BREAKBULK AMERICAS

BerthFlow: IoT-Driven Automated Berthing to Enhance Port Efficiency

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Abstract

This research investigates the integration of Internet of Things (IoT) technologies and automated berthing systems, focusing on Automatic Mooring systems (AMS) and the Shore Tugboat Control Station (STCS), to revolutionize port operations. Utilizing real-time data from IoT devices such as LiDAR for precise spatial mapping and Inertial Measurement Units (IMUs) for motion tracking, the STCS manages a coordinated fleet of autonomous tugboats and automated mooring systems. This integration reduces berthing times, minimizes human intervention, enhances operational safety, optimizes resource utilization, and supports the development of sustainable, smart port operations. The study explores the implications of these advancements for port operators and stakeholders, highlighting their potential to lower operational costs, increase port throughput, and align with environmental and safety regulations. Through case studies and performance analysis, the research demonstrates how such technologies can transform traditional port logistics into a more efficient and reliable system, paving the way for future maritime logistics and management innovations.

IoT Devices in Autonomous Berthing

IoT devices are crucial in transforming traditional berthing operations into autonomous processes by providing real-time data and precise control. Key technologies like LiDAR, IMUs, and the (STCS) enable accurate navigation, obstacle detection, and coordinated vessel alignment. These devices enhance safety, efficiency, and reliability in complex port environments.

Figure 1: Illustration of IoT devices working together to provide comprehensive port operational insights.

Figure 2: Lidar combined with Wit Motion 9-Axis Sensor (adapted from Sawada & Hirata, 2023)

LiDAR Systems:

Function
- Use laser pulses for high-resolution mapping.

Application
- Enable precise navigation and docking maneuvers.

Figure 3: Witmotion.com *9-Axis Sensor*

Inertial Measurement Units (IMUs):

Function
- Measure the ship's movement in three axes (acceleration, angular velocity).

Application
- Provides real-time orientation data for precise maneuvering during docking.

MOSES PROJECT: Case Study

The MOSES Project is a European Union funded project that aims to improve various aspects related to ocean shipping in European ports via the adoption of the MOSES AutoDock system in conjunction with other IoT-driven technologies that will assist in autonomous berthing of ocean vessels aims to decrease docking times by up to 20%.

Consisting of 17 partners from 7 European countries, and involving everyone from engineers to end users, the MOSES consortium's end goal is to address the strain related to the global supply chain, ultimately decongesting ports, reduce pollutants related to ocean shipping, reduce the time required to dock/undock, increase safety measures, and improve throughput.

The project consists of three components related to optimizing port operations:
- Innovative Feeder Vessel and Robotic Container-Handling System
- AutoDock
- Matchmaking Logistics Platform

Figure 4: MOSES Concept. Source: (Kanellopoulos et. al)

Figure 5: MOSES Concept. Source: (Kanellopoulos et. al)

STCS: Central Hub for Tugboat Operations

The Shore Tugboat Control Station (STCS) is the central hub for managing autonomous tugboat operations. It integrates data from various IoT devices, such as LiDAR, IMUs, and cameras installed on the tugboats. The STCS allows remote operators to oversee and control the tugboat swarm in real-time, ensuring precise navigation and efficient docking. It provides a comprehensive interface that displays real-time data, including vessel positions, weather conditions, and system status, allowing for proactive decision-making and seamless coordination.

Communication
- Interfaces with automated mooring systems and Vessel Traffic Service (VTS)
- Synchronizes tugboat movements and mooring operations

Operational Efficiency
- Minimizes the need for human intervention
- Reduces berthing times

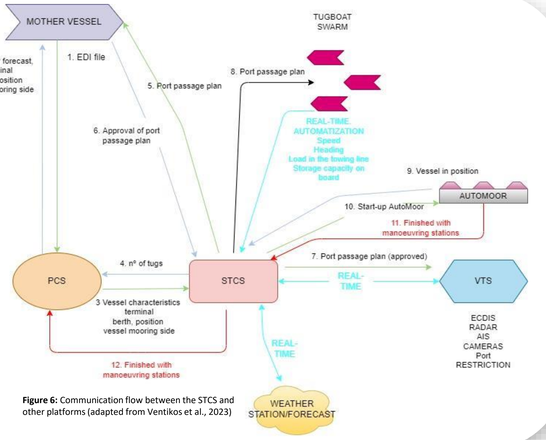

Figure 6: Communication flow between the STCS and other platforms (adapted from Ventikos et al., 2023)

Redefining Berthing with AMS and STCS Integration

Traditional mooring methods are labor-intensive, pose safety risks, and are inefficient for modern port operations. Trelleborg's AMS, integrated with the Shore Tugboat Control Station (STCS), offers a state-of-the-art solution that streamlines berthing processes. By automating the mooring process with advanced vacuum technology, AMS secures vessels without ropes, reducing berthing times and minimizing manual intervention. This innovative system boosts operational efficiency and safety and positions ports as leaders in adopting cutting-edge technology, making them more attractive to shipping partners and investors focused on long-term value.

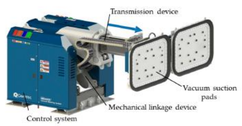

Figure 7: The components of automated vacuum mooring systems (adapted from Yan et al., 2022)

Control System
- Centralizes mooring system operation and management, coordinating component actions.

Transmission Device
- Transfers mechanical power and control signals from the control system to vacuum suction pads.

Mechanical Linkage Device
- Links transmission device to vacuum suction pads, allowing controlled movement and adjustments.

Vacuum Suction Pads
- Securely attach to the vessel's hull using vacuum pressure, replacing traditional ropes.

Figure 8: Trelleborg AutoMoor mooring systems single suction cup (adapted from Yan et al., 2022)

High Efficiency
- Completes mooring in less than 60 seconds and de-mooring in under 30 seconds.

Safety and Control
- Constructed with high-strength materials and supports remote operation for safe management.

Foundation and Mounting
- It is suitable for surface-mounted concrete or steel foundations, ensuring secure installation in various port infrastructures.

Impact Evaluation

Emissions Reduction Highlights

- **Significant Emission Reductions:** Automated vacuum mooring systems have shown over 98% reduction in CO_2 emissions compared to traditional rope mooring methods in ports like Salalah, Beirut, and Ngqura.
- **Operational Efficiency:** Over a decade (2009-2019), these systems have collectively reduced nearly 9.4 million tons of CO_2 emissions, demonstrating their long-term sustainability benefits.
- **Global Impact:** Adopting automated systems in various ports contributes to substantial environmental improvements, aligning with international efforts to reduce the maritime industry's carbon footprint.

Ports	AE Ropes	AE AMS	AER	N° TEUs	AE Ropes TEU	AEAMS TEU	TERTEU
Salalah	721,880	12,030	709,850	268,217	2.7	0.05	2.6
Beirut	245,890	4090	241,800	99,866	2.5	0.04	2.4
Ngqura	252,160	4200	247,930	55,918	4.5	0.07	4.4
Media	406,643	6773	399,860	141,334	2.9	0.05	2.9

Table 1: Calculating emissions with ropes and an AMS and emissions reduction per TEU. Monthly decrease in CO2 emissions (results in kilograms of CO2) (adapted from Navamuel et al.)

Operational Efficiency

Integrating STCS and AMS technology reduces the time required for berthing by up to 25%, optimizing vessel maneuvering and minimizing delays. This efficiency extends the operational hours of tugboats, lowers fuel consumption, and enhances port service capacity, contributing to overall cost savings and reduced environmental impact.

Conclusion

As global trade continues to grow, ports face growing pressure to accommodate the surge in ocean shipping volumes. The impact of IoT-driven technologies can significantly benefit the berthing process, leading to less congestion, reducing idle times and fuel consumption, leading to economic and environmental benefits. Backed by government funded research over the course of 2020-2023, the autonomous berthing aspects of the MOSES project have proved to successfully contribute to sustainability efforts and increase port efficiency compared to traditional shipping practices. For future research considerations, ports around the world can follow in the footsteps of those that contributed to the MOSES project, enhancing their own operational capabilities while moving towards a better future for all.

References

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