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NFC TECHNOLOGY FOR PRECISE LOCALIZATION IN AREAS WITH LIMITED GLOBAL NAVIGATION SATELLITE SYSTEM SIGNAL

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Summary

The emergence of modern technologies and widespread access to the Internet has led to an increase in interest in mapping websites. The data provided by online mapping geoportals is a rich source of information for society. Today, thanks to these geoportals, the location of objects in the field is widely available. This approach makes it possible to locate objects that are not visible in the field, such as underground electrical cables, underground water lines, or property boundaries. The technology used for object localization is GNSS (Global Navigation Satellite System). GNSS technology is based on the transmission of signals from satellites. However, this technology is limited in areas where satellite signals are restricted, such as high-rise buildings in city centers, dense forests, or tunnels. NFC technology is becoming increasingly available thanks to mobile phones that are equipped with NFC tags. This technology is widely used for payments via a mobile phone. This article presents a method of using the near-field communication (NFC) for easy positioning of infrastructure objects in a given area. This technology is particularly useful in areas with limited GNSS signals, such as urbanized, forested, or mountainous areas.

Keywords

GPS • GNSS • precise positioning • geodetic mark • plot boundaries • NFC technology

1. Introduction

The advent of modern technologies and widespread internet access has led to increased interest in map portals. The Google Maps website has made a significant contribution to the dissemination of map data. This website offers a variety of useful information (e.g. traffic intensity data), which, in turn, has a significant influence on goods logistics, public transport and tourism.

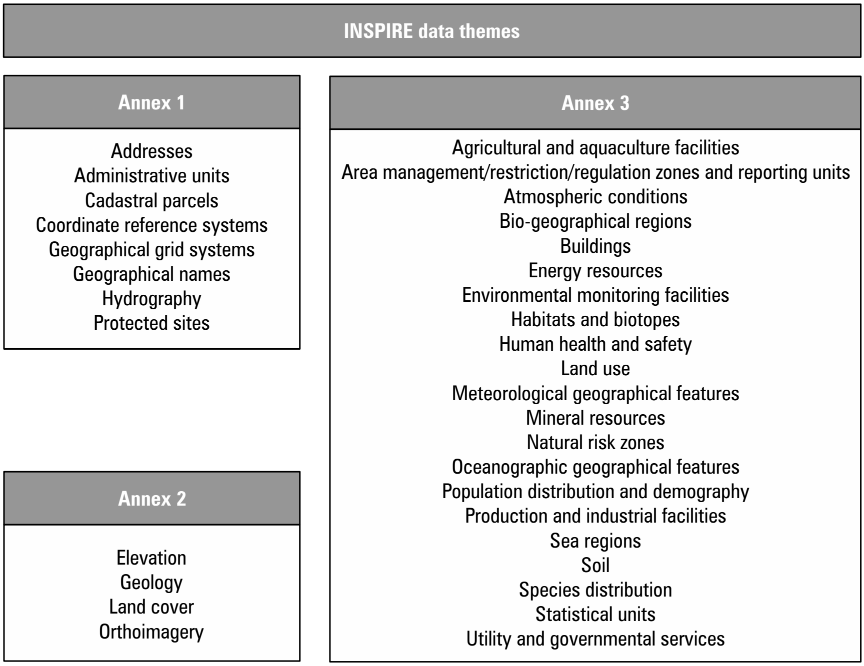
Social interest in mapping services is one of the reasons why the European Commission developed its INSPIRE directive in 2007, which regulates the sharing of geospatial data within the European Union. The main goal of this directive was to create an information society. To achieve this, it was necessary to unify the description of datasets collected by individual institutions (metadata) and to integrate spatial data

(ISO 19115) [Perego 2012, Veeckman 2017, Baumann and Escriu 2019]. The INSPIRE directive facilitated the unification of spatial data infrastructures between the European Union member states.

The EU Geoportal will be established with the standards and specifications originating from the European, international and industry consensus building processes. All connections to services in the member states and other countries participating in the establishment of the ESDI must be based on a minimum set of required standards and specifications to ensure interoperability [Bernard 2005].

2. Assumptions of the INSPIRE directive

Data shared by offices and other national institutions are available through specialized services and websites, which offer, among other things, agricultural, marine and spatial data. Detailed specifications of collected and shared data are shown in Figure 1. This scheme was based on three INSPIRE directive annexes. These specify subject fields for geospatial datasets shared under the INSPIRE directive.



Source: INSPIRE directive [2007]

Fig. 1. INSPIRE themes

Thanks to the INSPIRE directive, European Union citizens should have easy access to geospatial data from a variety of institutions and offices. The sharing of this information is executed by national and local geoportals. Those interested can get cadastral information, spatial planning data or information on underground utilities. Such information can be obtained without having to visit the offices where particular registers are kept.

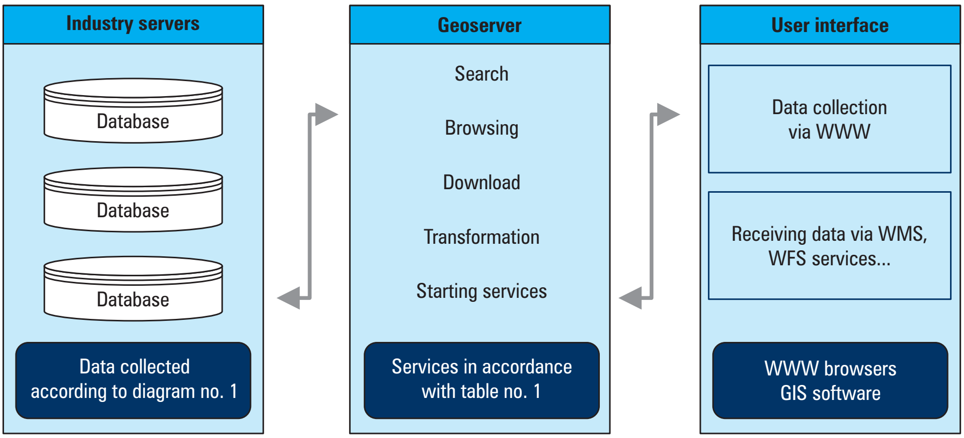
Another important aspect of spatial data is the sharing of spatial data services. According to the INSPIRE directive, member states can create and support the net of spatial data services described in Table 1 below [INSPIRE directive 2007].

Table 1. Spatial data services

Discovery Services	Discovery services making it possible to search for spatial data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata.
View Services	View services making it possible, as a minimum, to display, navigate, zoom in/out, pan or overlay viewable spatial data sets and to display legend information and any relevant content of metadata
Download Services	Download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly
Transformation Services	Transformation services, enabling spatial data sets to be transformed with a view to achieving interoperability
Invoke Spatial Data Services	Services allowing spatial data services to be invoked

Source: INSPIRE directive [2007]

Services covered by the INSPIRE directive facilitate various types of geospatial analysis, which are useful for many economic decisions, such as investment localization. The technology for sharing data with users is shown in Figure 2.



Source: Authors' own study

Fig 2. The technology for sharing data with users

An important element in the development of geospatial information accessibility is the ability to easily verify data in the field using existing infrastructure and mobile internet. However, such verification can be challenging due to the nature of certain spatial data. Some data presented on maps may not be visible in the field. An example of data that is not visible in the field are utilities. Another example can be data on the cadastral parcel boundaries. Parcel boundaries are not marked in the field, and boundary points are only present at the corners of these boundaries. It should be noted that the only way to be certain of the location of boundary points is to stabilize them in the field, in the presence of the parties involved, and with appropriate documentation. Unstabilized points will always have measurement errors when surveyed in the field. Therefore, it is highly desirable for all boundary points to have permanent stabilization in the field. Precise identification of such data [Schofield and Breach 2007, Krzyzek 2010] is only possible through specialized survey measurements.

Determining such data in the field thus requires the employment of professional firms with qualified personnel and specialized equipment, which incurs costs for obtaining such information. Providing universal and free access to these data requires the creation of an appropriate technical infrastructure.

Achieving simple, precise, and universally accessible identification of normally invisible objects in space therefore requires the construction of a suitable system. For such a system to be widespread and universally accessible, it should be based on technically available solutions for the majority of interested parties. Solutions could be based, for example, on smartphones. Smartphones have the capability to install dedicated applications and determine positions through GPS (US navigation system), GLONASS (Russian satellite navigation system), BeiDou (Chinese navigation satellite system), Galileo (European satellite navigation system), or GSM triangulation [Chan 1994, Salcic 2000].

By obtaining coordinates from the INSPIRE database and using smartphone applications, users can localize objects in space. However, smartphone-based positioning is not precise enough to satisfy all users. Furthermore, the precision with which locations are identified is highly dependent on the environment and atmospheric conditions. This can be especially problematic in places with a lot of interference (such as a city center). This article presents conceptual solutions that facilitate common access to spatial identification of chosen objects using INSPIRE databases. This concept is described on the basis of geodetic databases (e.g., cadastral parcel database, utility database and benchmark database).

3. Extending the functionality of the INSPIRE directive and geolocation accessibility using NFC technology (near-field communication)

Solutions, in terms of geodetic data, could include geodetic marking of field points in an interactive system. Such a system would allow key information about specific field points to be identified and collected. The characteristic markings of geodetic database elements could be stored directly in the field using NFC technology.

NFC technology is based on inductive coupling between two antennas located on NFC-supporting devices, which communicate in one or both directions. Such technology includes radio-frequency identification (RFID) extension, which was first used in radar technology during World War II to identify allied aircraft [Lehpamer 2012].

NFC is a relatively new technology that has been developed over the last decade and is gaining in popularity [Miaoa and Jayakarb 2016]. This technology allows users to open and save data in an NFC tag. NFC works automatically. When a smartphone finds a compatible tag, the relevant application is automatically activated, and tag information is displayed [Coskun et al. 2011].

Our suggested solution includes attributing NFC tags to field points. These tags would be loaded with geodetic data containing essential information about specific field points. These data would be obtained from various geodetic databases (e.g., cadastral parcel database, utility database and survey benchmarks database). Examples of such data are shown in Figure 3.

Scheme	Example 1	Example 2
Data in NFC	Data in NFC	Data in NFC
Database Name	**Utility and governmental services**	**Cadastral parcels**
Coordinate – longitude	50°02′05.511″N	52°20′03.131″N
Coordinate – latitude	19°59′30.606″E	20°58′11.160″E
Coordinate – H	342.27	–
Additional information	Power cable 110 KV	Marker post no. 131 on road

Source: Authors' own study

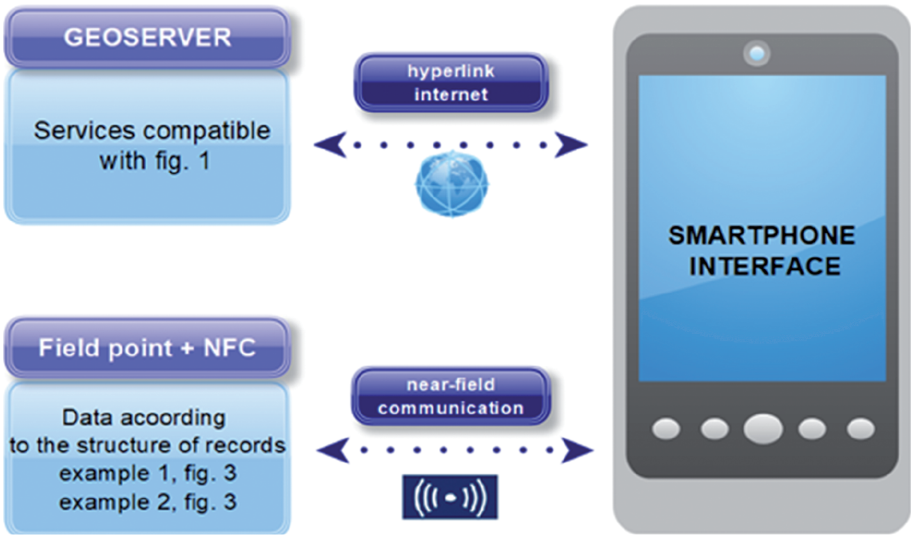
Fig 3. Geodetic data structure in the NFC

NFC tags are passive devices that operate without the need for a power supply and have a data-storage capacity of between 96 and 8192 bytes (NFC forum). Figure 3 presents specific geodetic point data saved on an NFC (95 and 85 bytes for examples 1 and 2, respectively).

NFC technology consists of the following modules: a smartphone (or other device) supporting NFC, a reader (which makes communication with the tag possible) and a passive tag containing information (NFC is actuated by a reader or smartphone) [Coskun et al. 2013]. This solution can be used to integrate geodetic data, as shown in Figure 4. Using smartphones and NFC technology to access such data will become more common.

4. Restricted access to GNSS signals

Localization is a crucial factor in enabling the deployment of autonomous mobile robots. Although, autonomous UAVs can rely on the Global Positioning System (GPS) for localization outdoors GPS signals are unreliable in indoor settings. Specifically, indoor construction sites are cluttered and dynamically changing environments, which causes significant challenges for UAV localization and autonomous navigation [Kayhani et al. 2022].



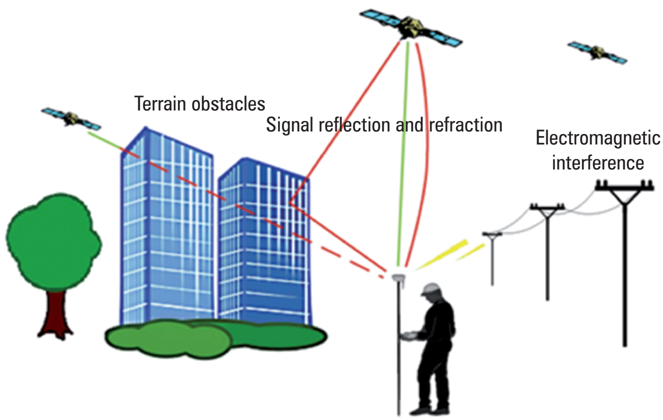
Source: Authors' own study

Fig. 4. Data integration diagram using NFC technology

As already mentioned, this technology can be used in areas where GNSS signals are disrupted, weak or even absent. GNSS signal disruptions can be classified into two types [Smith 1985, Sánchez-Naranjo et al. 2017, Ferrara et al. 2018]: natural disruptions (propagation-based disruptions) and targeted disruptions (jamming, spoofing, and meaconing).

Natural disruptions consist of waves propagated through the air. The environment in which we find ourselves also affects the precision of measurement. This is caused by the fact that a receiver not only receives waves from satellites but also reflected waves from different terrain obstacles.

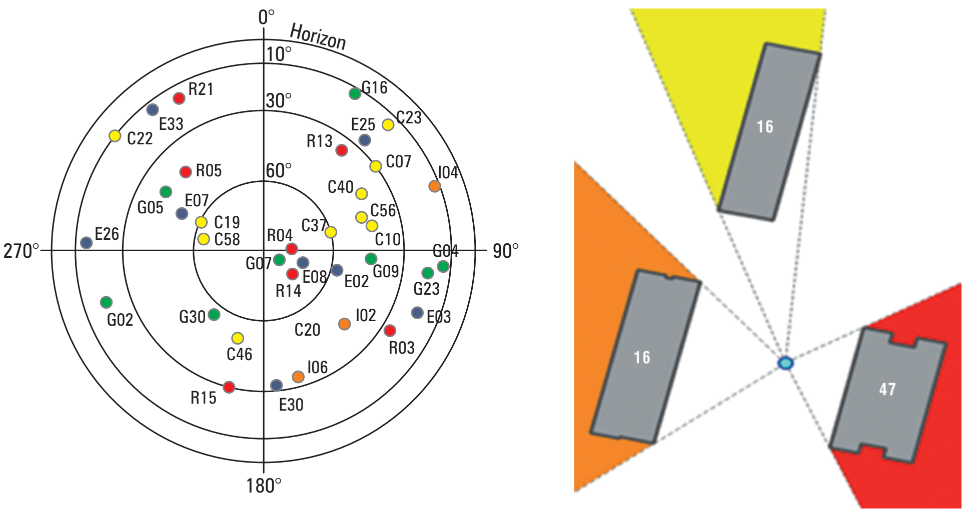
The quality of GNSS measurements is dependent on the visibility of satellites and their configurations in the sky, so a degree of error can be calculated when coordinates are being determined. Such error is described as a function of the geometric satellite distribution in relation to the observers' dilutions of precision (DOP). DOP values can be expressed in different ways depending on the influence of satellites on different components of receiver localization: geometrical dilution of precision (GDOP), positional dilution of precision (PDOP), horizontal dilution of precision (HDOP), vertical dilution of precision (VDOP) and time dilution of precision (TDOP) [Langley 1999, Santerre et al. 2017].



Source: Authors' own study based on www.gugik.gov.pl

Fig. 5. Local factors affecting GNSS signals

As can be seen from the following descriptions and formulas, the precision of coordinates depends on the availability of visible satellites. Graphical imaging is shown in Figure 6.



Source: authors' own study

Fig. 6. Availability of GNSS signals with regard to satellite constellation. **a.** a view of available satellites in the sky (https://www.gnssplanning.com/#/skyplot). **b.** areas with limited satellite visibility

The left part of Figure 6 shows the distribution of satellites in the sky for the tested terrain, with an elevation cutoff of 10°. Satellites are marked with colors and symbols depending on their location within the given system. GPS system satellites are marked in green; GLONAS system satellites are marked in red; satellites belonging to the Galileo system are shown in blue; the BEIDOU system is marked in yellow; and satellites marked with an orange color belong to the IRNSS system. The analysis does not include the Japanese QZSS system because its satellites were not visible in the sky.

The right part of Figure 6 shows the observed measurement point marked with a blue dot. The color gray indicates buildings surrounding the measurement point and the limit of satellite visibility. The numbers on the buildings indicate the height of structures in this terrain. The amount of sky covered by a building depends on its hight and proximity to the measurement point. Covered areas of sky are also marked with different colors: yellow indicates areas with a view restriction of 30°; areas marked in orange have a restriction of 45°; and lastly, red indicates areas with a restriction of 60°.

5. Restricted signal access in the zone model

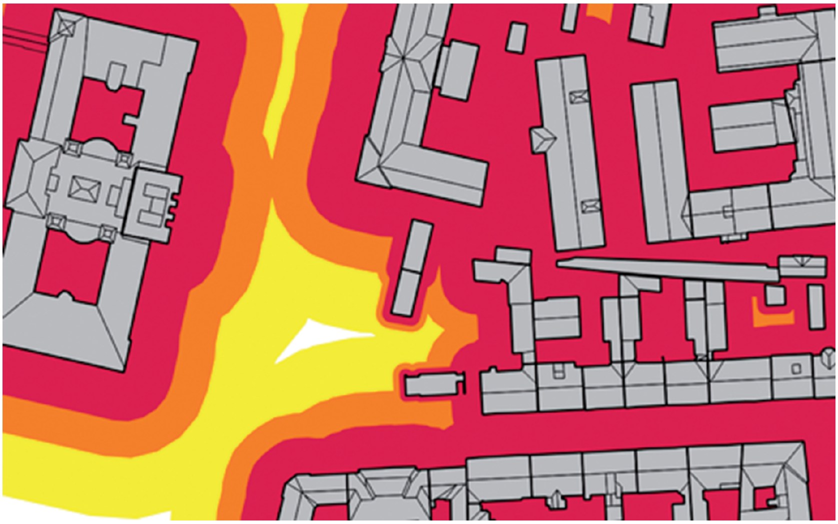
The quality of available GNSS signals was analysed in this study. To perform this analysis, it was necessary to develop a signal-availability model. The research area was located near the AGH University of Science and Technology and the University of Agriculture in Krakow. This is a highly urbanized area with buildings of varying height (5 to 30 meters tall). The average height is about 20 meters. A spatial view of the area is shown in Figure 7 using the Google Earth application. In order to create this model, spatial data describing 3D buildings (including roof shape) were used.

Source: Authors' own study based on data from Google Earth

Fig. 7. View of the study area

Figure 8 shows the results of our analysis of the amount of sky is covered by GNSS signals, with surface objects (e.g., buildings) shown in gray. The model indicates areas with a limited view of the sky. Zones with a limited view are marked with various colors:

red indicates zones where surface objects cover more than 60° of the horizon; orange indicates zones where surface objects cover more than 45°; and lastly, yellow indicates zones where surface objects cover more than 30°.



Source: Authors' own study

Fig. 8. Model of zones with limited sky view access

As stated above, the model shows highly urbanized areas where access to GNSS signals is limited. Precise GNSS measurements marked in red represent areas that are problematic, i.e., where determination requires professional geodetic knowledge and use of other geodetic techniques that do not rely on GNSS signals.

6. Discussion – fields for NFC technology usage

In this paper, we have described how NFC tags can be used to expand accessibility to localization and the chosen characteristics of spatial objects in areas where GNSS technology cannot determine localization. These areas include the following:

- Highly urbanized areas, where dense and high buildings limit access to GNSS signals. These areas are characterized by large numbers of objects that interfere with GNSS signals, meaning that even if the signals are apparently available, point measurements are likely to include a significant degree of error [Wang et al. 2013].
- Forested areas, including hills and foothills. Such areas do not have access to GNSS signals, or the signals are highly restricted. Leaves which reflect signals mean that localization determination is only possible using traditional geodetic techniques. Hills and foothills (ravines and valleys in particular) are especially limiting [Deckert 1996, Tuček and Ligoš 2002, Bastos et al. 2013, McGaughey et al. 2017].

- In areas such as mines and underground buildings, it is extremely difficult, if not impossible, to receive GNSS signals. The only way to determine localization in these places is by traditional geodetic mining (mine survey) techniques [Schofield and Breach 2007, Pielok 2011].

The areas described above are examples of potential application of NFC technology to capture spatial information. Such technology could also be used in places that have access to GNSS signals but where a high level of precision is required in terms of determining localization, necessitating geodetic GNSS-signal receivers. Benchmarks in survey areas should include areas designated for investment, where NFC tags could be used to create border marks, providing precise points of reference for investment decisions.

7. Conclusions

This article discusses the benefits of NFC tag technology and its ability to provide location information and spatial object data. Such signs may be placed on geodetic benchmarks, boundary markers, outbuildings, government facilities or other landmarks. Easy access to the spatial coordinates of such objects (using free software for smartphones) gives many possibilities of use. This applies especially to places with limited access.

In summary, the following conclusions can be drawn:

1. NFC tags can be used to improve the availability of locations and selected characteristics of spatial objects in areas where location cannot be determined using GNSS technology.
2. NFC technology can be used to acquire spatial information without the use of specialized equipment or cumbersome measurements and calculations.
3. NFC tags may be placed on geodetic benchmarks, boundary markers, public buildings, government facilities or other landmarks to facilitate access to the spatial coordinates of these facilities.
4. NFC technology can be used to integrate geodetic data, and the use of smartphones enables the dissemination of this technology in this area.
5. Spatial data obtained from various geodetic databases can be loaded into NFC tags and combined with the physical objects they represent.
6. The presented technology gives the user quick and cheap access to precise data on the location of selected spatial objects.

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