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Duking It Out at the Smartphone Mobile App Mapping API Corral: Apple, Google, and the Competition[*] [†]

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ABSTRACT

The recent introduction of the Apple iPhone 5 and the accompanying iOS6 software environment which, among other changes, replaced the use of the Google Maps API in iOS5 by Apple's own Maps API, has led to significant changes in the user experience with apps that make use of maps and has resulted in closer scrutiny of mapping applications on mobile devices. Many of these changes in the user experience deal with the quality of the data that is being produced and presented to the user, and has led to a wide ranging discussion of data quality and the seeming lack of quality assurance policies and protocols by Apple. These are widely documented in web postings. However, equally important are significant changes in the manner in which the data is presented to the user, but, surprisingly, not much attention has been paid to this aspect of the user experience which is somewhat analogous to the concept of the "last mile" when discussing the bandwidth of communications networks and its associated costs. The changes in the presentation and in the amount of data that are presented to the user on the Apple mapping platform, with an emphasis on mobile devices with a small form factor such as smartphones, are tabulated and compared along with other mapping platforms such as the iOS apps of ESRI, MapQuest, and OpenSeaMap (using the open source map data of OpenStreetMap), as well as Bing Maps and Nokia Maps for which no iOS app exists and thus the corresponding mobile web versions are used.

Categories and Subject Descriptors

H.2.8 [**Database Applications**]: Spatial databases and GIS; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms

Design, Human Factors, Performance

Keywords

Mobile Applications, Mapping, API, Smartphones

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†For a version of this paper with images with smartphone form factor sizes see `http://www.umiacs.umd.edu/smartphone-mapping-apps`.

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1. INTRODUCTION AND OVERVIEW

The explosive growth of the Internet coupled with the increasing use of location-enabled devices such as smart phones has led to an increasing awareness of the importance of location information, which traditionally has been presented with a map. In particular, for centuries, maps have been used to convey abstractions of spatial information in a manner that is aesthetically pleasing and familiar to their users, often at the expense of accuracy, which, nevertheless, users have found to be acceptable often due to conformance with commonly held beliefs (e.g., that the Earth was flat in pre-Columbus times). For example, labels for place names are placed on the map in such a manner that their location does not overlap names of other nearby places, winding roads with switchbacks are represented with a screw-like symbol where the number of turns in the symbol has no correlation with the number of switchbacks that are actually present, etc. In the past, maps were used not only to present the information but also to store the information, and provide an easy and rapid way to access it (also known as *indexing* using today's parlance).

Traditionally, maps were drawn by cartographers who often had the social and professional standing of artists. This took a considerable amount of skill, effort, and time, and the maps are still recognized by their value (both financial and artistic). The advent of computers and the increase in their use to produce maps, as well as the diversity and increasing sophistication of the output devices with which their output can be presented and viewed, has led to a dramatic decrease in the time needed to produce maps, and hence in their variety and distribution. In particular, maps are no longer created and produced only when there is a sufficient demand for them, where "sufficient" is defined quantitatively. Moreover, maps are not necessarily printed nor assembled in collections such as atlases which often have a common theme such as the display of particular attributes like crops, landuse, rainfall, etc. Instead, maps are produced in a custom made manner to display some specific spatial relationship rather than in groups, and most often in units of one.

The rise of the use of the world wide web and the ease with which documents can be accessed, regardless of their physical location, has had a profound impact on the accessibility of maps and their customized generation and use. People don't hesitate for a moment in deciding whether or not they need a map, and, in fact, the results of many search queries are often accompanied by a map when the result involves some location information. The results can be viewed dynamically, unlike atlases which are usually static, meaning that changes can be made through actions such as browsing (e.g., [18, 29, 30, 34]) or manipulating what is termed a spatial spreadsheet [20]. Moreover, the web has made it easier to find and retrieve data by location (i.e., index it) regardless of whether the location is specified explicitly or, increasingly more importantly, implicitly by virtue of the physical location of the user.

The explicit specification of location has traditionally been geometric (e.g., as latitude-longitude pairs of numbers). This is often cumbersome as users don't think of a location in this way, and often don't know it in this way or have easy access to it, and, more importantly, are not accustomed to communicate it to others in this way. Instead, they are used to specify a location textually (including verbally). A textual specification has a number of advantages. The first is that it is easy to communicate especially on smartphone devices where a textual (also increasingly verbal via speech recognition such as Siri on the Apple platform) input capability is always present. Another important advantage is that the text acts like a polymorphic type in the sense that one size fits all. In particular, depending on the application which makes use of this information, a term such as "Washington" can be interpreted both as a point or as an area, and the user need not be concerned with this question. The drawback of the textual specification of location data is that it is ambiguous. In particular, there are many possible locations named "Washington" and they must be resolved (i.e., "toponym resolution") [23]. Moreover, in some cases we are not even sure that the term "Washington" denotes a location as it could be a reference to the name of a person (i.e., "toponym recognition") [22]. This can be the case when processing documents such as newspaper articles, tweets, blogs, etc. The process of understanding and converting location text to its geometric specification is known as *geotagging* (e.g., [21]) and is beyond the scope of this paper.

The implicit specification of location is achieved either by the IP address of the user's computing platform (regardless of its size) or, increasingly more commonly, by an embedded GPS capability which provides the user's physical location.

Still another technique of location specification that is increasingly coming into play with the rising popularity of touch interfaces is one that combines the implicit and explicit specifications to yield an approximate specification. Observe that a map, coupled with the ability to pan and to vary the zoom level at which the world is viewed, provides an inherent granularity to the location specification process which facilitates this approximate specification. In particular, the act of pointing at a location (i.e., by the appropriate positioning of a pointing device with the aid of panning) and making the interpretation of the precision of this positioning specification dependent on the zoom level is equivalent to permitting the use of spatial synonyms, which are the hallmarks of approximate specifications. For example, users posing a query seeking a concert in Manhattan would be satisfied by the return of a concert in Brooklyn. Thus users no longer need to know the exact name or position of the desired location. In other words, the touch interface serves as an implicit access structure to the data accomplished with direct manipulation. Of course, an index is still required whose access is achieved by software that translates the screen coordinates (via use of some nearest neighbor techniques as in a "pick" operation in computer graphics [19]) to the ones used by the index.

The almost universal adoption of smartphones, and, to a lesser but increasing extent, tablets (virtually all of which have an embedded GPS) has made location information a cornerstone of queries and has led to the reinforcement of the above realization that the map is the most convenient way (especially on the smartphone which has a limited display size) of presenting the associated query result information to the user. Thus it has become a de facto rule that whenever operations (invariably queries) involve any location information, the query result is presented using a map, and increasingly so is the formulation of the query. This has led to a wide range of applications and the use of a wide range of sources for the maps, the drawback of which is that the maps are not produced in a manner consistent with the traditional concerns for the factors of/trade-offs between accuracy, aesthetics, and completeness, as well as in line with generally accepted cartographic principles (e.g., [28]). To a large extent, the airing (as well as increasingly venting) of these drawbacks has lain dormant in the sense that people were subconsciously aware of them but were so satisfied with the resulting increase in capabilities that they were either inhibited from or did not feel it necessary to express their disappointment in the failure to live up them.

However, all of these inhibitions were abandoned with the introduction of the Apple iPhone 5 and the accompanying iOS6 software environment which, among other changes, replaced the use of the Google Maps API on iOS5 by Apple's own Maps API (referred to here as the *Apple Maps API*). The applications on the mobile devices (smartphones and tablets), are not the traditional ones where the map has been used in a passive manner as is the case in atlases containing maps that are browsed leisurely. Instead, the map is used in an active manner as a tool to enable such tasks as navigation and location finding where accuracy is paramount, and now issues of data quality and lack of quality assurance policies and protocols became very apparent (e.g., [7, 17]). These include issues of completeness in the sense of missing data (e.g., the towns of Stratford-upon-Avon and Solihull in the UK are missing [3]) incorrectly placed data (e.g., the town of Uckfield in East Sussex in the UK is incorrectly placed [3]), mislabeling of locations such as marking "Airfield House" in Ireland as an airport when it is really a farm [3] and the Helsinki railway station as a park [7] as well as also locations in the US such as labeling much of the east side of Portland, OR as a park [7], and misplacing the Washington Monument [6]; while others are of duplicate data (e.g., the disputed Senkaku (Japanese) and Diaoyu (Chinese) Islands in the Pacific shown twice in Apple Maps — once as belonging to Japan and once as belonging to China [3]). The source of these errors could be attributed to multiple data providers where the appropriate checks for pruning and integrating duplicates were not detected and applied due to conflicting positions. Still other issues of accuracy can be attributed to the use of out of date data, simple positioning errors, as well as missing points of interest or wrong locations for them.

Some other well-documented examples [11] of the shortcomings of Apple Maps versus Google Maps on iOS5 include the amount of map details where Google Maps on iOS5 has more street names, building names, etc. In essence, there are fewer points of interest that are not shops or eating establishments on Apple Maps which is attributed to the different sources used by Apple Maps for the data with a heavier influence for Yelp and Trip Advisor [1]. There is also the absence of directions for use on public transit for navigation on Apple Maps (thereby requiring an outside App [10]) while they are included in both the iOS5 and Android Google Maps.

In fact, the same is true for offline navigation which is offered on the Android while missing in both iOS5 and iOS6. The search on Google Maps (both iOS5 and Android) favors local search in the sense that when seeking a location (specified textually) that is ambiguous, both iOS5 and Android Google Maps return the location closest to the location of the query poser, while Apple Maps returns the one deemed the most likely interpretation (usually based on population, which, as we showed [25, 27], is not always the right thing to do as in newspaper articles where knowledge of the audience is the determinative factor). Thus for a query posed in College Park, MD, seeking "Damascus", iOS5 and Android Google Maps return "Damascus, MD" while Apple Maps returns "Damascus, Syria".

There has been quite a bit of finger pointing as to the source of the above errors primarily in the direction of Tom Tom, the provider of the data [3], as well as the sources for the data that is overlaid on the maps such as Yelp and Trip Advisor to name a few. Tom Tom counters [3] that it has been providing map and related content to other vendors of mobile devices with few complaints, and adds that the problems are really ones of user experience which it claims is largely determined by the use or misuse of their data and by the additional features added by the application builder to the map application which seems to point the finger at Apple, the provider of the API and the feature data that the API captures, which is not unreasonable from Tom Tom's perspective. In any case, these shortcomings are likely to diminish as problems continue to be identified and fixed in what has become a typical example of the utility of crowdsourcing, or what we more appropriately term *geocrowdsourcing*. Interestingly, the inability of Apple to capture such information as well as the locations queried from users in the case of the use of Google Maps with iOS5 is attributed by many (e.g., [9]) to be one of the main reasons for Apple's rush to come up with its own proprietary mapping platform.

In addition to the above shortcoming, Apple Maps is also lacking from the perspective of usability and aesthetics of the presentation. However, surprisingly, these shortcomings have not been given a large airing. Their airing is the main focus of this paper, and is discussed in greater detail in Section 2, which also includes examples from other mapping platforms. These shortcomings are especially apparent when we focus on the form factor of the mobile devices in the sense that they largely come into play on smartphones, such as the iPhone/iPod Touch, rather than on tablets, such as the iPad, where the display has much more screen "real estate". They arise because here we are evaluating the quality of the map from the perspectives of data access and presentation. In particular, the map provides an efficient way of accessing spatially-referenced data when we cannot look at all of it at once. Our observations are based on the experience that we gained in building the STEWARD [24], NewsStand [35] and TwitterStand [33] systems for accessing documents such as, but not limited to, news with a map query interface (i.e., by location and, to a lesser extent, also by topic [15]) and their adaptation (especially NewsStand and TwitterStand) to run on smartphones [31, 32]. In these applications, as well as in many related ones, the map serves as a device to help users orient answers to queries in which they want to take advantage of spatial synonyms. In addition, we are motivated by the desire to be able to place spatially-referenced information on the map such as icons for topics, image thumbnails (e.g., [26]), names of particular locations, names of people, diseases, or any other data that lends itself to being classified using an ontology (note that a Gazetteer which is used to translate textual specifications to geometric ones can also be considered as an ontology). The result is akin to a mashup except that in our case, the mashup is hierarchical in the sense that as we zoom in on the map, additional spatially-referenced information is displayed that was not of sufficient importance to be displayed when we are zoomed out.

Nevertheless, all is not negative on the user experience front in that Apple Maps uses vector graphics for drawing while the iOS5 Google Maps API makes use of raster graphics which means much faster and smoother performance for Apple Maps as less data needs to be downloaded. In particular, vector graphics enables resizing as zooming takes place while raster graphics requires new map tiles to be downloaded as users zoom in and out on their maps. Interestingly, Google Maps has been vector-based on the Android for several years [4].

2. A PRESENTATION AESTHETICS AND UTILITY-BASED EVALUATION

In this section we compare the iOS6 Apple Maps API with the iOS5 Google Maps API, and to a lesser extent with the Android Google Maps API (Maps version 6.12.0 on Android 4.0.4) which is quite similar but does not always yield the same result. However, when they do yield the same result, then we refer to them collectively as *Google Maps*; otherwise, we qualify them as the *Android Google Maps API* or the *iOS5 Google Maps API*, as is appropriate. Our comparison also include additional mapping platforms, not all of which have corresponding apps on the Apple devices in which case our examples make use of their mobile web versions that run on iOS6 on the iPhone/iPod Touch device unless explicitly stated otherwise. In particular, we include the iOS apps of ESRI (ArcGIS iOS App 2.3.2), MapQuest (iOS App 3.1), and OpenSeaMap denoted by *OSM* (using the open source map data of OpenStreetMap which could have also been used as the map data for the MapQuest App) [12, 13, 14], as well as the mobile web versions of Bing Maps and Nokia Maps (which also is increasingly serving as the source for Bing Maps's data [2]) as no iOS app exists for them.

We examine a number of example maps in our comparison which enables us to evaluate the mapping platforms for different map scales thereby implying different query output scenarios. Figure 1 is a small scale map such as Africa which is primarily of use for the display of spatially referenced information such as that which would be deployed in a mashup application. Figure 2 shows a map for a country such as the US which falls somewhere between a continent and a local region. Figure 3 is a larger scale map such as of the College Park, MD area which is of use for local tasks like finding particular points of interest such as restaurants, parks, etc., while Figure 5 is an example of such a map on an even larger scale which is used for the purpose of navigation. Figures 4 and 6 show the scope of the minimum level of zoom for the smartphone device (iPhone) in landscape and portrait modes, respectively. The screen shots here have been reduced in size. See `http://www.umiacs.umd.edu/smartphone-mapping-apps` for a version of this paper with screen shot images with smartphone form factor sizes. Note that Android screen shots are larger due to a 2.5×4 inch screen instead of a 2×3 inch screen of the iPhone/iPod Touch.

Before comparing the use of the various platforms for the above example maps, we briefly review a few properties whose satisfaction we found to be desirable, and which we used in some of our comparisons. They are summarized for the various platforms (using *A5* for iOS5 Google Maps, *A6* for Apple Maps, *G* for Android Google Maps, *B* for Bing Maps, *NK* for Nokia Maps, and *MQ* for MapQuest in Table 1 and explained in greater detail as necessary in the subsequent discussion. The table denotes whether the property does not ($\times$), partially (P), or holds ($\checkmark$).

Table 1: Comparison of Mobile Mapping Applications

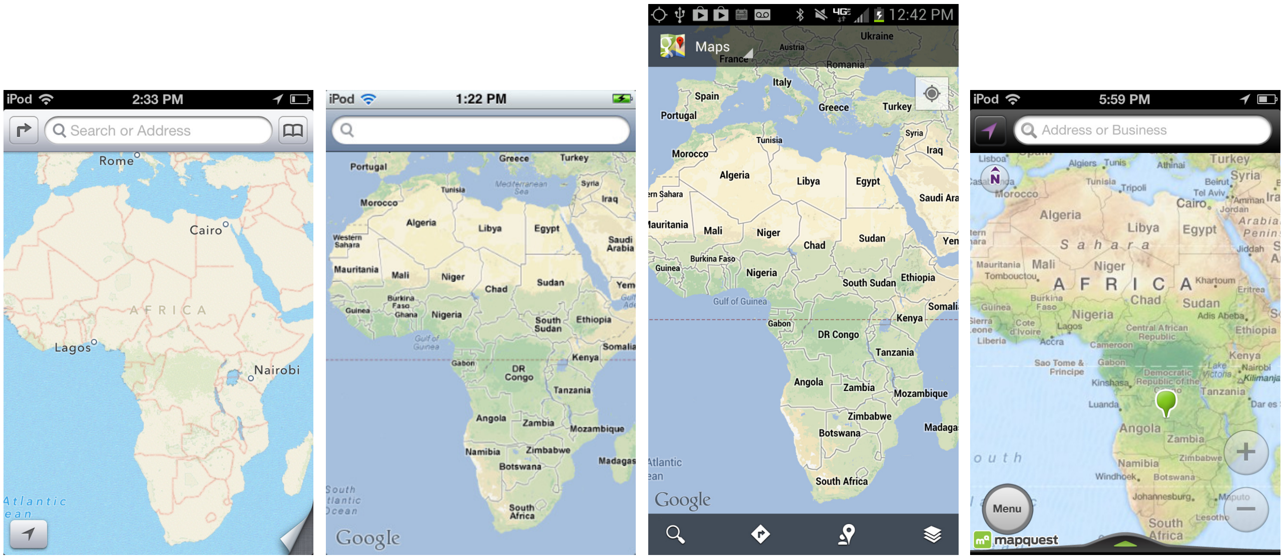
Features	Mapping Applications							
	A6	A5	G	B	NK	MQ	ESRI	OSM
Panning C	×	✓	✓	✓	✓	✓	✓	✓
Zoom C	×	✓	✓	✓	✓	✓	*P*	✓
No Overlaps	✓	✓	✓	*P*	✓	✓	✓	*P*
Hierarchical C	×	*P*	*P*	×	×	×	✓	✓
Sibling C	×	✓	×	✓	×	✓	✓	✓

1. *Panning consistency:* When panning on the map, the labels should be consistent and not disappear as long as the underlying space is visible. From our limited tests, at time of writing, all platforms other than Apple Maps satisfied this property.

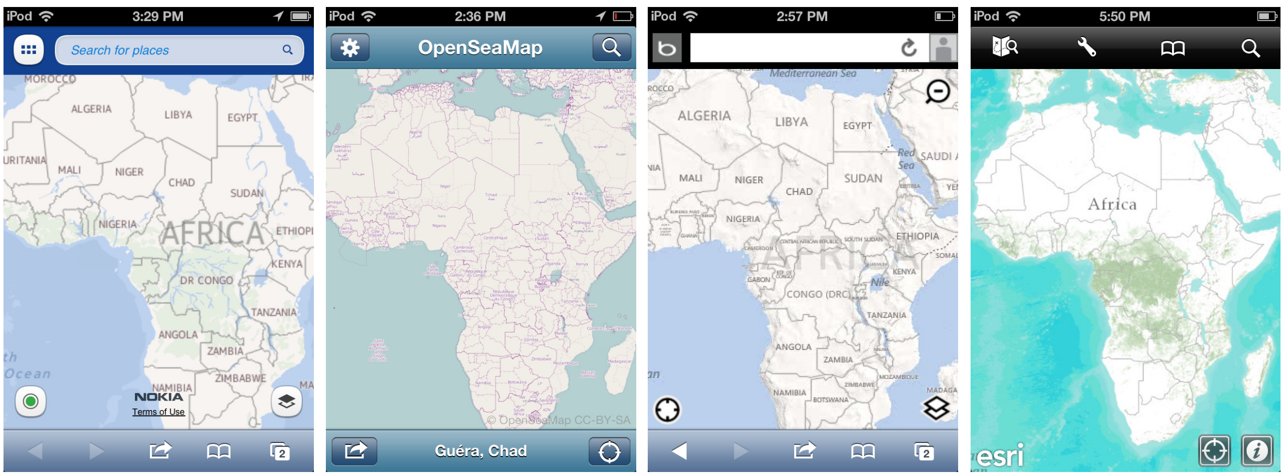
2. *Zoom consistency:* As the user zooms in, names of places that are displayed continue to be displayed, although names of large containers such as "United States" may vanish as the zoom gets very deep. This property holds for all platforms except for ESRI where it holds partially as long as the user does not mind that labels change their location at the different zoom levels, and for Apple Maps where it holds on the iPhone/iPod Touch but not on the iPad as can be seen by zooming into Africa in Figure 7 so that the zoom starts in Figure 7(a), where country names are present and mostly disappear at the first zoom shown in Figure 7(b), only to reappear again when zooming in further as in Figure 7(c).

3. *Overlap avoidance:* Place names should not overlap (e.g., [16]). This property is enforced in all of the platforms with the exception of OSM (e.g., Figure 2(f)) and only partially in Bing Maps where watermark style names are permitted to overlap other names (e.g., "Africa" in Figure 1(g)).

4. *Hierarchical Consistency:* Generally speaking, the name of a location should not be displayed without also displaying the name of its container location provided that the container location is visible in its entirety. Therefore, if Los Angeles is displayed, then so must its containing state California. This property only holds for ESRI and OSM and is most likely due to their geography/cartography roots. It does not hold uniformly in Google Maps which enforces it in Australia, Brazil, Canada, and the US but not in China and Mexico. Note the distinction from zoom consistency which deals with multiple map views while hierarchical consistency is concerned with just one map view.

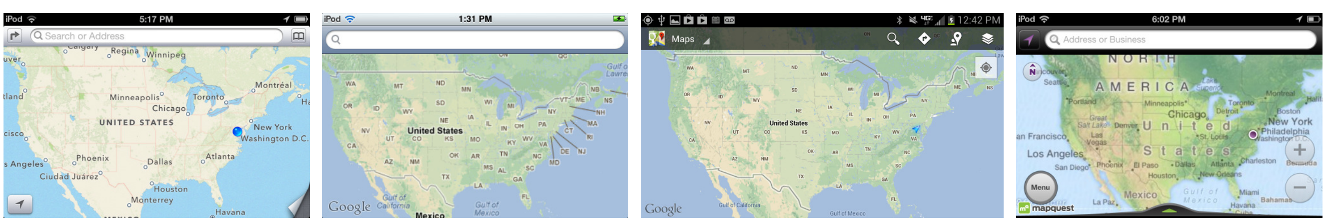


(a) iOS6 (b) iOS5 (c) Android (d) MapQuest

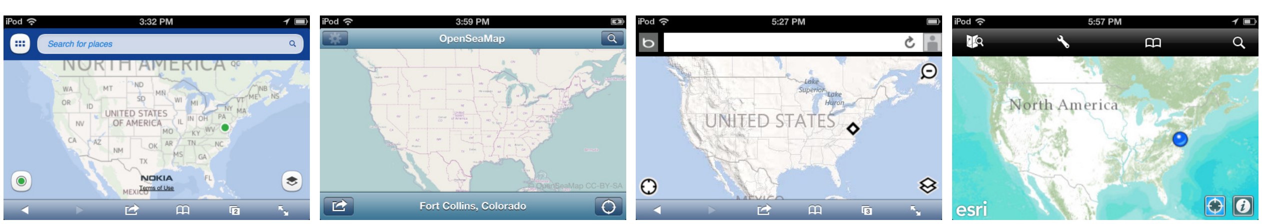


(e) Nokia (f) OSM (g) Bing (h) ESRI

Figure 1: Maps of Africa

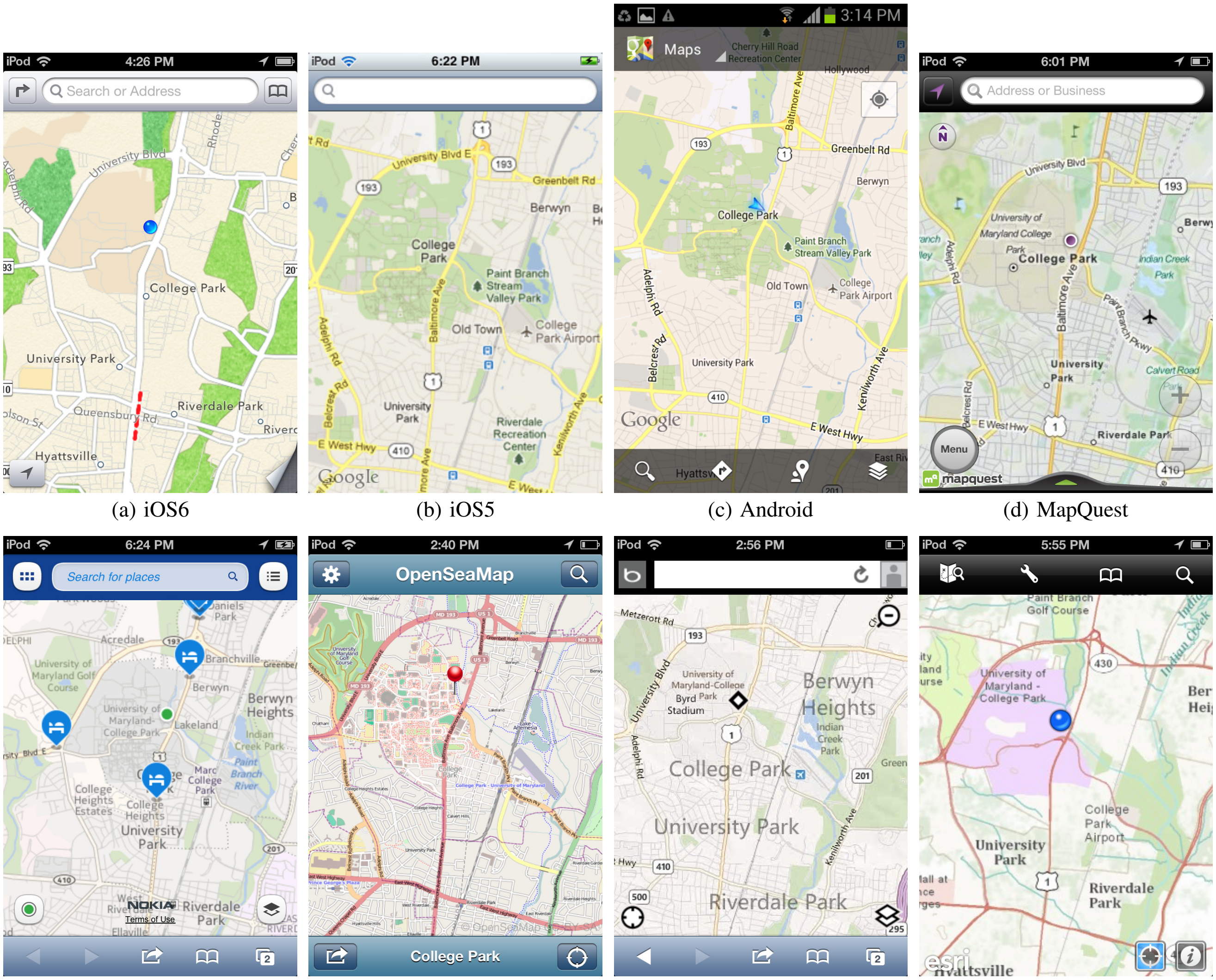


(a) iOS6 (b) iOS5 (c) Android (d) MapQuest



(e) Nokia (f) OSM (g) Bing (h) ESRI

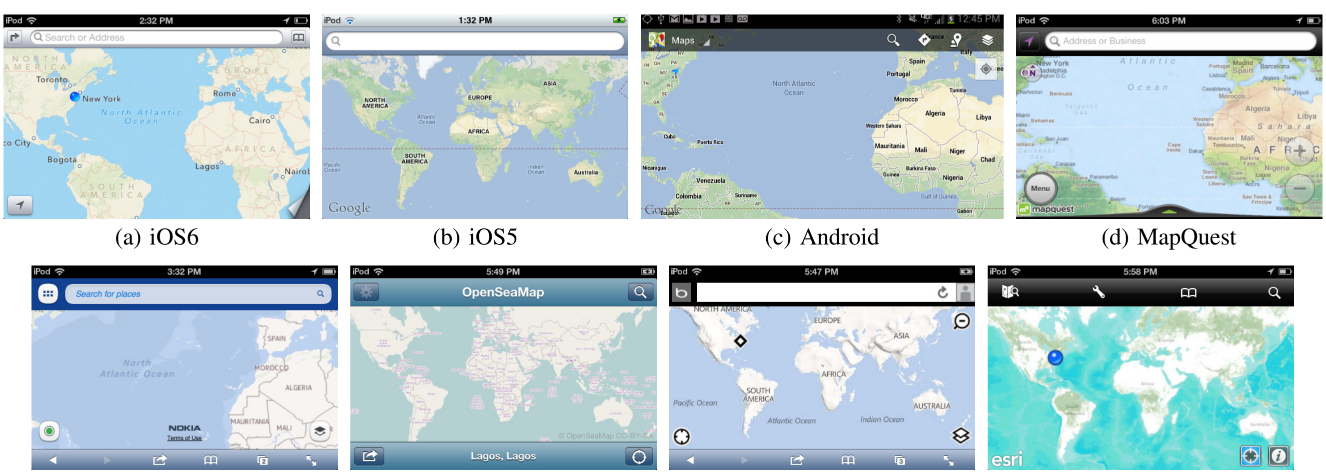
Figure 2: US Maps in landscape



(a) iOS6 (b) iOS5 (c) Android (d) MapQuest

(e) Nokia (f) OSM (g) Bing (h) ESRI

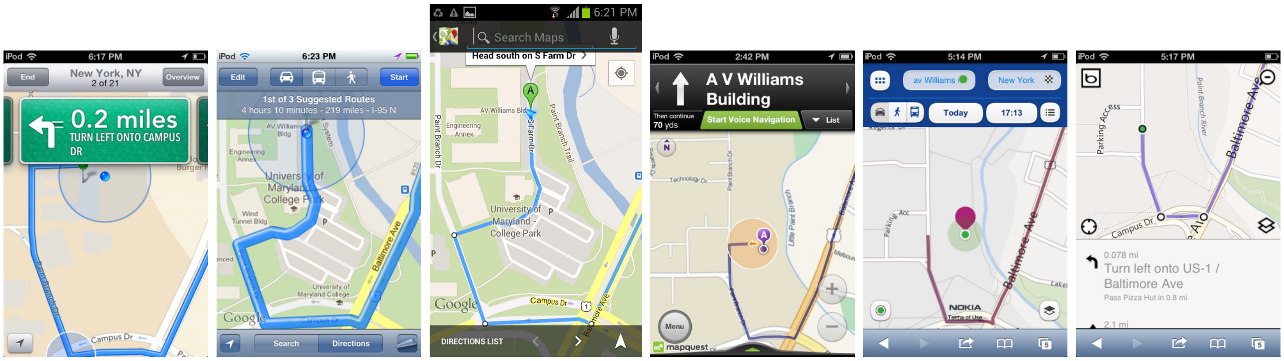
Figure 3: University of Maryland, College Park



(a) iOS6 (b) iOS5 (c) Android (d) MapQuest

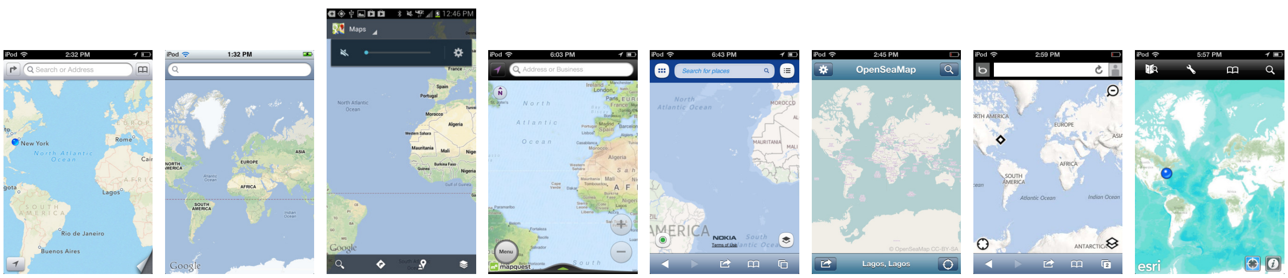
(e) Nokia (f) OSM (g) Bing (h) ESRI

Figure 4: World maps in landscape



(a) iOS6 (b) iOS5 (c) Android (d) MapQuest (e) Nokia (f) Bing

Figure 5: University of Maryland, College Park (navigation/directions mode)



(a) iOS6 (b) iOS5 (c) Android (d) MapQuest (e) Nokia (f) OSM (g) Bing (h) ESRI

Figure 6: World maps in portrait

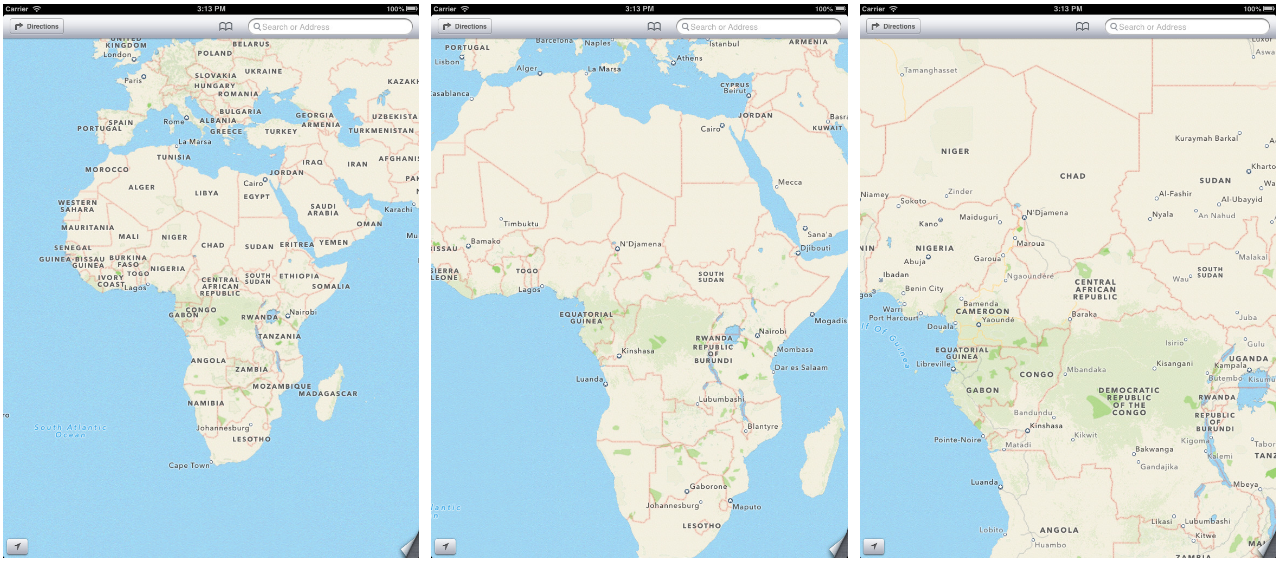
5. *Sibling Consistency:* If the name of a location at a particular depth of the mapping hierarchy is displayed, then the names of all of its visible sibling locations must also be displayed and using the same type and size of font or symbol. For example, if the abbreviated name of a state is displayed, then the names of the remaining visible states must be displayed in the same way using abbreviations. Notice that with respect to state names, this requirement is only enforced in the US and is only tabulated in this respect here.

Our first example examines how the mapping platforms deal with a relatively small scale map for the form factor of the device on which it is viewed (i.e., a smartphone such as the iPhone/iPod Touch) where much detail is not expected. Figure 1 shows the African continent. We immediately see that in Apple Maps (Figure 1(a)) both the continent and a very small number of cities are labeled (i.e., Cairo, Lagos, and Nairobi) which is hierarchically inconsistent. On the other hand, Google Maps is in essence hierarchically consistent save for completeness as it does not label all countries such as missing Ivory Coast. The two Google Maps versions differ in that (1) iOS5 includes Ghana while Android does not, and (2) all multi word names (e.g., Burkina Faso) are displayed in one line in Android (Figure 1(c)) and in two lines in iOS5 (Figure 1(b)). Note the presence of topography details in iOS5 and Android, while only a minimal amount is present in Apple Maps.

Switching to a smaller region like the European subcontinent shows stark differences between Apple Maps and iOS5 Google Maps as in Figure 8. We do not include the Android Google Maps variant as there is very little difference from the iOS5 variant for this example. We immediately notice that Apple Maps does a very poor job of label placement. We see a mixture of city and country names in Apple Maps (Figure 8(a)) without satisfying hierarchical consistency. In particular, when a city name appears, the name of the country is not always included such as Rome and not Italy (Figure 8(a)). Similarly, the countries that are labeled are not necessarily the most important ones (e.g., France, Germany, and Italy are absent). In particular, it seems that the countries near the center of the viewing window are given preference. Nonstandard country names are sometimes used (e.g., Alger instead of Algeria in Figure 8(a)). Apple Maps uses an all caps font which takes up too much space. Names of bodies of water such a the Mediterranean, North, and Norwegian Seas are not shown in Apple Maps (Figure 8(a)), while they are shown in iOS5 Google Maps (Figure 8(b)).

On the other hand, iOS5 Google Maps (Figure 8(b)) does a better job of deciding that at this level of display, the country entity is important and the labeled countries are chosen on the basis of who provides the best distribution over the space spanned by the query window. This is better than the Apple Maps approach of displaying names of countries without much thought paid to their spacing and also to their importance, leading to a cluttered appearance.

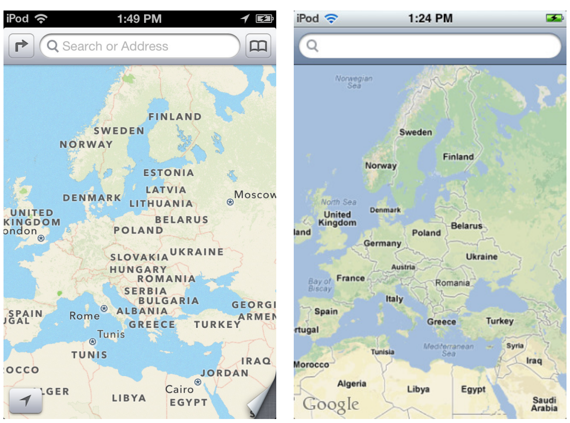
Figure 3 is an example of how the various mapping platforms deal with local information where more details are expected as in the case of a map which we might use for local tasks such as finding particular points of interest or simply to orient ourselves with respect to our surroundings. We immediately notice the difference in the amount of information and its type between Google Maps and Apple Maps. Google Maps displays many more street names than Apple Maps and also, unlike Apple Maps, Google Maps uses a color code to distinguish major streets, for which names are provided, from minor streets, for which no names are provided. Also, all labels for entities (i.e., roads, parks, towns, etc.) in Google Maps use the same font, font point size, and color, whereas Apple Maps uses a normal font and a black color for roads, a watermark style for towns, and italics for non-road features such as parks. However, fortunately, Apple Maps no longer uses all upper case for labels of places as in the case of the more global maps such as those seen in the maps of Africa (Figure 1(a)) and Europe (Figure 8(a)). The presentation of MapQuest is similar to Google Maps. OSM displays the richest variety of symbology differentiating between many feature types as well as labeling major roads although not identifying any points of interest. The presentation of Nokia Maps is not as vivid as Apple Maps in the sense of less use of color and a heavy use of watermark



(a) (b) (c)

Figure 7: Map of Africa at different zoom levels

style for labels. Nokia Maps and OSM identify far more names of towns and neighborhoods (with an edge to OSM although they are not readable on a smartphone form factor without significant zoom and likewise for the Africa and US maps in Figures 1(f) and 2(f), respectively) than any of the other mapping platforms. Bing Maps has similar information as Google Maps although it makes use of variable font point sizes and a watermark style for names of towns and neighborhoods. ESRI is relatively data poor with respect to the other mapping platforms although providing a stronger differentiation between major and minor roads. However, its data seems out of date as in the road labeled "430" which is no longer used to identify it [5].



(a) iOS6 (b) iOS5

Figure 8: Europe maps

Figure 5 is a related example of local information used in the navigation systems that we could find which are built using the mapping APIs (all but ESRI and OSM). In particular, we show the map of the initial step in the route from the AV Williams Building at the University of Maryland in College Park, MD to a point in New York City. The results are quite similar with Apple Maps being the clearest (very bold and large display of the navigation steps). A noticeable difference was in building names which are provided by Google Maps (Android and iOS5), while not by Apple Maps, MapQuest, Nokia Maps, and Bing Maps, although outlines of some buildings are provided in Apple Maps when applying much zooming in, but not in the smartphone form factor. Another important feature for navigation is the extent that parking lots and driveways are shown where Apple Maps and MapQuest fall short (this is only true for the MapQuest App), while the remaining platforms that we examined include prominent ones (i.e., Google Maps as seen in Figures 5(b) and 5(c), Nokia and Bing Maps although not in our example in Figures 5(e) and 5(f), respectively, and the web version of MapQuest).

Figures 4 and 6 serve to demonstrate the geographical scope of the information at the world level which can be presented on the device in landscape and portrait modes, respectively. Interestingly, in both these modes, iOS5 Google Maps, Bing Maps, ESRI, and OSM all present almost the entire world, while Android Google Maps, Nokia Maps, and MapQuest all present a much narrower view of the world with Apple Maps falling somewhere in the middle of the two extremes with surprisingly many place names being relatively well-distributed and readable. Seeing the entire world is important when we want to observe a feature's behavior over the entire world with one view rather than having to pan the map to see the behavior's full extent (e.g., news topics, disease mentions, people, etc. as in NewsStand [31, 32, 35] and TwitterStand [33]). The number of feature instances can be varied with a slider (e.g., NewsStand).

Figure 2 is a similar landscape map for the US; however, the differences among the platforms is more striking. ESRI and MapQuest display the same amount of detail as they do at the world level (too little for ESRI while a nice amount for MapQuest) with a heavy cartographic influence on the presentation (e.g., topography and hydrography) undoubtedly reflecting the historical roots of the platform, at least in the case of ESRI. Overall, most interesting is the relatively small number of labeled places in the US ranging from zero in Bing Maps and ESRI, to a few cities and the country name (hierarchical inconsistency as no state names) in Apple Maps and MapQuest, while Google Maps (iOS5 and Android), Nokia Maps, and OSM label the states with all states being labeled by both iOS5 (using pointers where there is not enough room) and OSM (by reducing the point size of the font) thereby satisfying sibling consistency. The other remaining platforms provide labels wherever they can fit, all of which is done with the aid of abbreviations (note the close similarity between Nokia Maps and Android Google Maps). Of course, care must be exercised to ensure the use of a consistent set of abbreviations which means coming from the same source. Observe that Google Maps and OSM use the USPS (US Postal Service) abbreviations, while Apple Maps and Bing Maps use the AP (Associated Press) abbreviations where Bing Maps only uses abbreviations for small states. Note that when we increase the zoom level or use a device with a larger screen, for the US map, Bing Maps, MapQuest, and ESRI all exhibit sibling consistency.

Not surprisingly, Nokia Maps and Bing Maps are often similar (e.g., Figures 1(e) and 1(g) and to a lesser degree, Figures 2(e) and 2(g)) as they have announced a unified map design for the user's experience [8]. Bing Maps and OSM are very similar to Google Maps with some important differences. In both Bing Maps and OSM there is a greater tendency to display the names of all countries in the window rather than the Google Maps approach of displaying just a subset. In other words, aesthetics and readability trump completeness in Google Maps. Bing Maps opts for completeness by using a smaller point size for some of the names. On the other hand, all three of Google Maps, Apple Maps, and OSM opt for a uniform point size with Apple Maps sometimes using a point size that is too large and all upper case (e.g., Figure 8(a)), while Google Maps and OSM use a normal label (although OSM is often far too small to be readable on a smartphone) where the first letter is capitalized as is appropriate for proper nouns (i.e., names). An interesting feature of OSM is the use of the country's language and alphabet for the country names although the city names are given in the Latin alphabet with the American English language spelling.

3. CONCLUDING REMARKS

We saw that the Android and iOS5 variants of Google Maps are similar save for the US landscape, and the entire world (both portrait and landscape) where iOS5 labels all states while Android only labels those that fit without conflict thereby omitting small states. Clearly, Google Maps exhibits an understanding and appreciation of the small form factor of the smartphone target device, thereby placing a heavy emphasis on having readable labels for entities (e.g., places, roads, etc.), color contrast, and a nice distribution over the display screen. This includes the font type, point size, and color, as well as avoiding the use of watermark style labels, while Apple Maps is similar although it does use watermark style labels for continent names (e.g., Figures 1(a), 4(a), and 6(a)). However, at times, the placement (and distribution) of place names in Apple Maps is relatively poor which is in part due to its use of large point sizes with fixed width fonts and a lack of sophistication in its name placement algorithms, although these factors are less of an issue on a tablet (e.g., iPad) which has a much larger form factor. Although not often mentioned in the same breath as Apple and Google Maps, MapQuest was always found to respect the form factor of the smartphone with the difference being the use of a greater topographic basis for the map which made them somewhat busy but still very readable.

The remaining platforms at times ignore the small form factor of the target device and the choice of the size and number of labels to display is made under the assumption that the form factor of the target device is large (e.g., a display monitor or even a tablet such as the iPad), or simply choose to display very few, if any, labels (e.g., ESRI in Figures 1(h) and 2(h)) which are often too small (e.g., ESRI in Figures 4(h) and 6(h)). This results in a very busy screen (e.g., OSM) or too many features such as topography (e.g., MapQuest) which reduces their utility for anchoring additional spatially-referenced information such as icons which is a critical requirement for mashups (e.g., NewsStand [31, 32, 35]) and is done so well on Google Maps (both on iOS5 and Android). Note that use of watermark style labels can mitigate the busy screen somewhat, but their use should not be all encompassing as in all of the APIs other than Google Maps.

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