Mobile Collaboration: Collaboratively Reading and Creating Children’s Stories on Mobile Devices

Jerry Alan Fails  
Department of Computer Science  
Montclair State University, Montclair NJ 07043  
failsj@mail.montclair.edu

Allison Druin, Mona Leigh Guha  
Human-Computer Interaction Lab, University of Maryland, College Park, MD 20742  
allisond@umiacs.umd.edu, mona@cs.umd.edu

ABSTRACT
This paper discusses design iterations of Mobile Stories – a mobile technology that empowers children to collaboratively read and create stories. We present the design and discuss the impact of different collocated collaborative configurations for mobile devices including: content splitting and space sharing. We share design experiences that illustrate how Mobile Stories supports collaboration and mobility, and identify how the collocated collaborative configurations are best suited for reading and sharing tasks. We also identify how creative tasks foster more mobility and dynamic interactions between collaborators.

General Terms
Design, Experimentation, Human Factors

Author Keywords
Children, mobile devices, collaboration, collaborative configurations, constructionism, narrative systems, stories, user interfaces

ACM Classification Keywords
H.5.3 [Group and Organization Interfaces]: Collaborative computing; H.5.2 [User Interfaces]: Interaction styles, prototyping, user-centered design.

INTRODUCTION
Social networks and mobile computing have permeated today’s society. But how can mobile devices and social interaction be employed for educational purposes? Herein we present Mobile Stories, a system that enables collaborative reading and creating of stories which embraces mobility and collaboration.

Besides the popularity of mobile devices, there are other reasons why mobility and collaboration are important characteristics of systems for children. Mobility is important not only because it can help combat the global obesity epidemic [1], but also because it enables in situ (in context) usage, and anytime, anywhere learning. Mobile systems can allow content creation when and where a user is inspired. Creative, constructive, and generative activities in situ are extremely educational as they help learners synthesize information as well as provoke further investigation [9, 28, 31]. We believe that supporting and encouraging in situ usage makes mobility a core purpose of the system, and not just an added feature. Collaboration is important for the cognitive and social development of young children [41]. Therefore, promoting collaboration can yield developmental benefits. We discuss later how face-to-face collaboration not only affords the advantages stated in the literature, but also provides the potential for new interface opportunities.

We present the evolution of Mobile Stories as it pertains to these two important concepts: mobility and collaboration. Mobile Stories uses mobile devices as collaborative tools for children ages 6-10 to construct narratives in context (see Figure 1). This research leverages lessons learned over several co-design sessions including many scenarios where children interacted with working prototypes of the developed technology to read and create stories. The co-design method used was Cooperative Inquiry, which gives children a voice in the design process by enabling children to partner with adults in the design process [13]. This research also investigates how bringing mobile devices together – at the same time and place – can afford different collaborative advantages for young children, and overcome some of the limitations of mobile devices [36].
RELATED WORK

Reading and creating narratives influences children’s learning [18]. As such, numerous narrative systems have been developed [3, 25], including those designed specifically to foster collaboration [14, 38]. Mobile narrative systems allow children to create content or digital artifacts while they are in the context of the object or situation for which they are creating a representation, which affords developmental benefits [10, 21]. While collaborative mobile device systems have been theorized as an effective educational method [28], systems supporting collaboration and story creation in context are scarce.

For children, mobile technologies are primarily used for communication, consumption of entertainment, or collecting information. Moving beyond fleeting dialog and consumption enables interactive learning [37], and allows the creation of shared artifacts which enables constructionist learning [27]. Generative activities, such as these, go beyond recall and recognition and lead to deeper understanding [29]. Papert’s theory of constructionism outlines the benefits of manipulating objects and building a public artifact. The theory states that it is in the construction of the artifact that children learn [4, 27]. By enabling collaborative story creation in context, children will be able to reap these benefits.

Many systems have been developed to foster story creation and sharing. MOOSE Crossing [7] is an online community where children can construct stories individually or collaboratively. In SAGE [5, 40], children ages 7-16 interacted with a stuffed rabbit connected to a computer by typing. Rosebud [17] links children’s stories to their toys and tries to evoke emotional responses via narrative. These systems do not enable mobile authoring which encourages mobility and exploration of real-world environments.

A few narrative systems have incorporated mobility to collect data and information. Some have the explicit purpose of gathering story parts (pictures and words) for making or composing a story on another platform, like a desktop computer [6, 20] or wall display [11]. Sketchy [2] and more recently other applications (developed for children on the iPhone) directly promote story creation, however they do not promote collaborative in-field authoring as does Mobile Stories. For example, in Sketchy users can create comic-strip or flip stories by drawing, copying and modifying successive pages or frames. Sketchy is designed for a classroom or home experience and does not support collaboration. While the ability to collaboratively view and create content in mobile settings is uncommon, we believe it affords several advantages.

While not a narrative system, Ambient Wood [33] does support the types of in-field investigation we are promoting. In Ambient Wood children use a technology probe to collect data which they use to learn about the environment. Facilitators – one per group and a remote tutor – ask probing questions to help direct students learning. While synthesis begins to occur in context, the children use the technology as collection devices to promote interest and investigation. The children do not author in the field nor collaborate beyond their partner. While this system encourages mobility and some collaboration, it does not promote the in-field collaborative authoring which would enable the aforementioned constructionist learning. None of the above systems offer collaborative mobile authoring, and those that address collocated collaboration are not in the mobile realm or simply allow single item sharing as the only mode of collaboration [3].

MOBILE STORIES 1.0

In the following subsections we present the first version of Mobile Stories, a mobile collaborative narrative system. Using Mobile Stories, children can create story pages that can contain various media elements: text, picture, and audio. Mobile Stories was developed for the Windows Mobile environment in C#. In the remainder of this paper we discuss the evolution of the design of the Mobile Stories system, including descriptions of in-field design experiences, and results on mobile collaboration from a formal study.

System Description

Mobile Stories 1.0 allowed devices to connect to a story server and for users to choose a story. These stories could be pre-authored stories such as one would find in a library or classroom activity, or they could be less structured such as a story starter or even a blank story. Once a story was selected the user could view an overview of a story (see Figure 2, left), zoom in to a page by touching it, and navigate using hardware buttons (see Figure 2, right). Once on a page, the picture, words and sounds could be changed by touching the respective item on the screen (see Figure 2, right). Multiple devices could connect to the same story. Changes made on one device were propagated to the others using a client-server architecture. The system used a last write protocol, where the last change was saved as the current version for others to view. With this architecture, the children could read a story, add things to it, view others’ additions and changes, and continually elaborate on their shared story.

![Figure 2. The Mobile Stories 1.0, interface; left, overview of book seeing all pages; right, viewing the elements of a page. (Axle the Freeway Cat by Thacher Hurd available at www.childrenslibrary.org)](image-url)
System in Action
This system was used at a national park by our team of six child design partners who were divided into three pairs. The children were given a story starter with five pages labeled: “Fort McHenry”, “Anthem”, “Battleship”, “What do you think?”, and “Magazine”. The children were asked to build on the story starter and create a shared narrative of their experience at Fort McHenry National Park, the birthplace of the national anthem of the United States. The children were free to explore the fort and create their narratives. They worked for approximately forty minutes on their shared narratives. The purpose of this experience was to directly observe children’s collaboration, construction, and elaboration using Mobile Stories, as well as to further the design process.

In this design experience we observed several instances of collaboration, elaboration, and construction, all while children exercised their mobility, which was a core purpose of the system. Children physically explored the fort carrying the mobile devices while collecting, creating, and collaborating for their shared story. They added elements about the structure, events and people associated with this historic site. One child recorded himself reading a placard out loud that described the magazine. He then wanted to share it with another child, but got impatient and decided the recording was too long so he rerecorded his previous entry by restating what the placard said in his own words. Another child added to the narrative by writing “this is a historic place” while walking around the inner fort. Two children walked through an exhibit that showed what weapons were used and where soldiers slept. Another group captured the audio from an exhibit illustrating life as a soldier. Another child added the words to the national anthem and a picture of a flag as he stood by a cannon overlooking the bay with the flag waving behind him.

Figure 3. Co-present collaboration on a shared story at Fort McHenry National Park in Baltimore, Maryland. (Each child has a device, but they only look at and interact with one.)

Not only did the children add, create and see each other’s additions, but they also came together geospatially to share and discuss what they added (see Figure 3). For example the boys in Figure 3 (Josh on the left, and Seth on the right; names have been changed for privacy concerns) were on opposite sides of the inner fort, and Seth yelled across the way to Josh that he wanted to show him something. So they ran together. Seth interacted with his device to adjust it to what he wanted to show Josh. Seth then held out his device so Josh could see. Josh looked closely and then began to interact with Seth’s device. It is of note that both Seth and Josh have a mobile device with the same story information.

Design Outcomes
In the experience at Fort McHenry National Park we observed how collaboration, elaboration, construction, and mobility were supported by the Mobile Stories system. Thus we met several of our initial design goals. However,
in this formative experience there were several times when children would come together to work and would end up only using one device (see Figure 3). These instances most frequently occurred between two individuals. While both had the same information available because the stories were shared, the interface did not adequately allow for the desired synchronicity in showing and modifying the story while working next to one another. While the use of one device is not necessarily bad, we sought to make better use of the resources available; namely using both devices. With this in mind, we identified that subsequent versions would need to have better support for collocated collaboration using at least two devices.

**DESIGN FOR COLLOCATED MOBILE COLLABORATION**

The importance of supporting face-to-face collaboration within the context of achieving collaborative learning [12, 23, 34], was illustrated in our initial field work at Fort McHenry National Park. In light of this importance we worked with children to improve collocated collaborative support. We worked with the children in several design sessions using the techniques described in the Cooperative Inquiry method [13]. Through this work, two main collaborative interface ideas emerged: *content splitting*, and *space sharing* (see Figure 5). Both of these interfaces concepts have synchronized data sharing and synchronized interface navigation.

Several factors influence collocated collaboration including: angle, size, and number of devices, user arrangement, privacy of information, and the mapping of display space to input space [22]. While collaborative spaces generally have private and public spaces – spaces where individuals can work alone (and others cannot see), and open spaces, where all is shared [24], for the purposes of this work we focused on a collocated situation where ideally both devices could be seen by both users. With this assumption, the only distinction we make is whether or not pairs are collaboratively connected. When devices are connected all is shared; when disconnected, each has their own view. The remainder of this section presents the collaborative configurations that emerged from our design sessions and a note about the relative positioning of devices.

**Collaborative Configurations**

**Content splitting**

Based on our work with children, the idea of *content splitting* has emerged. Content splitting is the notion of parsing out different content to each device (see Figure 5, middle). While picture and words make for a simple delineation of content, we have noticed, especially through our co-design sessions, that the concept of role assignment is not only appropriate, but an integral part of the collaborative process for children. Parsing content can be synonymous with role assignment as each collaborator can take ownership and responsibility for her segment. This division of roles can also allow collaborators to continue to work together even when they are not collocated.

**Space sharing**

Again, based on our work with children, the notion of *space sharing* emerged. This notion is one that suggests combining the visual space of multiple devices (see Figure 5, right). This configuration spreads the interface across the devices, simply expanding its visual display. By being able to expand a page across both devices, it made it possible to read the words from the book and still see the picture, whereas in some cases the text was illegible when shown on only one device.

Expanding an environment to multiple displays is an area of active research. Some systems enable connecting but generally have a shared public space and a private, personal interactive space [35, 39]. Other systems support opportunistic annexing [26, 30] where users can easily expand their interface to other devices. Dual display devices such as [8] could support space-sharing as well as content splitting. While the aforementioned research is applicable, it is fundamentally different in that these devices are directed primarily for a single user looking to expand their interactive space. The focus here is to allow multiple users to expand their interactive space together while they are collaborating.

Content splitting and space sharing were implemented in Mobile Stories 2.0. This system was demonstrated at an NSF sponsored workshop on mobile devices for children [16], and to our design partner children in the lab. While this interface was not formally evaluated, the overall response was positive. Users appreciated the ability to come together and expand the visual and interactive space. They noted how, by being able to expand a page across both devices, it made it possible to read the words from the book and still see the picture, whereas in some cases the text was illegible when shown on only one device. In this version, users explicitly changed modes between content splitting and space sharing using buttons in the menu.

**Automatic Switching (AutoSwitch)**

A third configuration, *Automatic Switching (AutoSwitch)*, was developed which combines both content splitting and space sharing. *AutoSwitch* presents different collaborative modes at different zoom levels. The concept of AutoSwitch is to allow seamless mode switching between the collaborative configurations of content splitting and space sharing. When connected, users see the interface spread...
across both devices (space sharing) and are able to zoom in
to more specifics. From a page view, touching the picture
on one will expand the picture on that device and show the
words on the other device (content splitting). Further
zooming in displays whatever is selected (picture or words)
spread across both devices (space sharing). The reason for
this approach is to allow a seamless (modeless) transition
between content splitting and space sharing, since modes
can be confusing [32]. Figure 6 shows an example of how
AutoSwitch could work for different zoom levels of a book.

AutoSwitch was implemented in Mobile Stories 3.0 and
used in a pilot study. The pilot study included seven design
partners using the technology for two one-hour sessions
separated by a week. During the pilot, most participants
primarily collaborated by just synchronizing data, and not
using the AutoSwitch navigation synchronization. Despite
having interacted with the technology for approximately
thirty minutes the first week and having had a review of the
use of the interface before using it the second week, the
children did not seem particularly comfortable using the
technology to navigate their stories using the AutoSwitch
configuration. It seemed as though they did not understand
how the zooming could change how they collaborated. One
child opted to always zoom out to the story level and then
zoom into a page, rarely zooming in further. Most would
simply use the page level (approximately 56% of the time)
and communicate verbally or showing/looking at each
other’s devices. The four zoom levels seemed to confuse
the participants which led to the exploration of just using
content splitting and space sharing.

Relative Positions
In designing collocated interfaces, it is important to decide
what relative positioning is appropriate. We addressed this
issue with our design team. Figure 7a shows how a single
display device would have the complete interface. In
working with our design team we also discussed the issue
of relative positioning between collaborating user’s devices.
The relative positions shown in Figure 7b and 7c were
deemed best by all members of the design team (adults and
children). This was noted because users could not only
share space visually, but using these relative positions,
users could still interact with their device via screen input
and physical buttons. Looking at other possible relative
positions, this input is not possible (see Figure 8). Thus, the
interface enabled users to take advantage of the increased
physical space, and both users could interact with their
device to change the overall state.

MOBILE STORIES 3.1
Mobile Stories 3.1 uses some of the enhancements from
previous prototypes, but adds the ability for the user to
explicitly switch between different collaborative modes. It
uses a peer-to-peer (P2P) architecture to synchronize data
and navigation. Story data is stored on each device. The
architecture supports different media elements; namely,
audio, text, and images. It also has a flexible architecture
that enables structured, semi-structured, and unstructured
narrative activities by having more or less preloaded
content.

User Interface
Mobile Stories 3.1 supports both content splitting and space
sharing and switching between collaborative modes (see the
top menu items in Figure 9). The three buttons across the
top (going left to right) represent a synchronized data mode,
content splitting, and space sharing. Currently the
synchronized data mode is selected which is indicated by the square highlight around that button. The synchronized data mode is reminiscent of how Mobile Stories 1.0 worked where data is synchronized, but navigation (e.g. zooming in and out, or changing pages) is not.

Figure 9. Mobile Stories 3.1 page-level interface, showing the menu.

The remainder of the buttons shown in Figure 9 have the following functionalities. The triangles at the bottom are directional arrows which enable switching from page to page. The left arrow is disabled because it is on the first page, but the user can go to the right to the next page. On the left, the camera and “ABC” button enable the user to add or change the image or add or change the text on that page. Users can also just press a camera physical button to initiate taking a picture, or open the slide out keyboard to change the words.

On the right of Figure 9, the double arrow button is a “switch” button which is context and mode dependent; when using the synchronized data collaborative mode it is disabled (as shown in Figure 9). While content splitting it switches which phone has the words or the picture. While space sharing it changes which phone is on the left or right (if users are on opposite sides of each other). The last button is the zoom out button. To zoom in, one would just touch the item they wanted to zoom in on. For example from the story view one could touch a page and the interface would zoom into that page. Touching the picture would further zoom into the picture, touching the words, would zoom into the words.

Notice in Figure 9 how all menu items are translucent. This is a design idea that came from design sessions with children. It allows users to interact with the menu while still being able to see the context behind with minimal occlusion. The menu is shown or hidden by pressing the direction pad’s (d-pad’s) center button – or the enter button. This simple interaction was deemed easy to remember by the children.

Audio playback and recording was also supported in Mobile Stories 3.1. For simplification purposes, it was not used in the collaborative story study (and thus is excluded in the menu description of Figure 9).

System in Action
We conducted a study to better understand the collaboration and mobility supported in Mobile Stories. In this study, 26 children (11 female, 15 male), ages 8-9 first used each of the synchronized collaborative modes to read a story (order was counter-balanced), then they created a story, and then shared the story they created with the adult facilitators. Children used each configuration to read for four minutes, then fifteen minutes to create a story, then as long as necessary to share their stories. Children were asked interview questions before and after each segment.

Herein we present a few example cases of how the children collaborated during the story creation portion of the study, and some of the comparisons between creating and reading/sharing tasks as they pertain to collaboration and mobility. More details of the study can be found in the dissertation of the first author [15]. (Children’s names have been changed to respect their privacy.)

Case #1 – Content Splitting
A pair of two girls (who will be referred to as Selina and Cora), used content splitting the whole time they were creating a story. They were very close to one another for a little more than twelve of the fifteen minutes, or ~81% of the time. Throughout the duration of the task Cora had the words and Selina had the pictures. Selina mostly sat talking about the story and helping Cora type by showing and telling her where the different buttons were on the keyboard. Cora painstakingly added different ideas, changed her mind, and then re-added words to the page. She also tried to be meticulous with spelling, punctuation, and capitalization, which greatly slowed her typing. With these contributing factors, even though in their discussions they planned an intricate and elaborate story, during the full fifteen minutes, they were only able to work on and almost complete one of the pages (see Figure 10).

Figure 10. Two girls’ (Selina and Cora) collaborative story.
Case #2 – Pictures Then Words; Competitive Captions
A pair of two boys (who will be referred to as Noah and Simon), was highly engaged throughout the fifteen minutes, but their interactions can probably best be described as competitive. During the first five minutes Noah and Simon each added pictures to the story – Noah adding five, and Simon adding two (changing one of Noah’s pictures). During the next ten minutes the participants only made changes to the words. The words were not necessarily part of a story, but more captions of what they thought of the pictures (e.g. “uglu” [meant “ugly”], “cool”, “I like this picture”). By the end of the creation time, while they were still engaged, and wished to continue, the participants had progressed to an almost competitive state where they were quickly adding nonsensical captions to the story (e.g. “sssss”). The final story is illustrated in Figure 11. While this is not the desired type of collaboration, it is an example of what can happen as some children choose to compete instead of collaborate.

Figure 11. Two boys’ (Noah and Simon) collaborative story.

Case #3 – Continuous Collaboration
The collaboration between the partners in this group was characterized by continuous verbal communication with one another. This pair consisted of two boys: Kuri and Max. First, the two participants had a discussion about what they wanted to do with their story before they even started. Some examples of their communication once they started are: “I’m going to take a picture” (Kuri), “I’m going to add words to this first page” (Max), “I’ll add words to the second page” (Kuri), “OK, now I’m going to start the second page” (Kuri). Also, even though they coordinated and were working in parallel, they would read their page out loud to the other after they had completed their page. In the allotted time, the group completed a title page and three pages. The final story is displayed in Figure 12.

Figure 12. Two boys’ (Kuri and Max) collaborative story.

Overall Observations
From the creation portion of the study we noted that collaboration was effectively negotiated between the pairs. While creating stories children frequently coordinated by identifying different roles such as photographer and writer (similar to content splitting), or working on adjacent pages (similar to space sharing – two page spread). Of note is that while these roles were explicitly supported using the collaborative configurations, children opted to coordinate this verbally while creating. Children, however, used the collaborative configurations effectively while reading and sharing stories. When reading or sharing, content splitting was preferred over space sharing. (Details of the reading/sharing results as well as the metrics used for this comparison are in the dissertation [15].)

Video of the interactions for creating stories were coded for numerous metrics including how close/far the children were relative to each other as well as mobility. The proxemic metrics used are shown in Table 1. Proxemic distances for reading, creating, and sharing tasks were coded for at least every ten second interval. Using these metrics several observations were made.

Table 1. Proxemic categories/distances [19] (in inches & feet).

<table>
<thead>
<tr>
<th>Proxemic Category/Distance</th>
<th>Distance</th>
<th>Close Phase / Label</th>
<th>Far Phase / Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intimate</td>
<td>0 – 18”</td>
<td>0 – 6”</td>
<td>6 – 18”</td>
</tr>
<tr>
<td>Personal</td>
<td>1.5 – 4”</td>
<td>1.5 – 2.5”</td>
<td>2.5 – 4’</td>
</tr>
<tr>
<td>Social</td>
<td>4 – 12’</td>
<td>4 – 7”</td>
<td>7 – 12’</td>
</tr>
<tr>
<td>Public</td>
<td>≥ 12’</td>
<td>12 – 25’</td>
<td>≥ 25’</td>
</tr>
</tbody>
</table>
Children were closer together while they were reading and further from each other when they were creating stories. To examine this, a paired-sample t-test was conducted using the video coding for mobility for reading and creation. Values were normalized as the length of times for the tasks were different (a total of 8 minutes for reading tasks, and 15 minutes for the creation task). There was a significant difference in the percent amount of time children were moving (which we use as a measurement of mobility) between the reading \([M = 0.0688, SD = 0.0393]\) and creation \([M = 0.2922, SD = 0.1969]\) tasks \([t(23) = -5.80, p < 0.00001]\). This means that children were more mobile while creating. This also leads to a design suggestion that when the goal of a system is to promote mobility, then it should also support and promote creative tasks.

A Pearson’s product-moment correlation was computed to assess the relationship between the number of pages read per group and their average proxemic distance. The results identified a significant correlation \([r = -0.45, n = 26, p < 0.03]\). This means that participants who were closer to one another read more pages. A crude measure of task completion for the creation task is how many pages were created. A Pearson product-moment correlation was conducted on the number of pages created and the average proxemic distance of each pair. There was a strong, significant correlation between these two variables \([r = 0.82, N = 11, p < 0.01]\). This means that for the creation task, pairs who were on average further from each other, created more pages. To summarize the meanings of these correlations: those who were closer, read more; and those who were further apart, added more pictures and words to the story. It is important to note that while children were further apart on average, they still came together frequently to share, discuss, and coordinate. This also supports the design suggestion to support collaboration with a goal of authoring or creating to promote mobility.

As far as gender differences, there was a significant difference in average proxemic distance between girl \([M = 3.75, SD = 1.50]\) and boy \([M = 7.31, SD = 1.67]\) groups \([t(9) = 3.73, p < 0.01]\). This means that, on average, girls were significantly closer than boys while creating their stories.

The story creation task was the most energizing and collaborative portion. There was a notable excitement during and after the fifteen minute period of creating a story. In fact, all of the groups wished they had more time to add more to their stories. Six of the participants were very excited about the ability to read and create stories and expressed how they really wanted to keep the devices. Two of the children offered to trade their Nintendo DSs for the mobile phones.

Similar excitement was expressed about sharing their stories with the adult facilitators. For the most part the children were very excited about sharing their stories; the only reason children were not excited seemed to be because they had not finished as much of their story as they had liked. For some, sharing stories included sound effects, and dramatic readings and actions. Children were also excited to share their stories with others, asking if they could take their stories home to show their parents.

**CONCLUSIONS & LESSONS LEARNED**

This paper discusses design iterations that explore mobile device collaboration. Through our initial design experiences we observed our goals of collaboration, elaboration, and in situ construction or authoring. Using co-design methods we then developed two collocated collaborative configurations: content splitting and space sharing. In comparing content splitting and space sharing, content splitting was preferred while reading and sharing, and verbal collaborative coordination while creating stories instead of the explicit collaborative modes.

Our experience suggests that system designers should concentrate on supporting collocated configurations for reading/sharing tasks, but not for mobile creation tasks. While the synchronized navigation of the collocated collaborative configurations is less appropriate for creative settings, it is important still to support synchronized data sharing so collaborating users can see the contributions of their peers. Our study also showed how mobility and proxemic distances were respectively greater and more dynamic during the creation task. Therefore systems that have a goal of promoting child mobility should primarily support creative tasks and be less consumption-oriented as reading tasks appear to lead to more sedentary actions.

We believe the collaborative configurations of content splitting and space sharing can be applied to more than just storybook reading and story creation, such as applying to widgets and other collaborative role assignment. Our design experiences have shown us that the collaborative configurations of content splitting and space sharing could leverage the ubiquity of mobile devices and overcome their alleged limitations.

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