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Indoor Localization Solutions for a Marine Industry Augmented Reality Tool

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Abstract

In this report are described means for indoor localization in special, challenging circumstances in marine industry. The work has been carried out in MARIN project, where a tool based on mobile augmented reality technologies for marine industry is developed. The tool can be used for various inspection and documentation tasks and it is aimed for improving the efficiency in design and construction work by offering the possibility to visualize the newest 3D-CAD model in real environment. Indoor localization is needed to support the system in initialization of the accurate camera pose calculation and automatically finding the right location in the 3D-CAD model. The suitability of each indoor localization method to the specific environment and circumstances is evaluated.

Keywords:

Indoor localization, marine industry, augmented reality, 3D-CAD model

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1 INTRODUCTION

1.1 Localization in Augmented Reality

An augmented reality system must be able to align the augmented, virtual content with real world. For this the location of the system must be known with high accuracy. This includes especially the camera, but also the display, especially if a see-through head-mounted display system (HMD) is used. This alignment is often called *registration* of the system. The exact location and direction of view of the system is known as the *pose*. To keep the system registered, we do *tracking*, which is a continuous process of determining the pose when the system moves in the environment.

When an AR system is starting up, it must be initialized by determining the pose. For this it must be first positioned; that is, the approximate location must be determined, and then certain computer vision algorithms can be used to do the exact matching of the real world to the virtual model in the system.

This document handles different means for determining the approximate location.

Approximate location may mean "in which room we are" or "in which part of the large space we are". For good usability, this should be determined more or less automatically so that the user would not have to concentrate on such a secondary task as defining the current location. A number of indoor positioning systems (IPS) based on various technical solutions do exist, but making use of such systems may not always be practical. For instance, in the construction phase of a ship there are limitations on what kind of systems can be installed.

It seems natural to combine some automatic positioning tools and manual methods of position input. This document describes a number of possible approaches and tries to analyze the feasibility of each of them as well as to find efficient combinations.

1.2 Specific challenges and requirements in ship construction environment

An important target for a system to be used at a construction site is to design equipment which automatically knows all the time where the user is, while user can move around in the ship or site. The ship and shipyard environment set difficult challenges for the implementation and technologies. A lot of metallic structures (walls etc.) are used and those impact heavily on radio signal propagation, magnetic and electrical fields. Also the environment is changing all the time during construction as new structures, modules and equipment, furniture are installed into the ship. This means additional challenge to all fingerprinting techniques i.e. those that are based on comparing the properties of magnetic field, radio signal propagation, soundscape or other signals to a predefined map of such signals.

The accuracy of the system must be high enough. System must be able to tell in which room or corridor the user is. Current approximation is that accuracy of 1–2 meters would be enough, but that basically still gives the error possibility e.g. that the system defines the location to the wrong side of the wall. It is not always enough to know the place where the user is. Knowing also direction where the camera is pointing or user is looking at would be very useful and make the camera pose initialization procedure faster.

An important requirement is that the equipment must be light, so easy to carry with and actually the target is that no additional equipment would be needed due to this coarse positioning but the otherwise existing equipment (smartphone or tablet computer) would be used.

Similarly as with the carried equipment the additional infrastructure or system needed should be minimized and aim is to use something that exists anyway for other uses. It depends of course on the cost and work amount for installation, if something specific is acceptable.

Indoor localization is a growing area, where many different types of solutions are being studied and developed. Below are listed the key requirements needed to be taken into account when developing the system for professional engineering tool used in ship or other construction project.

- General safety requirements must be fulfilled.
- Metallic environment (magnetic and electric fields distorted) must be tolerated

- Continuous changes in environment (new structures change fingerprints, especially in radio technologies) must be tolerated
- General performance: high accuracy, low error sensitivity and high reliability
- Ease of use
- Equipment must be mobile: wearable or easy to carry
- Need of added infrastructure/system (active components are more problematic) should be very limited
- Limited resources during the project, so mature existing technologies preferred
- Functionality in case of electrical failure (should not be dependent on electrical network availability in the ship)
- Suitability for different uses (other than marine industry)

1.3 Overview of positioning concepts

Each of the following general concepts is discussed in detail in the later chapters.

General, **global positioning systems**, like GPS and its upcoming European counterpart, Galileo, are meant to be used for outdoor positioning tasks. The gigahertz band signals of these systems do not reach inside of buildings or ships, so they could only be utilized on the upper outside decks.

GPS repeaters are devices that can transmit the GPS signal indoors, relaying the location of an outdoor GPS receiver to the users inside a building. To define the location within the building there should be as many repeaters as there are supported locations, so using repeaters seems not like a practical solution.

Local radio technologies can also be used for positioning. Existing wireless network signals, such as WLAN signals, can be used locally. Some vendors offer such systems commercially. The positioning algorithm may use signal strength, time of arrival and/or angle of arrival as the measured parameters.

Radio wave strength follows the inverse-square law in free field, which can be used to determine transmitter-receiver distance. However, in non-free field the obstacles make the situation complicated. Especially in a metal structure the field can be very complicated and unstable, so it would require a large number of transmitters within the ship to reach good reliability. Time of arrival and angle of arrival based methods also face difficulties caused by signal reflections.

A grid concept would use a dense network of low-power transmitters/receivers.

Positioning can be based on RFID tags carrying IDs that can be associated with locations. The range of passive tags is limited to a few meters maximum, but the tags themselves are cheap and reliable.

Positioning systems can be **based on beacons**. Beacons are, in general, permanently installed transmitters that send signals coded in a way so that a moving receiver can deduce its current location by interpreting the signals. The calculation of location may be based for example on time differences or angles of arrival of the received signals. The transmitted signals may be visible light, infrared light, radio waves or audio signals.

Inertial sensors (acceleration sensors and gyros) can be used as step counters, or they can measure motion directly.

The surrounding space characteristics, like distances from surfaces, can be measured and the results analyzed to find matching locations within the 3D model of the structure. The **spatial measurements** can be made using laser beams, audio signals or radio waves.

Visual recognition is also one possible method for determining location. The camera image can be interpreted and structural elements can act as cues for possible locations. Camera may see objects that are not part of the 3D model, like tools and construction materials, which make the task hard to accomplish. Often there are also multiple objects that look similar.

Images may also contain markings that can be interpreted, such as part numbers and other codes that may identify the location.

2 DESCRIPTION OF POSITIONING METHODS

2.1 Global positioning

2.1.1 GPS

GPS (Global Positioning system) is a satellite-based positioning system. It does not function indoors as such because the signals from the satellite cannot penetrate trough building materials and in this case ship materials like metals. There are available GPS repeaters, but those do not as such help in trying to determine location inside a ship or building. A repeater system consists of a GPS antenna outside. This antenna is connected to internal GPS transmitter by a cable. The receiver can then get the GPS signal indoors from the repeater, but it can only tell the location of one point i.e. the antenna outside. So in practice the receiver gets coordinates of the external antenna and thus for example the whole ship, but not the exact location of the receiver indoors.

There are studies about using GPS repeaters for real indoor localization. [1] The principle is to measure the phase offset (PoA, or alternatively time difference, TDoA) between signals transmitted from different repeaters, although they are basically repeating the same GPS signal from external antenna. Several repeaters are needed to determine one location.

GPS repeaters are commercially available from many sources. One manufacturer is Faltech. [2]

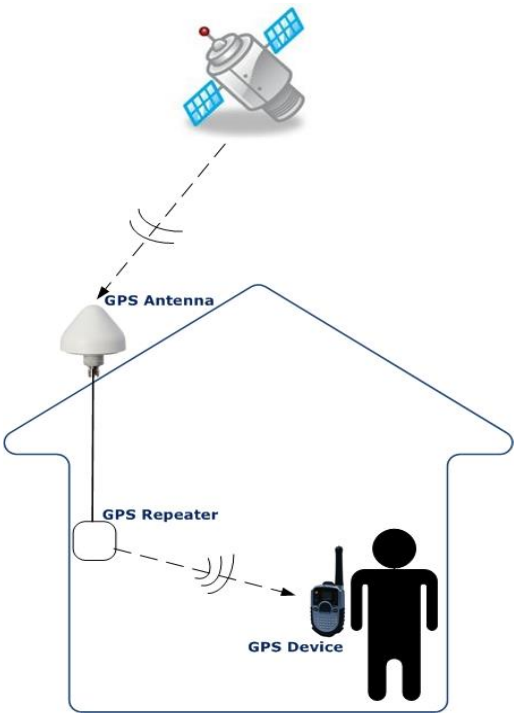

Figure 1. iGPS.

There are so called iGPS (Indoor GPS or Infrared GPS) systems, but they are based on optical beacon techniques rather than global satellite systems. There is more information about iGPS in chapter Spatial measurements.

Weakness	Severity
GPS is not available indoors and via repeaters only the location of the external antenna can be determined, not the location of the user inside ship or building	severe
The local position indoors is actually looked for, so the global position is not enough, more accurate information is needed	severe

Benefit	Significance
GPS receiver is built-in to most mobile devices	medium

Table 1. GPS in indoor localisation.

2.1.2 GSM

A number of systems have used GSM to estimate the location of mobile clients. GSM fingerprinting makes use of the existing GSM infrastructure, obviating the need for infrastructure investment and greatly increasing the possible area in which the system will work. Two factors lead to the good performance of radio fingerprinting in the wireless band used by GSM and 802.11 networks. The first is that the signal strengths observed by mobile devices exhibit considerable spatial variability at the 1–10 m level. That is to say, a given radio source may be heard stronger or not at all a few meters away. The second factor is that these same signal strengths are consistent in time; the signal strength from a given source at a given location is likely to be similar tomorrow and next week. In combination, this means that there is a radio profile that is feature-rich in space and reasonably consistent in time. Fingerprinting-based location techniques take advantage of this by capturing this radio profile for later reference. Otsason et al. [3] presented GSM-based indoor localization system that achieves medium accuracy comparable to an 802.11-based implementation. They showed that accurate indoor GSM-based localization is possible thanks to the use of wide signal-strength fingerprints that include readings of up to 29 GSM channels in addition to the 6-strongest cells. Their GSM-based indoor localization system achieves a median accuracy ranging from 2.48 m to 5.44 m in large multi-floor buildings. Moreover, their GSM-based system effectively differentiates between floors in both wooden and steel-reinforced concrete structures, achieving correct floor classifications between 89% and 97% of the time.

Weakness	Severity
GSM coverage is not good inside metal ship or middle of sea	high
Fingerprinting relies on a “training phase” in which a mobile device moves through the environment recording the strength of signals. Not suitable for a moving ship.	medium

Benefit	Significance
GSM coverage is good, better than WLAN	medium
GSM-based localization system would still work in situations where a building's electrical infrastructure has failed	high in case of emergency
No custom infrastructure needed for every area in which localization is to be performed	medium

Table 2. GSM in indoor localisation.

2.2 Local radio technologies

2.2.1 WLAN

The practical implementations of using Wireless Local Area Networks (WLAN; IEEE standard 802.11) for positioning are based on RSSI (Radio Signal Strength Indications). Other methods (ToA, TDoA, AoA) are less interesting due to complexity of the time delay and angular measurements. There are already available commercial solutions [4] [5] which are based on RSSI.

When RSSI is used to determine the receiver distance from the WLAN transmitter either theoretical or empirical radio signal propagation models can be used. Because shadowing, reflections, multipath propagation and absorption by the surrounding structures impact the attenuation the theoretical model does not give good enough accuracy, so in practice these methods are combined . The empirical model is often called radio map. Radio map is created by measurements and must be done for each location separately

The accuracy of WLAN RSSI based methods is at best around 1.5 m [6], 2-3 meters are commonly achievable. This is very often adequate accuracy; it is enough to know the room or space where the user is and continue with other methods to find more precise pose.

A potential problem in WLAN-based localization within a construction site is that, especially in early phases of construction, the network may not be available at all.

The radio map must be known beforehand, which means that an additional work step is needed for initializing or calibrating the system before using it for positioning. Also, during the construction if the RSSI (Radio Signal Strength Indications) changes for some reason the map must be updated. These changes can happen if the WLAN transmitters are moved or new walls are built or even some new equipment is brought in to the room. Depending on the material used these changes can impact the radio signal propagation. Even opening or closing a door can affect the signal strength significantly.

Smartphone or tablet, or basically any device having WLAN connectivity, can be used as WLAN tag i.e. its location can be calculated based on the signal strength it sends to the WLAN transceiver (fixed place). The actual calculation of the location happens in server/computer elsewhere (i.e. in a cloud), in this case the localization info should be sent back to user which would then use it for identifying the positioning in 3D CAD model.

Weakness	Severity
RSSI fingerprinting methods require pre-defined radio maps. Additional work step is needed.	medium
WLAN must be available	severe
RSSI is sensitive to changes in environment (new walls, equipment etc.)	severe
RSSI fingerprinting techniques require a lot of computational capacity. Mobile devices may be limited in that, other option is to use servers elsewhere.	medium

Benefit	Significance
No additional equipment needed for the user	medium
Long range , only few transceivers needed	medium
Commercial systems available so basically known technique. However no such systems which use smartphones.	medium

Table 3. WLAN in indoor localisation.

2.2.2 RFID

Radio-frequency identification (RFID) systems consist of RFID tags that have a unique ID and a reader, which can read the signals from tags. Tags can be active or passive. Active tags have battery and they are sending their ID regularly and reader basically scans the ID signals. Tags can also be passive. Passive tags do not have battery, and they get their energy by inductive coupling from the signal reader is sending. Using this energy they send back their ID to reader.

RFID is using several separate frequency bands and the range is heavily depending on the frequency used. The frequency bands are 120–150 kHz, 13.56 MHz, 433 MHz (UHF), 865–868 MHz (Europe), 902–928 MHz (North America), 2.450–5.8GHz, 3.1–10 GHz. Ranges are from 10 cm (LF) to 200 m (highest microwave area). Typically the range is 1–2 meters and used frequency ETSI 865.6–867.6 MHz (Europe).

Accuracy of the RFID system depends on the density of tags and the reading range of an individual tag. Since tags have individual serial numbers, the RFID system design can discriminate several tags that might be within the range of the RFID reader and read them simultaneously. The IDs can be programmed by user or they can be read only having a factory assigned ID.

RFID tags are well known, established and widely used technology, and they are very cheap, especially the passive tags. There are commercially available RFID readers which can be connected to mobile phone or computer via USB. [7] In practice the distance how far the RFID tag can be read depends about the actual equipment, radio signal strengths it can transmit, and receiver sensitivity. For indoor positioning purposes the target should be a few meters, so that equipment would be easy to use and no extra steps are needed in trying to find the tag. All the commercially available systems cannot achieve this target so it must be carefully checked which equipment is selected.

Using RFID tags for localization in ship construction means that the information of the tag must be somehow in the 3D CAD model also. This is needed for being able to map the identified tag to 3D CAD model and thus determine location. There are different kind of information already available, valve numbers etc. which can be programmed to RFID tags, and used for identification. Another option is to add the RFID tags to the 3D CAD model or link the RFID tags unique identification code to appropriate information in 3D CAD model simply in a conversion file. This is easy to implement, just one table needed. This solution would enable usage of the cheapest factory programmed tags.

RFID localization can be used in combination with other methods, e.g. inertial measurements, for improved accuracy and tracking. [8]

Weakness	Severity
Reader equipment needed	medium
Active tags have longer detection range, but need battery	medium
Very many tags needed to get sufficient coverage and accuracy	minor/medium

Benefit	Significance
Same tag can be used in construction phase and even during the service life	medium/high
Sufficient accuracy can be achieved	medium
Inexpensive, well known technology	high
Suitable to ship construction circumstances, because it is not sensitive to painting or wall materials (excluding metal)	minor / medium

Table 4. RFID in indoor localisation.

2.2.3 NFC

The principle in Near Field Communication (NFC) is similar to RFID. It is basically a subset of RFID. The main differences between RFID and NFC are the range and communication system. NFC range is few centimeters at maximum and the communication can be also two way.

The data rates are rather low, 106, 212 or 424 kbit/s. NFC uses 13.56 MHz frequency, which is one of the RFID frequencies also. Ideas have come up that RFID tags using this frequency could be read by NFC readers, which are becoming more and more common in smartphones.

Similarly as in RFID case, NFC tags must be also inserted to 3D CAD models for being able to determine location based on them, or the ID programmed into a tag can be used. The biggest drawback is that the reader i.e. phone must be put very near the tag, only a few centimeters in maximum. This may be inconvenient for the user.

The possibility to have two-way communication is useful in many NFC applications, but it does not help localisation.

Weakness	Severity
Reader must be put very near, only few centimeters from tag. This is very inconvenient and prevents user to move normally inside ship.	severe

Benefit	Significance
Same tag can be used in construction phase and during the service life	medium
No separate reader equipment needed, because smartphones support NFC (at least some models)	minor

Table 5. NFC in indoor localisation.

2.2.4 Bluetooth

Bluetooth (BT) is a personal area network technology that could be used to transmit location information between devices. There are two potential ways to use it for localisation:

- Installing fixed Bluetooth devices that transmit the location information to BT enabled devices that are in the proximity. This requires extra infrastructure and the battery life Weakness s cause maintenance needs for the fixed devices.
- Mobile devices exchange location data between each other. This means that one device that has its location determined can inform the other devices entering the area. Although this could not solve the initial localization problem for the first device within an area, it would offer easy/automatic localization to others.

Weakness	Severity
A system that could keep the device informed about the location would require active BT devices everywhere	severe/medium

Benefit	Significance
Unambiguous location data could be achieved	medium
Mobile devices typically have BT built-in	medium
Location information could be transmitted between portable devices without extra infrastructure or hardware	medium

Table 6. Bluetooth in indoor localisation.

2.3 Beacon Based Systems

2.3.1 Light

Optical communication, i.e. lamps can be used for indoor tracking. It is possible to use fluorescent lamps or led lights, for example. Variation of phase or frequency can be used to modulate light and generate code which is unique to each lamp. The modulation frequency is chosen to be greater than 20 kHz, such that audible noise is avoided. Light sensor can be either separate module or mobile phone camera can be used to identify unique code of each lamp and look it up in an online database to identify accurate position. To reach coverage using lamps means installing hundreds of devices in a large building, and then creating a map so that positioning signals can be turned into an accurate location.

ByteLight, a start-up based near Boston, claims its technology can fix locations to within a meter in as short time as a second. [9]

Weakness	Severity
Good coverage means many light bulbs, expensive	medium
Predefined light map needed, which is not always available in ship construction phase and updating needed often due to changing environment	medium
All lights cannot be installed in ship construction phase	medium

Benefit	Significance
Infrastructure is already in place, light bulb sockets needed	medium
Works with several LED manufacturers	medium
Easy installation	medium

Table 7. Light in indoor localisation.

2.3.2 Infrared Light

Infrared (IR) light is electromagnetic radiation with longer wavelengths than those of visible light. Infrared light is invisible to the human eye under most conditions. There-fore, this technology is less intrusive compared to indoor positioning based on visible light.

The four general methods of exploiting infrared signals are:

- Use of active beacons
- Reflective light sources
- Projected infrared structured light to capture 3D scene
- Infrared imaging using thermal radiation (See chapter: Temperature)

The active beacon approach is based on fixed infrared receivers placed at known locations throughout an indoor space and mobile beacons whose positions are unknown. In order to achieve meter-level precision or better, a configuration of an IR tracking system based on active beacons must include several receivers deployed in each room to disambiguate sectors of a room. Infrared light sensor can be either separate module or IR sensitive camera, which can use also reflective light sources.

The motion sensing device known as Kinect used for the video game console Xbox (Microsoft Kinect 2011) uses continuously projected infrared structured light to capture 3D scene information with an infrared camera. The 3D structure can be computed from the distortion of a pseudo random pattern of structured IR light dots. [10]

Weakness	Severity
Good coverage requires many IR light transmitters	medium
Predefined IR light map needed, which is not always available in ship construction phase and updating needed often due to changing environment	medium
May not function outside, in sunlight	medium
Requires (almost) line of sight between source and receiver	medium

Benefit	Significance
No extra hardware needed in mobile device, existing camera can be used	medium
3D structure can be computed	medium

Table 8. Infrared light in indoor localisation.

2.4 Spatial Measurements

This category includes all methods that try to observe the size and shape of the space around the user. Typically a signal is sent and received, and the response is analyzed to find out characteristics of the space. Measurements may be based on

- radio waves
- light (including infrared wavelengths)
- audio signals

2.4.1 Distance Measurement using Laser

A portable laser measuring tool can provide accurate data about distances to surfaces in exact directions. This would be helpful in defining the fine-grain location and pose. However, it would be difficult to make use of a few separate distance measures as a basis for defining the approximate location. Laser scanning the whole environment would theoretically be an option, but requires dedicated equipment and is time-consuming.

This kind of approach may be more suitable for tracking purposes than for finding the initial location.

Weakness	Severity
Requires additional measurement hardware (portable)	medium
Only one direction at a time can be measured	medium
Measured distance may be of a different object than assumed	medium

Benefit	Significance
No additional objects or equipment needed in structure	medium
Acquired data can be highly accurate	medium

Table 9. Spatial measurements in indoor localisation

2.4.2 iGPS

iGPS (infrared Global Positioning System) is an optical metrology system using multiple fixed-location transmitters and moving sensors. It is intended in factory-like environments and can achieve sub-millimeter precision typically.

Measurements are based on triangulation and timing between arriving infrared laser signals at the sensor. Each transmitter sends three optical signals: two rotating IR laser beam fans and one omnidirectional IR flash sent every second rotation of the transmitter.

The two laser beam fans are tilted in such a way that the time difference of the beams changes according to the elevation angle. Thus, the time between the two laser beams is used to calculate the elevation angle, and the time between the flash and laser beams to calculate the horizontal direction. At least two transmitters need to be observed to determine the 3D location.

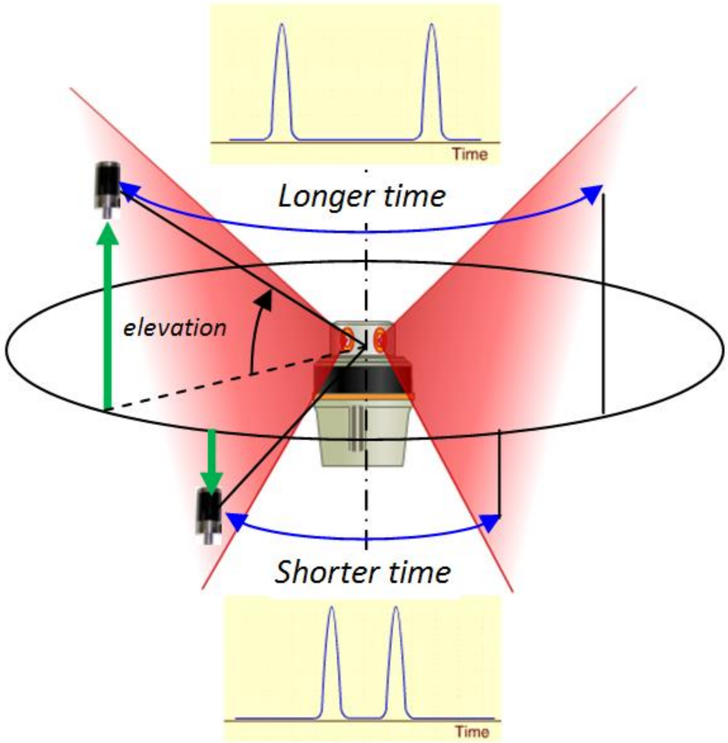

Figure 2. iGPS principle of detecting pulse time differences.
Image from www.amrikart.com

At least two transmitters must be visible wherever location capability is needed, which makes this kind of system impractical and too expensive to be installed inside a ship. However, it could be useful e.g. in block construction halls where the system would be permanently installed.

Nikon manufactures iGPS system. [11] Technical details are described e.g. in Amrikart.com. [12]

Weakness	Severity
Complex, expensive system to be installed in small/multiple locations	severe
Active transmitters and sensors	medium

Benefit	Significance
Good precision (mm range)	high /medium

Table 10. iGPS in indoor localisation.

2.5 Audio Measurements

Audio signals can in principle be used to find out some data of the size, shape and other characteristics of a closed space.

In the simplest form, a speaker emits a sound, a microphone records the response, and software analyses it to estimate distances to reflecting surfaces and reverberation time. With one microphone and an omnidirectional speaker we can't get directional data, but even incomplete distance data could be used to rule out spaces that would not be potential candidates. Some research has been done on the area [13] but it is not a thoroughly studied subject. It is hard to detect reflections from the recorded signal because the reflecting surfaces modify the signal in different ways depending on material, shape and other parameters.

The approach could be feasible if applied as a classifier, choosing potential ones from a list of known spaces. Better (more accurate) results could be achieved using directional measurements, i.e. sonar type equipment.

Weakness	Severity
Audio response is complicated and it is difficult to extract space characteristics	severe
Environment may be noisy: disturbance to measurements	medium
The shape of the space cannot be accurately reconstructed from omnidirectional audio signal	medium

Benefit	Significance
Audio signal scans all directions simultaneously	medium/high
Mobile device can do the analysis without extra hardware	medium

Table 11. Audio response measurements in indoor localisation.

Sakari Tervo from Aalto University has studied the problem of estimating room dimensions from impulse responses. [13] Algorithms for estimating and classifying volumes are presented in [14], [15].

2.5.1 Radar

A radar system measures directions and distances to objects using radio signal reflections. That could be used to determine the size and shape of the environment, and that data could then be matched with the 3D model, using similar algorithms as with visual data.

There are several different operating principles in use:

- With the original concept of radar a directional (rotating) antenna is used to measure the angle of incidence. Such an antenna system would be highly impractical in mobile use.
- Frequency Modulated Continuous Wave (FMCW) radar transmits a signal with increasing frequency over time. Thus the returning (delayed) signal has a different frequency than the signal transmitted, and this time/frequency difference is used to define the travelled distance.
- Chirp Spread Spectrum (CSS) is a spread spectrum technology as FMCW, however using a linear frequency modulated pulses, not continuous signal. This

reduces the needed transmission power, and the wide bandwidth used makes it more tolerant to noise.

- Doppler radar. Used to detect moving targets and measure relative speeds, based on the Doppler shift of the reflected signal.

Radar requires extra hardware to be carried. If good directional resolution is wanted, the needed antennas would be rather complex and relatively large. Power consumption is an issue as well, but since the system would not need to be active all the time, it might not be a significant restriction.

Being based on radio waves, the radar signal can penetrate non-metallic materials, which would enable to detect the metal structure behind installed surface materials like ceilings, insulations and light walls. This could be useful in many cases.

Weakness	Severity
Extra hardware to be carried	medium
Power consumption (when active)	minor

Benefit	Significance
If omnidirectional, scans all directions simultaneously	high
Radar can penetrate non-metallic materials: sees the structure behind some installations	medium

Table 12. Radar in indoor localisation.

2.5.2 Audio Beacons

Audio beacons send coded tones that mobile devices can read and identify, deducing the approximate location. This method requires no special hardware in mobile device side, while active beacons obviously are needed. In this simple form the device can be localized to the nearest identified beacon, but not to a specific location within the audible range of the beacon. The range of one beacon may be about 20 m. Beacon signals can be on a frequency range that is hardly audible to humans, i.e. high frequencies.

A study about audio beacon solution for mobile phones is presented in [16].

Weakness	Severity
Requires infrastructure: active sound sources	high
Noisy environment causes disturbances	medium

Benefit	Significance
No extra hardware needed in mobile device	medium
Unique signals would give the position without ambiguity	medium

Table 13. Audio beacons in indoor localisation.

2.6 Inertial navigation systems

Acceleration and rotational (gyroscope) sensors can be used to approximate the motion of the device. This principle is used in inertial navigation systems (INS). It is not possible to define the location based on inertial sensors alone. However, when the absolute position can be frequently refreshed with other methods, INS can be used to track the short-term movements with relatively high precision.

For consistent results, it might be best to install the sensors in a known location in user's clothing, e.g. in the back of a coat, or in a helmet. Mobile devices have sensors built in, but holding the device in hand means a significant amount of unknowns must be tackled.

2.6.1 Step meter

A simple step meter (implemented using the acceleration sensor) counts the user's steps and can tell approximately the distance moved. The accuracy of such measurement is not very good, however. It may require personal adjustment – the step length varies from person to person. The direction may not be sensed, and the accuracy may depend on how the device with sensors is carried: is it in the pocket or e.g. held in hand. Also, the movement of the user may differ a lot depending on the situation: are you walking normally from place to place or doing work in one location, taking steps infrequently to any direction.

Step count combined with approximate direction data may be used to track the approximate location, especially if the environment contains corridors and a sparse number of doors where the user may move. Still, it is necessary to refresh the absolute location with frequent intervals to keep the accuracy at a reasonable level.

Weakness	Severity
Number of steps is not as accurate measure of movement as direct integration of acceleration	medium
Accuracy may be poor depending on how the device is carried and what kind of movements the user makes	medium
Only for relative movements, can't determine absolute locations	medium

Benefit	Significance
No extra infrastructure needed	medium/high
No extra hardware needed in mobile device (but accuracy may be improved if dedicated sensor devices are used)	medium

Table 14. Step meter in indoor localisation.

2.6.2 IMU-based sensing

Movement estimation based on acceleration and orientation changes can provide better location approximation than a simple step meter. An IMU (Inertial Measurement Unit) measures movement in all six degrees of freedom – three-axis acceleration as well as orientation change – and can deduce the moved distance by integrating the data from these.

In practice, typical mobile device's sensors aren't capable of a great accuracy and there is always some drift that causes error in the results. Getting speed and distance requires continuously eliminating the gravity out of the sensor data, and even small inaccuracy in this will cause major errors in the result. The built-in sensors in mobile devices are typically rather noisy, and enabled sampling frequencies are low.

A foot-mounted movement sensor can improve movement accuracy significantly, as the velocity can be calibrated to zero when the foot is in stance stage. It looks like a good approach to combine IMU data to RFID-based location or some other means of absolute positioning. [8]

The orientation and pose can be also refreshed using visual means whenever there are recognizable objects in the camera's view.

The Windows Phone environment offers a combined Motion object and API that uses all available sensors of the device (acceleration sensor, gyro and compass) and delivers an easy-to-use interface to the device movement and orientation. This, however, only uses the built-in sensors of the phone. A foot-mounted IMU would require another interface.

Weakness	Severity
Error accumulates and causes drift when integrating sensor data	medium
Only for relative movements, can't determine absolute locations	medium

Benefit	Significance
No extra infrastructure needed	high
No extra hardware needed in mobile device (but accuracy may be improved if dedicated sensor devices are used)	medium
Short-term movement tracking may result in good accuracy	medium

Table 15. Inertial sensors in indoor localisation

2.6.3 Orientation sensing

Rotational sensor (gyro) can be used alone for keeping track of the direction/orientation of the device for short times. This would be useful if the location is known using another method of good precision. There is inevitable drift of orientation that will accumulate over time, but the sensor can inform the system about its orientation for seconds or minutes when no other cues are available. The orientation data can be checked/updated using visual means whenever there are recognizable objects in the camera's view.

2.7 Visual recognition methods

Here we mean methods that use camera as the only or main source of data. There are at least three different approaches for using camera data:

- Find structural features from images and match them with the 3D model.

- Find part codes and other existing markings in the parts and match them with 3D model and database.
- Use markers placed in the environment specifically for localization purposes.

2.7.1 Structural features

Computer vision algorithms are used to find visual features from the camera image. If we have a reference of the environment – either a 3D model, or reference images taken previously from known positions – we can try to find matches between the features in the camera image and the reference, and thus define the position.

It is also possible to generate a geometric model of the observed environment without previous knowledge of it. This is usually called simultaneous location and mapping (SLAM). Some amount of SLAM capability is needed in cases where the environment contains objects not found in the 3D model. The system should be able to add non-modeled objects in its internal (temporary) world model e.g. for tracking purposes.

Dimensions of the observed objects must be known to align the real world objects to the model. This can be achieved in a few different ways:

- If a modeled object can be recognized from the image, its real size will be known based on the model, and the size of the 2D projection on camera sensor can be used to calculate the distance from the object.
- The distance to an unknown object can be calculated based on angular information when the camera moves. For that we need some means of estimating the camera movement. This method is sometimes referred to as synthetic stereo vision.
- A rough estimate of the distance may be obtained from camera's autofocus, if the camera has one.
- A stereo camera system can be used to get depth information based on the angular data and the (known) baseline between the two cameras. The accuracy is inversely proportional to the baseline length, so absolute miniaturization of the equipment is not desirable. However, in professional use, having two cameras attached e.g. on the sides of a helmet may be reasonable.

Camera image is interpreted using computer vision technologies to find characteristic features of the environment, for example edges and corners. Then the system tries to match features with the 3D model.

There are various algorithms that can be used to find features in the camera image. In this report we do not go into details of the methods, but for example the well-known SIFT [17] and SURF [18] feature recognition methods have been in use in the project.

The accuracy of vision-based positioning can be on the order of a few centimeters. This type of visual matching will be needed for pose estimation (exact positioning). There are serious ambiguity challenges in using structural features alone for coarse positioning.

Weakness	Severity
Image analysis is processor-intensive	medium
Ambiguity: similar features may exist in many places	severe
Objects that do not belong to the 3D model may confuse the recognizer	severe
Certain parts in the model are simplified and do not actually resemble the real world objects (e.g. valves)	medium

Benefit	Significance
Structure is used as is; no additional equipment needed	medium

Table 16. Structural feature recognition in indoor localisation.

2.7.2 Part codes and other markings in structure

Many metal sheet parts and other components have machine-printed part codes that could be used to identify the part, and further the location in the structure. Also, there may be hand-written markings that may help in locating the place. For example the directions towards aft or fore may be marked.

Metal sheet parts are marked already before construction. These markings become covered in painting, but pipes, valves and other fittings get their own labels that could also be used for location later on.

Interpreting such markings requires optical character recognition (OCR) software. When markings have been recognized, a database search would provide potential matches in ship structure and location.

Weakness	Severity
Image analysis is processor-intensive	medium
Markings may easily become blocked or are not in view	medium
Painting eventually covers markings on plates	minor

Benefit	Significance
No additional objects or equipment needed in structure	medium
Unique codes: no ambiguity once recognized	medium

Table 17. Recognition of visual markings in indoor localisation.

2.7.3 Markers

Fiducial markers can be used to identify locations. These are typically black-and-white square-shaped figures with a unique pattern inside. Such a marker is relatively easy to recognize using computer vision algorithms, and when each marker contains a unique ID, it can identify the location without ambiguity. The positioning accuracy can be on the order of a few centimeters. Marker-based positioning is common in augmented reality research and demonstrations due to its reliability.

VTT has a public software library ALVAR for marker-based augmented reality applications. [19]

Weakness	Severity
Requires specific objects (markers) to be installed	medium
Markers may become blocked by other objects & paint	medium

Benefit	Significance
Unique codes: no ambiguity once recognized	medium
Easier to recognize than structural features or text	medium

Table 18. Markers in indoor localisation.

2.7.4 Reference from projected targets

Microsoft Kinect [10] is an example of a system that projects a reference pattern (of infrared light) around and creates a model of the environment based on the camera image of the pattern, using triangulation. This is an effective means for analyzing the environment.

Similar matching with the 3D model is needed as with other camera-based techniques. Also similar issues with ambiguity exist.

Weakness	Severity
Requires specific hardware to be carried	medium
Continuous projection of the pattern consumes power	medium
Ambiguity: recognizing the correct location is not certain	medium

Benefit	Significance
Good accuracy of modeling the surrounding objects	high
No additional objects needed in structure	medium

Table 19. Projected targets in indoor localisation.

2.8 Manual input

As there will probably not be a certainty of obtaining reliable position information by automated means, we will need some ways to enter the information manually into the system. This should work always, either as the backup, or as the primary means of localization if the user so wishes.

Some of these manual methods assume that the user knows the location and only has to input it to the system – which may not always be the case.

Some automatic means of localization may end up to an ambiguous situation where more than one location is possible. Then the system may request the user to choose the correct one among the candidate locations.

2.8.1 Maps

The system displays a map of the ship where the user can choose the current location by pointing. In practice this would mean offering the schematic in several levels of detail for choosing a deck and/or a subsection of the ship, and then the specific location. Probably two or three taps should be sufficient on a tablet display, perhaps more on a phone. For glasses the feasibility in real conditions should be tested.

Weakness	Severity
User may not be aware of the current location	high/medium
Presenting a map requires a sufficiently large screen	medium

Benefit	Significance
No extra infrastructure needed	high
Relatively easy to determine the location, assuming the user knows it	medium

Table 20. Usage of maps in indoor localisation.

2.8.2 Codes and keywords

The fastest way to define the coarse grain location may be textual input. The user would enter a code or name, such as:

- the code of the area and/or space (e.g. a 5-digit number)
- part or equipment code (e.g. a valve number)
- a keyword that could identify the location (e.g. restaurant fore)

The system would determine the actual location using a database where such codes and keywords would be associated with locations.

In cases where the user is not aware of the current location, such codes that are visible at the location would be immediately useful. Codes not visible in real world can only be used when the user knows them already or can find them e.g. in the 3D model.

The input may be done using

- a keyboard or other input device
- speech

Speech input would free the user from holding a device, looking at a display and using hands.

Reliability of speech input is worse than more conventional inputs, and a noisy environment can decrease it further. On the other hand, in professional use the system could be trained for user-dependent recognition and application-specific vocabulary, which improves the recognition rate.

Weakness	Severity
Some cases require that the user knows the location	medium

Benefit	Significance
No extra infrastructure needed	high
Reliable and quick input of data	medium
Many different kinds of data can be applied	medium

Table 21. Manual input of location in indoor localisation.

2.9 Other concepts

2.9.1 Electric and magnetic fields

Positioning systems using artificial magnetic and electromagnetic fields are described in this chapter. Magnetic fields can be generated from permanent magnets or from coils using Alternating Current (AC) or pulsed Direct Current (DC) fields. Electromagnetic fields can also be used for positioning in combined use of their electric field and magnetic field. Static charge produces electric field and current produces magnetic field.

If artificially generated magnetic fields are used, pre-deployed coils are required. The received strength of the magnetic field (B) can be converted to a measurement distance. If the coordinates of the coils are known, trilateration can be applied to estimate the receiver's position. A significant advantage of this type of system is that the artificially generated magnetic field is not affected by most obstacles, hence multipath or non-line-of-sight errors are avoided. Significant magnetic disturbances in indoor environments impact on the positioning accuracy. On the other hand, the anomalies caused by magnetic disturbances can be used as a unique "fingerprint" to describe the environment, and be used for position detection.

Unmodulated carrier wave signals supplied to power line infrastructure in a building are wirelessly received by passive tags and, at the tag's resonance frequency, a signal is inductively coupled back to the power line. This signal can be detected in a so-called power line interface and used for position detection if each tag has differing resonance frequency.

Positioning systems can be divided in

- Systems using electric field
- Systems using the antenna near field
- Systems using magnetic fields from currents
- Systems using permanent magnets
- Systems using magnetic fingerprinting
- Power line positioning

2.9.1.1 Systems using electric field

When a conducting or dielectric object is placed in an electric field it will necessarily perturb that field. If this object then moves, a changing electric field will be generated and can be measured. This approach has many advantages, in particular the ability to determine presence and location, even in the event that a subject remains stationary. The ambient 50 Hz (or 60 Hz) field, which occurs as a result of the mains electrical supply, can be used as the excitation signal and the variation in the amplitude of this AC signal in response to the subject can be measured.

The electric potential sensor (EPS) detects changes in the ambient electric field. Typical 50 Hz field levels in domestic/laboratory environments range from ∼50–250 mV/m, corresponding to a distance of 2.5–0.3 m from a trailing mains lead respectively. By extrapolation this leads to the conclusion that the 50 Hz signal would be measurable above the sensor noise floor in a 5 Hz window at a distance of ∼30 m. This corresponds to 60 m spacing for a pair of sensors and a 60 m × 60 m space.

Noise from appliances tends to be more problematic for magnetic methods, since the current varies when switched on and off, but the voltage does not. Mains wiring is fixed in most instances, however the use of trailing extension sockets would change the relative ambient levels of 50 Hz and require the system to be recalibrated. Periodic recalibration should be included in any real system. [20]

Weakness	Severity
Separate infrastructure is needed, several electric potential sensors/receivers, expensive. Passive system does not identify person, would need another infrastructure.	high
Trailing extension sockets would change the relative ambient levels of 50 Hz and require the system to be recalibrated	medium
Metal structure resists electric field	medium

Benefit	Significance
Ability to determine presence and location, even in the event that a subject remains stationary, or behind walls	medium
Fairly high accuracy (~10 cm) on short distances (a few meters)	medium

Table 22. Electric field in indoor localisation.

2.9.1.2 System using antenna near field

Near-field electromagnetic ranging (NFER) is an emerging real time location system technology that employs transmitter tags and one or more receiving units. Operating within a half-wavelength of a receiver, transmitter tags must use relatively low frequencies (less than 30 MHz) to achieve significant ranging. Depending on the choice of frequency, NFER has the potential for range resolution of 30 cm and ranges up to 300 m. Close to a small antenna, the electric and magnetic field components (E and H, respectively) of a radio wave are 90 degrees out of phase. As the distance from the antenna increases, the EH phase difference decreases. Far from a small antenna in the far-field, the EH phase difference goes to zero. Thus a receiver that can separately measure the electric and magnetic field components of a near-field signal and compare their phases can measure the range to the transmitter. [21]

Weakness	Severity
Low RF frequencies require large receiver antenna, quarter-wavelength in size	high
Separate receiver is needed	high
Metal structure resists magnetic field	medium

Benefit	Significance
NFER does not require synchronization or signal modulation (small bandwidth)	medium
If low frequencies are used (<1 MHz) signals have potential to penetrate walls (not metal)	medium

Table 23. Antenna near field in indoor localisation.

2.9.1.3 *Systems using magnetic fields from current*

Magnetic fields are produced by magnetic material or electrical current. This positioning system makes exclusive use of the strength and the direction of the magnetic field. Direct Current (DC) magnetics use pulsed direct currents where the current frequency is low enough to be considered static. Static magnetic fields are caused by different direct current sources, such as coils or wires. A useful property of a coil based magnetic field is that it can be well predicted from a theoretic model. Arumugam et al. [22] have used an emitter driven at 387 kHz consisting of 45 turns of a copper wire to generate a magnetoquasistatic field. Theoretical results derived from infinitesimal dipole approximation are compared with experimental results, indicating that distances up to 50 m can be estimated with an accuracy of 20 cm. Unlike systems based on coils using pulsed DC technology, AC (Alternating Current) based magnetic tracking systems are less affected by the Earth's magnetic field and artificial magnet fields from electric devices.

Weakness	Severity
Separate infrastructure is needed, transmitter coils and receivers	high
Metal structure resist magnetic field	medium

Benefit	Significance
If low frequencies are used (<1 MHz) signals have potential to penetrate walls	medium

Table 24. Systems using Magnetic fields from current in indoor localisation.

2.9.1.4 Systems using permanent magnets

The second method of using the magnetic flux density for positioning is through magnetic fields created by permanent magnets. Current approaches indicate a measurement volume of 1 m^3, which restricts the method to close range usage, such as medical applications.

2.9.1.5 Systems using magnetic fingerprinting

The idea of magnetic fingerprinting arises from animals that determine their position from local anomalies of the Earth's magnetic field. Likewise in buildings, each location has its unique signature of its magnetic flux density. These fluctuations in space arise from natural and manmade sources, such as metal building material, electric power systems and industrial devices. The anomalies of the magnetic field have sufficient variability in space to be detected by a magnetometer. Under the assumption that the magnetic field inside a building is approximately static, a fingerprinting method can be applied. A magnetic map of the rooms is taken in a setup phase, and the current location is determined by comparing the current flux density with the flux density values stored in the database.

Haverinen and Kemppainen [23] have mounted a 3-axis magnetometer on a robot to determine its location within a building by magnetic fingerprinting. The magnetometer has been mounted at the end of a rod with a length of 0.4 m to avoid influence of the ambient magnetic field from the robot's motor. Subsequent to a calibration phase, the detection of the robot's location along a path length of 278 m was possible. The robot needed to travel 25 m on average in order to get localized by comparing the magnetic flux values. Along that one-dimensional path, the reported accuracy was 0.2 m.

Modern steel and concrete buildings, for instance, have internal magnetic fields that vary subtly throughout their structure. Hull of the ship is made with iron and steel and is resistive for magnetic fields. Mobile phones may be able to determine their positions indoors using their internal digital compasses and magnetic fingerprint map.

IndoorAtlas, [24] a start-up based in Finland, claims it can provide indoor accuracy of less than two meters using this method, once a venue has been surveyed.

Weakness	Severity
Predefined magnetic map needed, which is not always available in ship construction phase and updating needed often due to changing environment	medium
Metal structure of ship resist magnetic field	severe
Tracking is not possible when ship is moving, magnetic field is changing all the time	high

Benefit	Significance
No additional equipment needed by user	medium
Work even in buildings where power has been cut off	high in case of emergency

Table 25. Magnetic fingerprinting in indoor localisation.

2.9.1.6 Power line positioning

Power Line Positioning (PLP) is a fingerprinting-based method to provide sub-room positioning in a household based on the existing electrical grid. In comparison to RFID systems which require dense deployment of RFID chips, PLP simply uses the power line infrastructure in a building. The principle of PLP is that unmodulated carrier wave signals in the frequency range between a few kHz to 20 MHz are generated by an interface module plugged into an electrical outlet in a home. These signals consist of energy rich electrical transients and can be wirelessly received by passive tags. At the tag's resonance frequency, the resonator inductively couples back a signal into the power line. This signal can be detected in a so-called power line interface as a decaying swinging. If multiple tags with differing resonance frequencies are used, an individual identification of the tags becomes possible. Patel et al. (2009) present a proof of concept of their power line location system based on battery-less tags. For the current system the read distance along the power line is 3 m to 4 m and the maximal reading distance between the tags and the electrical wiring is 50 cm. [25]

Weakness	Severity
Separate infrastructure modules are needed for power lines, transmitters/receivers + tags	high
Quite short reading distance from power lines	medium

Benefit	Significance
Existing electrical grid can be used, power lines	high

Table 26. Power line positioning in indoor localisation.

2.9.2 Atmospheric pressure

Pressure varies smoothly from the Earth's surface. Although the pressure changes with the weather, conditions have averaged for all parts of the earth year-round. As altitude increases, atmospheric pressure decreases. One can calculate the atmospheric pressure at a given altitude. Temperature and humidity also affect the atmospheric pressure, and it is necessary to know these to compute an accurate figure. At low altitudes above the sea level, the pressure decreases by appr. 1.2 kPa for every 100 meters. Using pressure information we could possibly estimate the current floor (deck) of the ship, but sealed room or area would affect the atmospheric pressure measurement. Atmospheric pressure is measured with barometer, the accuracy of which is high enough to determine floor of the ship, 0.5 meter barometer measurement accuracy can be reached easily. [26] However, sea level barometric pressure may be rising or falling quite fast. During calm stable weather, this drift may only be the equivalent of 10–20 m in one day, but on occasions it may be many tens of meters over a period of a few hours [27]. To be able to use atmospheric pressure for tracking, calibration would need to be done quite often on sea levels due to weather changes.

2.9.3 Temperature

By measuring temperature remotely (infrared light fingerprinting) of each part of the chip we could possible estimate the position, at least on coarse level. Of course, there are many disturbance issues for example radiation of the sun etc., which might affect temperature measurements. Best option to use this would be together with some other camera based methods, if camera could see normal and infrared light.

2.9.4 Soundscapes

The ships are built near the sea and the sea is a powerful generator of infrasound. Infrasound, sometimes referred to as low-frequency sound, is sound that is lower in frequency than 20 Hz, the "normal" limit of human hearing. Hearing becomes gradually less sensitive as frequency decreases, so for humans to perceive infrasound, the sound pressure must be sufficiently high. The ear is the primary organ for sensing infrasound, but at higher intensities it is possible to feel infrasound vibrations in various parts of the body.

In acoustics, microbaroms, also known as the "voice of the sea", are a class of atmospheric infrasonic waves generated in marine storms by a non-linear interaction of ocean surface waves with the atmosphere. They typically have narrow-band, nearly sinusoidal, waveforms with amplitudes up to a few microbars, and wave periods near 5 seconds (0.2 hertz). Due to low atmospheric absorption at these low frequencies, microbaroms can propagate thousands of kilometers in the atmosphere, and can be readily detected by widely separated instruments on the Earth's surface.

By measuring “voice of the sea” we could possibly detect infrasound signature and with “fingerprint map” the position in the ship.

Due to the long wavelength of infrasound, the accuracy of localization using this data is not very good. Also, the propagation route of the sound waves to the inner spaces may be rather complex, causing further inaccuracy.

2.9.5 Leaky Feeder –cable

RSS fingerprinting (Received Signal Strength) using wireless local area networks, like WLAN using multiple access points (APs), has frequently been suggested as an alternative to provide location information for indoor areas. This technique is relatively simple and more robust under multipath conditions compared to other techniques like Angle of Arrival (AoA) or Time of Arrival (ToA) without the need of special hardware. This makes the implementation of the system very cost efficient. A severe drawback of this approach however is the laborious effort to calibrate the radio map. The major drawback of this method is the unstable nature of the signal which is affected by different propagation conditions, interferences, multipath and scattering effects, which in case of metal ship under construction can be significant. Such fluctuations imply severe degradation of the positioning accuracy.

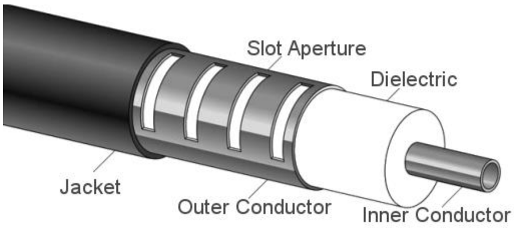

Figure 3. Structure of a Leaky Feeder-cable [28]

Leaky feeder cables are designed to provide homogeneous RF coverage throughout a building or a metal hulled cruiser where no normal signal from an antenna could get through. Leaky feeder has different outer shield, which allows the signal to leak out evenly along its length. A low longitudinal attenuation leads to increased coverage ranges compared to standard antennas. This makes the application of leaky feeder cable from the coverage point of view attractive and interesting, especially in special environments such as “tunnels”. Leaky Feeder-cables are widely used in mining for example. Fingerprinting has also been tested for GSM and WLAN over Leaky Feeder-cable. A central cable can be connected to a series of leaky feeder loops, and would be better to serve each deck of the cruiser, and can provide different RF frequency (GSM/WLAN) simultaneously. Besides the coverage advantages in tunnels and long halls, radio channel remains more stable and environmental changes will not have such a significant impact on the stability of the RSS fingerprint. Accuracy to about 6 m (in 80% of cases) is reached, which is very close to the accuracy of the AP installation, which is about 5 m at 80% when using 2 AP signals in the same hallway. [29]

Weakness	Severity
Separate Leaky-feeder infrastructure needed, but that can offer better GSM/WLAN coverage at the same time for cruiser	medium
Accuracy is medium level, 6 m / 80%	medium
Fingerprinting relies on a “training phase” in which a mobile device moves through the environment recording the strength of signals.	minor (line of sight)

Benefit	Significance
Offer very good WLAN/GSM network, and location	high

Table 27. Leaky Feeder-cable in indoor localisation

3 CONCLUSION

For MARIN project especially, and industrial construction tools in general, important requirements include overall ease of use, reliability and usability in varying conditions within construction sites. For mobile tools in general, lightweight equipment and reasonably low processing power and data storage needs are essential. As the actual AR related tracking algorithms, computer vision and 3D model rendering will require a lot of computing power, the load from indoor localization needs should be minimized.

Currently WLAN and Bluetooth based systems are commercially available. For example WLAN based systems have been used in cruising ships in some passenger related applications. However, the need to have an installed WLAN network, as well as the need of an initialization phase every time the radio map changes, makes this system problematic for construction time use. The radio map is changing during the construction all the time, and a working network cannot be installed in very early phases of construction. Many other methods presented in this report need a significant amount of infrastructure to be installed, which makes them impractical and economically unfavorable. Many systems are also on idea or research state, so a lot of research and development work is needed before they could be applied in practice. In some cases, like air pressure, challenges can be seen in achieving required accuracy and reliability.

Visual tracking methods are essential for camera tracking, but they alone are typically not capable of defining the coarse system location.

In MARIN the proposed plan is to use a combination of methods to achieve coarse localization:

- RFID tags will be used to more or less automatic updates of location. They are cheap, do not require constant power (assuming passive tags), and give an unambiguous location when recognized.
- Manual input methods will be a backup for positioning. These will ensure that there is always a possibility to update the system’s location data, and they can be made easy and fast to use too.
- Using sensors (gyros and accelerometers) will be studied further also. These sensors are able to track the system’s movements once the location (pose) has been defined by some means.

The main reasons for selecting these methods are that they are simple to implement, and they use existing technologies and so do not require a lot of extra work.

4 TERMINOLOGY & ABBREVIATIONS

AR	**Augmented Reality** According to the definition by Azuma, an augmented reality system has three capabilities: - combination of real and virtual imagery - registration (alignment) of computer graphics with the objects in real 3D environment - interactivity in real time
EPS	**Electric Potential Sensor**
FP	**Fingerprinting** Fingerprinting means mapping based on received signal strength in a location. FP is often used in radio frequency positioning, but it is possible to apply it also to visual or audio signals. Fingerprinting maps can be measured empirically, or calculated analytically based on models. In operation, the measured signal strengths are compared to the maps and the best match is searched.
HMD	**Head-mounted display** A display system where the view is projected in front of the user's eyes using eyeglasses or a helmet. There are variations: - monocular display: one eye only sees the image - biocular display: both eyes see a similar image - binocular display: separate view for each eye; stereoscopic - optical see-through: real world is seen through the device - video see-through: real world is displayed as video
iGPS	**Infrared Global Positioning System (formerly called Indoor GPS)** An optical (infrared) metrology system that allows the positioning and tracking of objects e.g. in a factory with good precision.
IMU	**Inertial Measurement Unit** A device that measures velocity, orientation and gravitational forces, typically using a combination of three or-

	thogonally arranged accelerometers and three gyroscopes, possibly also magnetometers.
INS	**Inertial Navigation System** A device that provides an estimate of velocity, orientation and (possibly) position based on the data from an IMU. Position and orientation can be tracked from measured data if the initial position and orientation is known.
NFC	**Near Field Communication** A very short range radio communication standard, based on RFID technology.
OCR	**Optical Character Recognition** Conversion of text and numbers from images to textual data.
PAN	**Personal Area Network** A local, wireless networking system that can be used e.g. to connect mobile devices and accessories. Bluetooth is an example of a PAN technology.
PoA	**Phase of Arrival**
Pose	The exact location, with an accuracy of a few centimeters or better, and direction of view.
Position	Determining the approximate location, meaning an accuracy of less than a few meters or better. Same as l*ocation*.
RSSI	**Received Signal Strength Indication** (or Radio Signal Strength Indication) Measurement of the received signal strength can be used for estimation of the distance between transmitter and receiver.
SLAM	**Simultaneous Location and Mapping** A technique used to build up a map within an unknown environment, or to update and fill in a map within a known environment, while at the same time keeping track of their current location.
TDoA	**Time Difference of Arrival**
ToA	**Time of Arrival**
Tracking	Following the pose in (practically) real time, so that the system can keep updating the virtual view without significant delay.

WLAN	**Wireless Local Area Network**

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