.

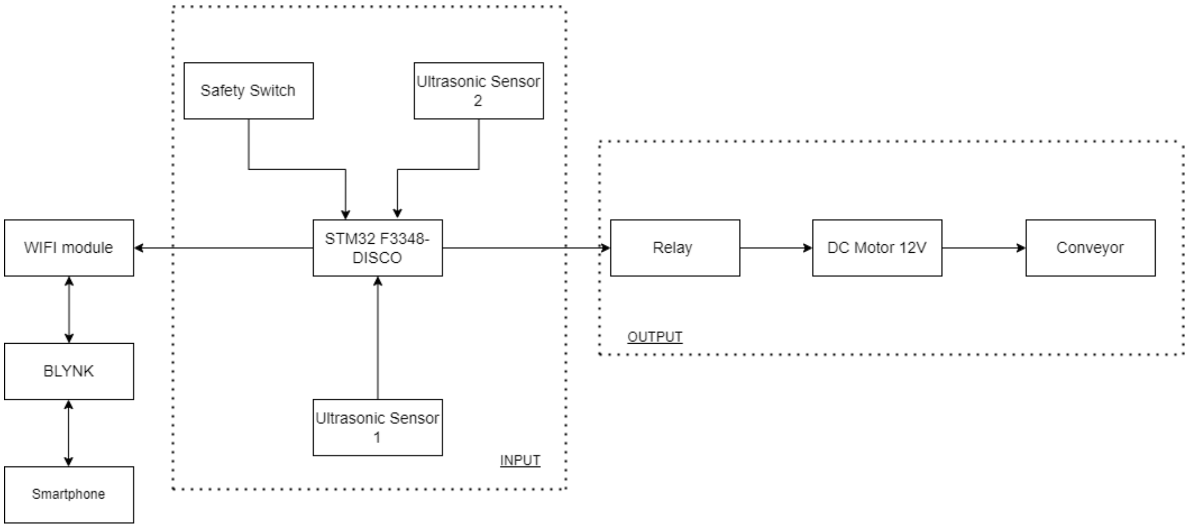

Fig 3: Block diagram of the project

Figure 4 shows the experimental setup of the project. The main controllers for this project are STM32 F3348-DISCO and ESP32. STM32 controls all the systems for autonomous control systems while ESP32 controls for counting process. A battery within 12 V is used as a power supply to supply the conveyor. In this project, it uses 2 infrared sensors. The first infrared sensor will cooperate with STM32 for the filling system while the other one is for the capping system. The sensor will be placed on the conveyor. If the first sensor detects an obstacle on the conveyor, the conveyor will stop for 20 seconds and the filling process take place if the second sensor detects an obstacle on the conveyor, the conveyor will stop for 4 seconds and the capping process will take place. The 12V power supply is used to supply the motor drive and drive the conveyor. Blynk is used to display the stock value after the calculation process.

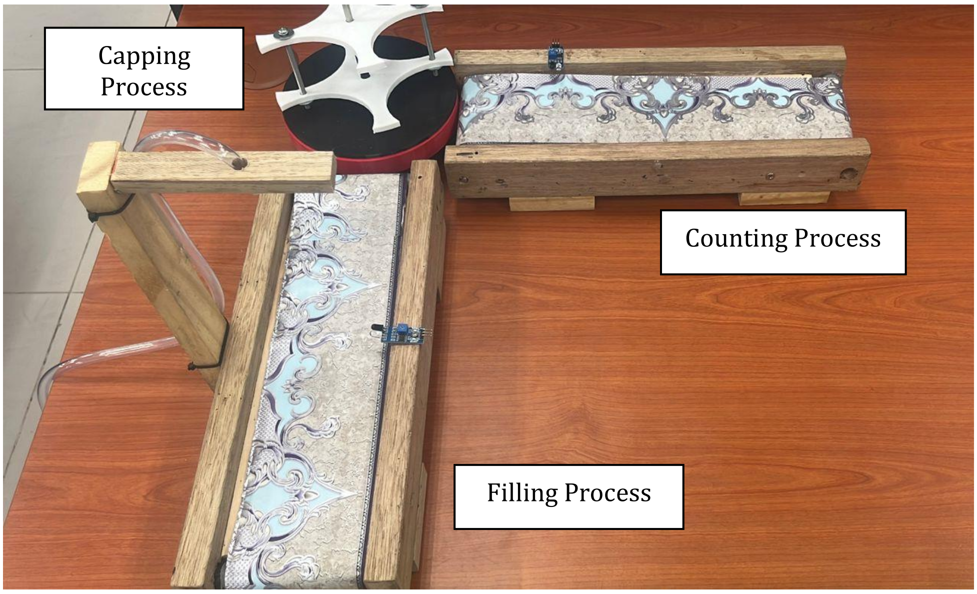

Fig 4: Experiment setup of the project

3. Result

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The results of the bottling system process and discusses its implications for the overall production system. The focus is on the time taken to fill a 500ml bottle with water and how this affects production efficiency. By analyzing these results, it can identify areas that need improvement and suggest potential optimizations to improve the bottling process. Table 1 shows the results of the water-filling process.

Table 1: Results of the water-filling process

Bottle Size (ml)	Level of bottle	Time to Fill (seconds)	Figure
500	Half	10	
500	Full	20	

The table shows how long it takes to fill a 500ml bottle with water. It takes 10 seconds to fill half the bottle (250ml) and 20 seconds to fill the whole bottle (500ml). This means that the machine fills at a rate of 25ml per second. With current capabilities, the developed system is expected to be able to fully fill 180 bottles within 1 hour.

This steady filling rate indicates that the machine is running at a constant speed, resulting in reliability. However, other factors such as liquid viscosity, machine pressure, and nozzle design can affect the filling time.

Maintaining a stable filling rate is critical for production. For example, at this rate to fill 1000 bottles, it takes about 5.56 hours to complete. This shows the need to speed up the process. Increasing the filling pressure, using additional filling heads to fill multiple bottles simultaneously, or integrating an automated system to detect and address any lag can achieve this. Understanding the time, it takes to fill a bottle helps identify areas to improve the production process, making it faster and more efficient. By analyzing and improving the factors that affect fill rate, production goals can be met consistently.

The capping process on the bottling system takes about 4 seconds for each bottle. This consistent timing ensures that the process occurs in the same way every time a bottle is capped, thus maintaining smooth operations on the production line. Stable capping times are critical for efficiency, as they have a direct impact on the overall production flow. Figure 5 and Figure 6 show putting the cp process and capping process.

Fig 5: Putting cap process

Fig 6: Capping process

Each bottle takes about 4 seconds to close, including putting the cap on the bottle and tightening it tightly to prevent spillage. This fixed duration for closure aligns with the time taken to fill the bottle. For a full 500ml bottle, the filling process takes approximately 20 seconds. With capping taking an additional 4 seconds, the production line can organize the workflow efficiently, producing many bottles every hour.

Maintaining a consistent capping time helps the production line run efficiently. The capping process closely matches the bottle filling time, creating a synchronized and efficient production rhythm. This efficiency ensures the maximum number of bottles that can be produced in each timeframe, thus contributing to the overall productivity of the bottling system.

The results and implications of the counting process using Blynk on a bottling system. The focus is on how effectively Blynk helps count bottles as they move along the conveyor belt. Figure 7 shows a dashboard of Blynk on a laptop while Figure 8 shows a dashboard of Blynk on a mobile phone.

Based on the figure, it shows that Blynk can accurately count the bottles as the pass through the sensors. Over multiple trials, the counting process was consistent, with minimal errors. This reliability ensures that the production line can accurately track the number of bottles produced. The consistency of counting supports the efficiency and reliability of the production process.

The accurate and real-time counting provided by Blynk contributes to improved production efficiency. By accurately counting the number of bottles produced, manufacturers can better manage inventory, track production rates, and identify potential bottlenecks in the production process. This precise tracking helps in planning and optimizing the overall production workflow.

Blynk integrates seamlessly with existing production lines, making it easy to integrate into bottling systems. Its easy-to-use interface and compatibility with various sensors and devices make it a valuable tool for automated counting in industrial environments. The ease of integration and use ensures minimal disruption to the production process and facilitates efficient counting.

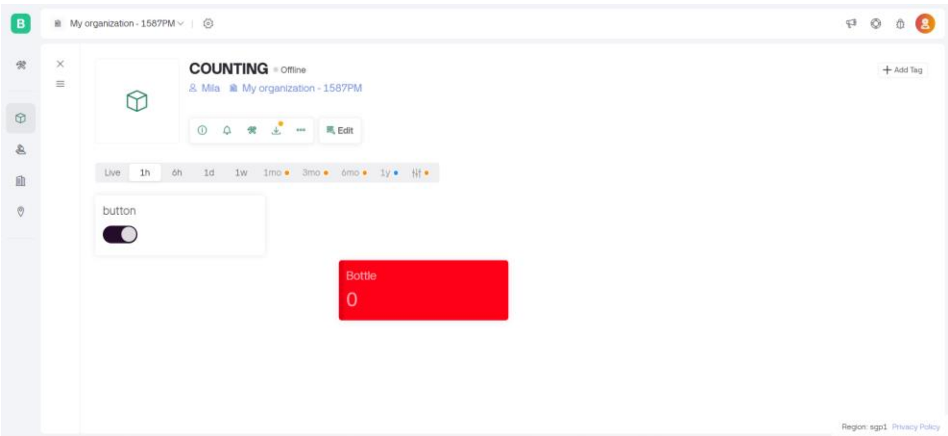

Fig 7: Dashboard Blynk on a laptop

Fig 8: Blynk on a mobile phone

The entire bottling process, from bottle travel on the conveyor to filling and capping, and its impact on production line efficiency. The process starts with the bottle carried by the conveyor and it takes 3 seconds to reach the first sensor, which detects the presence of the bottle. Once detected, the water filling process begins, taking 10 seconds to fill half the bottle (250ml) and 20 seconds to fill the entire bottle (500ml) with a constant filling rate of 25 ml per second. Once filled, the bottle will move to the next station for the capping process which takes 4 seconds per bottle.

Consistent timing at each step of the process - 3 seconds to reach the sensor, 20 seconds to fill the bottle, and 4 seconds to cap it - ensures a smooth workflow. The overall time to process one bottle is about 25 seconds. This time helps in planning production capacity, which means it can produce around 144 bottles per hour.

To make the process more efficient, can use an automated system to check if the bottles have been filled and capped correctly. Also, the use of machines that can fill and cap more than one bottle at a time will speed up the production process.

4. Conclusion

In conclusion, the implementation of an automated water bottling system with IoT-based real-time monitoring significantly enhances the efficiency and accuracy of SME production lines. The system reduces manual handling errors, improves production speed, and optimizes inventory management. Future recommendations include expanding the system's capabilities to handle different types of products and integrating more advanced sensors for further efficiency gains. The successful deployment of this system positions SMEs to be more competitive in the industry by leveraging Industry 4.0 technologies.

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References

[1] P. W. Rusimamto *et al.*, "Fluid Mixing Process Based on Programmable Logic Controller as Training Kit for Electrical Engineering Education Students," *International Journal of Integrated Engineering*, vol. 13, no. 4, May 2021, doi: 10.30880/ijie.2021.13.04.009.

[2] A. Eh Poon, N. H. Roslan, J. Othman, A. Anuar, and M. Yousefi Nejad, "The Effect of Enterprise Risk Management (ERM) Implementation on SMEs Performance in Malaysia," *Malaysian Journal of Social Sciences and Humanities (MJSSH)*, vol. 7, no. 4, p. e001460, Apr. 2022, doi: 10.47405/mjssh.v7i4.1460.

[3] A. P. H. Wong and D. M. H. Kee, "Driving Factors of Industry 4.0 Readiness among Manufacturing SMEs in Malaysia," *Information (Switzerland)*, vol. 13, no. 12, Dec. 2022, doi: 10.3390/info13120552.

[4] M. Rivas Pellicer, M. Y. Tungekar, and S. Carpitella, "Where to Place Monitoring Sensors for Improving Complex Manufacturing Systems? Discussing a Real Case in the Food Industry," *Sensors*, vol. 23, no. 7, Apr. 2023, doi: 10.3390/s23073768.

[5] H. Liu, "Detection of the impurities in bottled mineral water based on computer vision system," in *Journal of Physics: Conference Series*, IOP Publishing Ltd, Sep. 2021. doi: 10.1088/1742-6596/2031/1/012038.

[6] "Smart Control and Monitoring of Bottle Filling System Based on SCADA," *International Journal of Recent Technology and Engineering*, vol. 8, no. 2S11, pp. 2117–2119, Nov. 2019, doi: 10.35940/ijrte.B1214.0982S1119.

[7] P. W. Rusimamto *et al.*, "Fluid Mixing Process Based on Programmable Logic Controller as Training Kit for Electrical Engineering Education Students," *International Journal of Integrated Engineering*, vol. 13, no. 4, May 2021, doi: 10.30880/ijie.2021.13.04.009.

[8] M. Ali, B. Salah, and T. Habib, "Utilizing industry 4.0-related technologies and modern techniques for manufacturing customized products – Smart yogurt filling system," Journal of Engineering Research, p. 100144, Jul. 2023, doi: 10.1016/j.jer.2023.100144.

[9] Asset Packaging Machines PTY LTD, "How Does A Volumetric Filling Machine Work?," ASSET (Fillers Cappers Conveyers). Accessed: Jun. 11, 2024. [Online]. Available: https://assetpackaging.com.au/articles/how-does-a-volumetric-filling- machine-work/#%3A~%3Atext%3DA%20volumetric%20filler%20is%20a%2Cof%20the%20container%20being%20filled

[10] Y. Mashayekhy, A. Babaei, X. M. Yuan, and A. Xue, "Impact of Internet of Things (IoT) on Inventory Management: A Literature Survey," Logistics, vol. 6, no. 2. MDPI, Jun. 01, 2022. doi:10.3390/logistics6020033.

[11] "Smart Control and Monitoring of Bottle Filling System Based on SCADA," International Journal of Recent Technology and Engineering, vol. 8, no. 2S11, pp.2117–2119, Nov. 2019, doi: 10.35940/ijrte.B1214.0982S1119.

[12] Anand J, Gowtham H, Lingeshwaran R, Ajin J, and Karthikeyan J, "IoT Based Smart Electrolytic Bottle Monitoring," 2021. doi: 10.3233/APC210163.

[13] O. Abdullah, W. Abbood, and H. Hussein, "Development of automated liquid filling system based on the interactive design approach," FME Transactions, vol. 48, no. 4, pp. 938–945, 2020, doi: 10.5937/fme2004938A.

[14] A. Sharif et al., "Making assembly line in supply chain robust and secure using UHF RFID," Sci Rep, vol. 11, no. 1, Dec. 2021, doi: 10.1038/s41598-021-97598-5.

[15] P. F. Tchouakeu Betnga, E. Longo, S. Poggesi, and E. Boselli, "Effects of transport conditions on the stability and sensory quality of wines," OENO One, vol. 55, no. 2, Apr. 2021, doi: 10.20870/oeno-one.2021.55.2.4524.

[16] C. Emeraud, S. Yilmaz, N. Fortineau, G. Cuzon, and L. Dortet, "Quality indicators for blood culture: 1 year of monitoring with BacT/Alert Virtuo at a French hospital," J Med Microbiol, vol. 70, no. 3, Mar. 2021, doi: 10.1099/jmm.0.001300.