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Mathematical content browsing for print-disabled readers based on virtual-world exploration and audio-visual sensory substitution

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Abstract

Documents containing mathematical content remain largely inaccessible to blind and visually impaired readers because they are predominantly published as untagged PDF which does not include the semantic data necessary for effective accessibility. We present a browsing approach for print-disabled readers specifically aimed at such mathematical content. This approach draws on the navigational mechanisms often used to explore the virtual worlds of text adventure games with audio-visual sensory substitution for graphical content. The relative spatial placement of the elements of an equation are represented as a virtual world, so that the reader can navigate from element to element. Text elements are announced conventionally using synthesised speech while graphical elements, such as roots and fraction lines, are rendered using a modification of the vOICe algorithm. The virtual world allows the reader to interactively discover the spatial structure of the equation, while the rendition of graphical elements as sound allows the shape and identity of elements that cannot be synthesised as speech to be discovered and recognised. The browsing approach was evaluated by eleven blind and fourteen sighted participants in a user trial that included the identification of twelve equations extracted from PDF documents. Overall, equations were identified completely correctly in 78% of cases (74% and 83% respectively for blind and sighted subjects). If partial correctness is considered, the performance is substantially higher. We conclude that the integration of a spatial model represented as a virtual world in conjunction with audio-visual sensory substitution for non-textual elements can be an effective way for blind and visually impaired readers to read currently inaccessible mathematical content in PDF documents.