Location Spoofing in a Location-Based Game: A Case Study of Pokémon Go

Bo Zhao and Qinying Chen

Abstract The worldwide Pokémon Go fever has brought location spoofing into the public's spotlight. Location spoofing is an intentional act to masquerade locational information to somewhere other than the actual location where a network communication takes place. In the realm of Cartography and GIScience, compared with well-studied spatial quality issues, our knowledge of location spoofing is still quite limited. By reviewing five frequently-conducted location spoofing techniques for Pokémon Go, this paper critically examines location spoofing as an emerging spatial data quality issue. To unveil the hidden motivation for location spoofing, we discuss the uneven spatial distribution of game rewards through mapping a large volunteered data set of worldwide Pokémons, and gaze at the major actors in the location-based game, including location spoofers, game designers, hackers and bots. Though the research scope of this paper lies in a location-based game per se, location spoofing widely exists in Internet applications and is not fundamentally different from other deceptive phenomena in the real world. We encourage cartographers and GIScientists to face this spoofing phenomena head-on in order to promote more effective and trustworthy uses of geospatial big data.

Keywords Location spoofing · Location-based game · Spatial data quality · Actor-network theory

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1 Introduction

Pokémon Go (PG) is a location-based game for mobile phone users developed by the game company—Niantic. Initially released in selected countries in July 2016, PG has quickly become popular. By September 2016, it has been downloaded more than 500 million times (Gilbert 2016). As a location-based game, the location of a game player in the digital game world is identical to her/his location in the real world. With the positioning capability of a mobile phone, a game player can locate, catch, train and battle with Pokémon (a virtual cartoon creature), who appears on the screen as if being in the same location.

Based on our observation, a number of PG fans from countries where the game had not been released yet have falsified their locational information to download and play this game. Some PG players spoofed their locations to join in remote battles or to accelerate the process of training Pokémons. To our surprise, PG players adopted and even invented several kinds of location spoofing techniques (Zhao and Sui 2017), including, but not limited to, drone spoofing (Sofka 2016), VPN spoofing (Jenner 2014), WiFi spoofing (Harvey 2016), GPS spoofing (Schurgot et al. 2015), and bots with location spoofing functions (Kang et al. 2013).

In the era of big data, spatial data quality is a critical concern for cartographers and GIScientists. Compared with various studies on uncertainty (Hunsaker et al. 2013), noise, and outlier (Lovelace et al. 2016), our knowledge on location spoofing is still limited. Using Pokémon Go—a popular location-based game as the research scope—we closely scrutinize this deceptive phenomenon as a severe spatial data quality issue, discuss game players' hidden motivation for falsifying location, and reflect on the behaviors of other stakeholders related to this game.

Section 2 of this paper is a review of location-based game and actor-network theory. Section 3 explores the location spoofing phenomena in PG; Sect. 4 explains location spoofing under the context of spatial data quality; Sect. 5 discusses the motivation for spoofing; this is followed by the concluding remarks.

2 Related Works

This section introduces two strands of works related to this study: a review of location-based gaming and a brief introduction to Actor-Network Theory. The review of location-based gaming provides a general background of the interaction between the digital and real world of PG. Actor-Network Theory helps place the network of actors related to PG, and further unveils the hidden reasons why game players falsify their locations.

2.1 Location-Based Game

The location-based game (Wetzel et al. 2012) is a mobile game using location to link the real world (where the game player lives and plays) and the digital world (where the avatar of the game player exists). The concept of location-based games originated from an outdoor activity named geocaching (O'Hara 2008). The geocache is a waterproof container having a logbook, a pen, and some trade items. It can be hidden anywhere in the world and its location is shared in the form of longitude and latitude on an openly available website. With the help of a GPS-enabled mobile device, a player is able to look for geocaches. Once a cache is found, the player records this exploits both in the logbook and online, but must return the cache to the same coordinates so that other players can find them.

In a location-based game, locational information is acquired by the positioning function of mobile devices (e.g., iPhone, iPad, Android phones). To accurately position a location, most mobile devices need to receive and parse a series of radio frequency readings, such as GPS signal, cell tower signals, crowdsourced WiFi signals, or even other sensors (Sommers and Barford 2012). GPS is the most accurate method. Though its measurement error can be as small as a few meters, its accuracy is vulnerable to several factors: the quality of GPS chipset, the exposure area to the sky, building materials, and the number of accessible satellites. So, when the GPS signal is weak, mobile devices turn to an assisted-GPS algorithm. This algorithm combines the available GPS with the locational information of nearby cell towers in order to estimate a result. The accuracy is approximately within 1000 m. Today, crowdsourced WiFi data are frequently used for positioning. It is faster than GPS and more reliable than cell tower data, especially in urban areas where WiFi hotspots are ubiquitous but GPS signals may be blocked by buildings.

2.2 Actor-Network Theory

To further examine why game players falsify their locational information, we bring in Actor-Network Theory. Location spoofers can be treated as agents who interact with other actors and have their own motivation in the network. Actor-Network Theory was developed in the 1980s in Paris and is associated with scholars such as Callon (1999), Latour (1987) and Law and Hassard (1999). Different from traditional views that humans are in charge of technologies, Actor-Network Theory treats humans and non-humans (e.g., technologies, materials, and media) as equal and interactive agents or actors. Also, the theory assumes that each agent or actor achieves their shape and attributes by interacting with other elements. In other words, non-human technical actors mediate the way in which people react to them, so human and non-human agents or actors coordinate and evolve collectively rather than separately in social processes.

In Actor-Network Theory, actions are not the special properties of humans, but the properties of the associations of human and/or non-human agents. The intentions, meaning and values of actions keep adjusting and altering through the dynamic relationships among agents or actors. As Latour says, "when the two agents join, any number of unintended goals can emerge which are made possible only by their association in the collective." (Latour 1999, pp. 179).

By applying Actor Network Theory into game studies, we can overcome the limitation of only focusing on game players, and expand our view to a holistic picture depicting a mixed net of all human and non-human actors. Games are simple in terms of their rules, but games could become super complex when multiple human and non-human actors are involved, such as game players and their communities, game makers, the game itself, platforms, technologies, hackers, and even outsiders who are not directly related to the game. Many popular digital games have a huge number of users, and are embedded in sophisticated technical infrastructures, which largely increases the complexity of the games.

3 Location Spoofing in Pokémon Go

As a typical location-based game, PG uses location to link the game frame and the real world. In the game, one can easily locate oneself using the location of one's avatar in the game frame. The terrain and environment of the game frame are built by the geospatial data from Google Maps; and major locations, such as PokéStops, gyms, are collected from crowdsourced geographic data. PokéStops recharge players with game items, such as eggs, Pokéballs, and potions; Gyms serve as battle locations for matches between teams. A player may throw a Pokéball to catch a nearby wild Pokémon. Once the Pokémon is caught, the player gains some game rewards—Pokécoins. These game rewards can be used to evolve or level up Pokémons. Since players have limited Pokéballs, if players need more or cannot wait to hatch the eggs by devoting extra time and energy, they can buy Pokécoins—approximately 0.99 dollars for 100 Pokécoins.

PG published strict location-based game rules. For example, a player must walk continuously to level up a Pokémon, and physically travel to a location to enjoy the game resources associated with that location. Since walking a long way is tedious and some places are difficult to access, a number of game players choose to falsify their locations. Below, we list some frequently-used location spoofing techniques on PG.

PokéDrone: PG players use drone mounted smartphones to catch remote Pokémons, visit distant gyms, or hatch eggs. To do that, a smartphone, attached to a drone, is remotely accessed by a computer through the Internet (see Fig. 1a). A player controls the drone with a app named AirDroid. The drone can take the phone to any nearby places with Internet access. Especially in urban areas, the drone can almost visit any places because of the well mobile data coverage. Based on the same idea, a company named TRNDlabs developed another drone-based device—PokéDrone

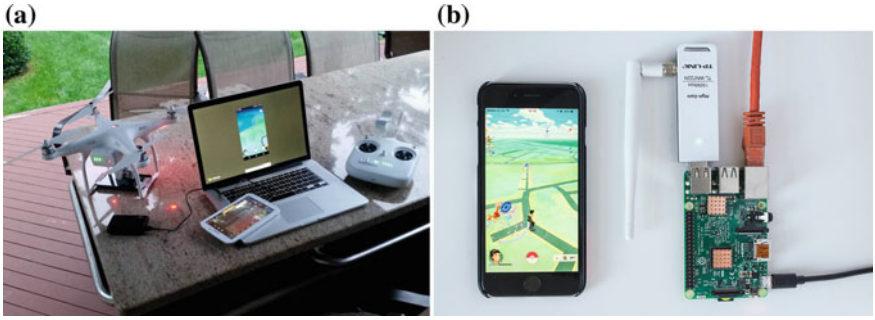

Fig. 1 (**a**) Drone for PG (Muoio 2016), (**b**) SKYLIFT (Harvey 2016)

(Sofka 2016). It has an external camera to navigate to a designated location. TRNDlabs did not treat PokéDrone as a device for location spoofing, arguing that the PokéDrone merely brought GPS chipsets out of the phone, and players could travel to nearby places, which were not approachable by walking.

VPN Spoofing: The initial release of PG was only available in the U.S. version of Google Play Store and Apple App Store, meaning that the PG fans outside of U. S. could not even download the game app. Therefore, in order to play this game, PG fans in other countries spoofed their IP addresses through VPN (virtual private network). While connecting to a VPN, a device will be tunneled to another IP address. Since the IP address is bound to a physical location, most web services will treat the device at the new location. As a result, VPN enables PG players outside of U.S. to download and play PG.

WiFi Spoofing allows the user to spoof to a particular place using a simulated WiFi environment. SKYLIFT (Harvey 2016) is such a low-cost WiFi spoofing device consisting of a Raspberry Pi Computer, a WiFi dongle and an Ethernet cable. It was alleged that a SKYLIFT had enabled a PG player to spoof to a PokéStop at London's Ecuadorian embassy—the home of Julian Assange. To spoof, SKYLIFT scans and collects the records of all surrounding WiFi devices at the target location (i.e., the embassy) with each record containing a MAC address (BSSID) and a WiFi name. Then, all the WiFi records are rebroadcast to simulate the WiFi environment at the target location. Since PG prioritizes GPS signals over cell-tower and crowdsourced Wi-Fi positioning methods, a PG user would need to shield the GPS signals while conducting WiFi spoofing. Consequently, a player can successfully cheat a PG app to believe that they are at the reported location.

GPS Spoofing Apps trick a phone's built-in GPS by transmitting a false set of coordinates. By this means, players can virtually go anywhere in the world. Specifically, one would need a GPS spoofing app to take over the GPS chipset of a mobile phone and to report a designated location instead of the actual location parsed by GPS. PG players are permanently banned if they are caught using a GPS spoofing app. So, to avoid being caught, some players try to spoof their locations at

a reasonable speed. For example, the speed between two reported locations should not surpass that of a normal human travelling with an available vehicle.

Bot with location spoofing function is a computer program which can execute automated tasks, such as simulating the way a real human being plays a game. The advantage of a bot is obvious, it can move to anywhere anytime, which makes the level-up much faster. Most available bot services claim themselves safe and would not break any cyber security rules, however, bots are designed in the same idea as Trojan horses—both can bypass the firewall or anti-virus functions, and there are growing concerns about bot users' Internet security. For example, a bot may easily steal private information. So, most anti-virus tools treat bots as malicious software.

There are a variety of location spoofing techniques used by PG players. Basically, location spoofing represents a deliberate locational inconsistency between the reported location and actual geographic location where a specific network communication is made to location-based game or other kinds of Internet applications. Indeed, location spoofing does not only manifest itself as a locational inconsistency between the reported location and the ground truth, but also associates with a spoofing motivation that triggers the inconsistency.

4 Technical Nuisance or Intentional Plot?

To further understand location spoofing, we aim to analyze the inherent locational inconsistency. In Fig. 2, the x axis indicates the value of locational information, and the y axis indicates the probability that a value is reported. When making a measurement of the object, the operator generally assumes that some ground truth exists based on how they define what is being measured. The operator reports the result usually by specifying a range of values, and expects this ground truth to fall within the range. Since the readings are more likely to fall near the mean than further away, the spread of all the measured results would possibly represent a Gaussian

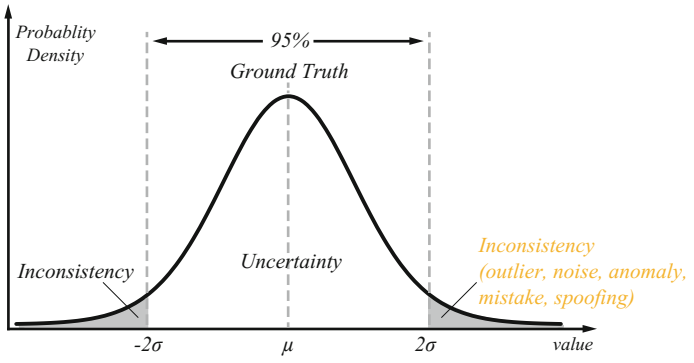

Fig. 2 Comparing uncertainty to spoofing

distribution with the mean being the best estimation of the ground truth. The systematic error is consistent and repeatable, and is a constant offset between the best estimation and the ground truth, whereas the random error arises from random fluctuations. The range of uncertainty is bounded by the two limits of random error, and the inconsistent readings fall out of the range of uncertainty.

Contingent upon different circumstances, the operator sets the limit of random error as multiple times the standard deviation to rule out inconsistent readings. For example, if another reading of the same object has a 95% chance that the measurement is consistent, it will fall within the two limits of double standard deviations to the mean; however, if the reading has 5% chance that the measurement is inconsistent, it will fall outside of these limits.

In most quantitative studies, the inconsistency is often referred to as a data quality issue, such as outlier, anomaly, or noise. However, spoofing is seldom studied in the context of spatial quality, and is often categorized as an outlier or noise. It is worth noting that the terms outlier or noise have a certain degree of ambiguity. They mostly describe inconsistencies caused by some unknown, unclear or inherent factors, such as the environment uncertainties, the measurement uncertainties, or limited knowledge about measurement. Intentional errors/uncertainties are not included. In this regard, location spoofing, as a deliberate locational inconsistency, cannot be regarded as an outlier or noise. To differentiate spoofing from other types of inconsistencies, we suggest investigating the hidden motivations for spoofing, which are discussed in the next section.

5 Generative Mechanisms for Spoofing

After presenting the location spoofing techniques and differentiating location spoofing phenomena from pure noises, the following two issues warrant our further discussion in terms of understanding why game players falsify their locational information.

5.1 Uneven Distribution of Pokémons

We mapped the Pokémons at both global and local level. To do that, we use an API from pokemapper.co to get the Pokémon locations. Pokemapper.co is a volunteered web-map of Pokémons. Once a wild Pokémon is found on the street, a game player can voluntarily upload the information of this Pokémon (e.g., location, timing, and species) to pokemapper.co. In this way, pokemapper.co has acquired a tremendous dataset of Pokémons. On October 21 2016, we visited its data API at https://pokedata.c66.me/sightings (site no longer active), a list of Pokémons' locations in GeoJSON format streamed to our client (data available here: https://github.com/jakobzhao/pokemongo). In the end, we collected 77,445 Pokémons for the whole world. Using QGIS, we plotted this large dataset as maps at different scales.

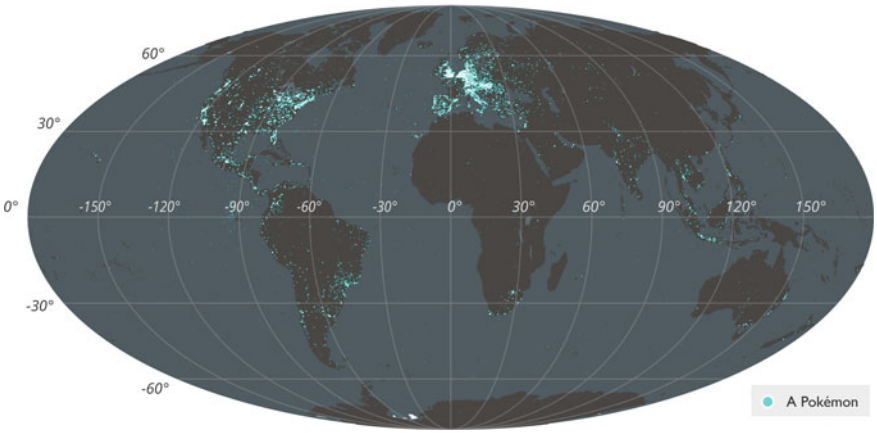

Fig. 3 Global distribution of Pokémons in the Mollweide projection

Figure 3 illustrates the the world-wide Pokémon resources. As observed, most of the Pokémons are located across Europe and North America, and are also clustered in a few cities in Central and South America, Japan, India, Southeast Asia, Australia, New Zealand and South Africa. We also observed that a few Pokémons scattered in oceans, and especially a large amount of Pokémons were around Galápagos Islands of Ecuador.

The map clearly illustrates an uneven global distribution of Pokémon resources among different countries. This uneven spatial pattern suggests why PG fans in the countries with fewer Pokémons want to spoof their locations. Only by spoofing a location to a country where Pokémon Go is released, can a fan download and play this game. Valid locational information becomes the *passport* to access the game. Moreover, in a country with fewer Pokémon resources, it becomes very competitive to catch a Pokémon; this situation urges PG players to find places which possess more Pokémons. Obviously, location spoofing is a much more convenient way to discover the digital landscape of PG, even at the risk of being blocked.

The Pokémon resources also indicate unique spatial characteristics in urban areas. In New York City, for example, (see Fig. 4), most Pokémons are clustered around places like World Trade Center, Time Square, Central Park, while less Pokémons are scattered around the suburban areas. Though PG does encourage people to play outside in the parks and crowded streets, and meet with people there, PG players who live in suburban areas have very limited access to Pokémons. This uneven resource distribution at the local level would possibly result in long travel times or location spoofing to places with more Pokémon resources.

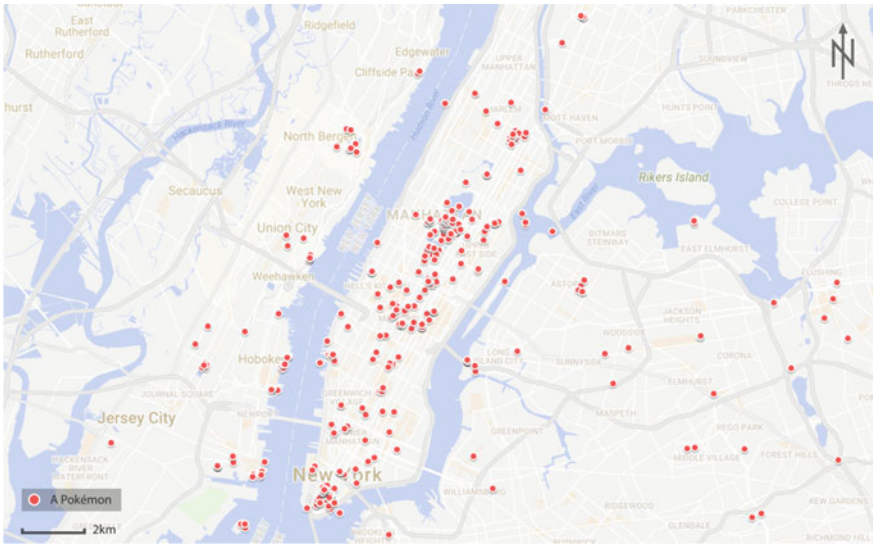

Fig. 4 Pokémons in New York City. The base map uses the Google map in the light political theme

5.2 Individual Motivations

To further comprehend the motivations for spoofing, we apply Actor-Network Theory to analyze PG, focusing on location spoofing and anti-location spoofing behaviors. The experience of autonomy (the extent to which the game prefers flexibility over strategies, choice over tasks and goals, and rewards that provide feedback and not control) and competence (the extent to which tasks offer ongoing challenges and opportunities) influence the level of motivation and satisfaction a player can gain from the game (Przybylski et al. 2010). In PG, players collect Pokémons and battle with each other to obtain rarer and stronger Pokémons. If PG was fully virtual, like many other video games, players might just walk around the virtual map by their mouse-clicks or keyboard-touches. However, PG requires players to move in the real world, which brings many uncertainties to users, such as the places where they live, their daily routines, weather, and the safety of the surrounding areas.

What is more crucial to players is the unequal distribution of Pokémons, which is illustrated in Sect. 5.1. The uneven distribution on one hand motivates players to go to further places, and on the other hand frustrates some players, especially the ones who live in the places having less Pokémons and are not capable to overcome their geographical limitations. In fact, PG offers players one alternative way to overcome the limitations, that is buying incense or lure module with PokéCoins. While using incense or lure module, players have higher chances to encounter wild Pokémons, instead of moving to places further away. However, PokéCoins cost real

money. In this situations, some players who desire to catch more Pokémons have devised location spoofing.

Location spoofing offers players a shortcut to overcome their geographical limitation and go to more places. For players who use location spoofing, their satisfaction for the game are dual: the first-level satisfaction comes from catching rarer and stronger Pokémons, and competing with other players in an easy way; the second-level of satisfaction is that they strengthen their autonomy to reshape the game and challenge the underlying logic of it by mastering new techniques. However, the location-spoofing actions irritate other agents in the network.

Niantic, the game developer, is aware of the issues caused by location spoofing activities in the game. Location spoofing activities break the game rules Niantic set up, and destroy the game experience of regular players. In the long run, the population of active users may shrink, and so do the profits of Niantic. Therefore, Niantic is very strict on location spoofing. Pokémon Go's terms of use warn players not to use "any unauthorized third-party software (e.g., bots, mods, hacks, and scripts) to modify or automate operation," or "attempt to circumvent any restriction in any service," including restrictions on geography. If one violates the terms of use, Niantic can "suspend or terminate your access to some or all" functions of the game. At the same time, Niantic works on strategies to detect location spoofing behavior more effectively, and improving the program to make it harder to spoof.

Although Niantic does not condone cheating, Niantic does not ban online volunteer-based maps, such as Pokemapper.co and a few similar ones like Go Radar, Poké Radar, and Pokécrew. These maps, being embedded in websites or apps, track all Pokémons around the world in a real-time fashion by using crowdsourced data from users, and can show users the exact locations of nearby Pokémons. One reason for not banning the volunteered maps may be that these volunteer activities can help promote friendly player communities, and keep players active and engaged in the game.

Hackers are a special group of location spoofers in the network. Various kinds of bots were developed by hackers to simulate humans playing PG. Most hackers are anonymous in online communities, but some hackers offer simple contact information to help players contact them for bots or services. Many hackers do not profit from their activites and, only some sell bots to get profits, or charge plug-in services. Hackers are rule breakers and get a feeling of fulfillment from acquiring the root privilege.

The dynamic network which is built upon PG makes us revisit the main concept of location. In PG, location spoofers and other users are competing for Pokémons, which are distributed unevenly at global and local level. Pokémons, as a type of resource, are attached to locations. They are locational resources in the digital space, and also connected to the locational resources in the real world. Each agent has different capabilities to turn the locational resources into the capital they want (Zaheer and Nachum 2011). Location spoofers use advanced techniques to break the connections between locational resources in the digital spaces and in the real world, and occupy more locational resources in the digital space without moving to the real locations. Location spoofing in PG warns us to pay attention to the

disconnectedness between "the digital" and "the physical" in the geospatial data and other real-world situations.

6 Concluding Remarks

Location spoofing is defined here as an intentional act of falsifying one's true location to somewhere else. After reviewing several techniques for location spoofing with Pokémon Go, this paper regards location spoofing as an emerging spatial data quality issue that is closely connected with the operator's motivation. To holistically comprehend location spoofing, we further discuss its generative mechanism: a fundamental mechanism which triggers players' motivation to spoof is the uneven distribution of game rewards. At the individual level, we analyze a variety of motivations for location spoofing from players, game designer, bots, and hackers.

Though the research scope of this paper lies in a location-based game, location spoofing widely exists in Internet applications and is not fundamentally different from other forms of deception. Contingent upon specific circumstances, location spoofing could have significant impacts on our daily lives, social developments, and even national security. We hope this paper can raise awareness of the multiple dimensions of location spoofing when geospatial data are used in research or policy-making. We encourage cartographers and GIScientists to face this spoofing phenomena head-on whenever necessary in order to promote more effective and trustworthy uses of geospatial data.

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