Looking forward by looking back: Applying lessons from 20 years of African language technology

Martin Benjamin
École Polytechnique Fédérale de Lausanne
Lausanne, Switzerland
martin@kamusi.org

Mohomodou Houssouba
Songhay.org
Basel, Switzerland
mohomodou.houssouba@unibas.ch

Abstract

This paper takes a frank look at what has and has not been achieved in African language technology during the past two decades. Several questions are addressed: What was the status of technology for African languages 20 years ago? What were the major initiatives during that time? What were their successes and failures? What can we learn from these experiences? How does this inform the work that we are planning going forward? Examining in particular the history of Swahili, it is argued that technology projects have often achieved their expressed aims, but have collectively not significantly advanced the normalization of African languages as operable within the technical sphere, even while Africa has become blanketed with mobile technology. It is argued that future projects will succeed only by asserting the goal that technology of 2035 must be fully operational in users' primary languages, and gearing policy, funding, and individual project efforts toward gathering and deploying linguistic data for a large number of African languages to meet cutting-edge technologies as they emerge.

Keywords: HLT, localization, African languages, digital content, lexicography, Wikipedia, Swahili, equity, policy

1. African languages and technology in 1995

In 1995, when graphical browsers were first opening the Internet to dial-up home-computer users in some Northern countries, African languages had virtually no representation in the technical sphere. The computer support department of a major American university questioned when a project proposed for a large African language would ever be used by its native speakers. At a time when Tanzania had just one telephone per each 300-odd inhabitants (and only 2000 mobile phones),[1] and Mali had 17,164 phones in the entire country,[2] the notion that Africa would have more than two-thirds of a billion mobile devices twenty years later[3] was unthinkable. Arguably, this failure to imagine the future led to chronic unpreparedness; while the number of devices and reach of networks available to Africans have grown exponentially, the ability to use those resources in and for even the largest of the continent's 2000 languages has barely gotten off the ground. In this paper, we review some of the major technological developments in support of African languages during that time, discuss the obstacles and opportunities those experiences reveal, and make suggestions for building those lessons into work going forward.

ICT in 1995 was dominated by English, a consequence of the locations of the predominant early developers and mass markets. European and Asian languages improved their resources over the next two decades in response to market forces, government initiatives, and academic interest. It is difficult to remember that in 1995, rendering standard European diacritical characters such as "á" demanded contortions such as "á". African characters such as Yoruba "ọ̀" were literally impossible to type. With essentially no electronic wordlists for African languages, basic tools such as spellcheckers or OCR could not exist. While the full text search of known Internet pages that became possible with the release of WebCrawler in 1994 was in principle language neutral, African language content was almost entirely absent online and thus search was irrelevant. Before the release of the Netscape graphical web browser at the end of 1994, few organizations had even contemplated having a "homepage", to say nothing of translated versions of their interface or content. Windows 95 was available to the brave[4] for French, German, Italian, Russian, Arabic, Hebrew, Japanese, Korean, and Traditional Chinese, and a Swedish version of Word was spotted in Dar es Salaam by 1996, but neither Microsoft nor most other corporations attempted localization for Swahili or other large African languages until a decade ago at the

[1] Tanzania Communications Regulatory Authority, "Trends of Telephone Subscription", https://www.tcra.go.tz/index.php/25-statistics, accessed 9/9/15

[2] The World Bank Databank, "Fixed Telephone Subcriptions", http://data.worldbank.org/indicator/IT.MLT.MAIN?page=3, accessed 9/9/15

[3] The World Bank Databank, "World Development Indicators: Power and communications, Table 5.11", http://wdi.worldbank.org/table/5.11, accessed 9/9/15

[4] Setting up Windows 95 for Multiple Languages, http://www.ficorp.com/multi/, accessed 9/9/15

earliest. Video game consoles had not yet appeared on the market in most African countries. Other hardware, such as keyboards and mobile phones, was still in the early days of supporting European languages other than English (Diki-Kidiri 2007). In essence, "African language technology" was oxymoronic in 1995, and few people envisioned that would change.

2.! Major initiatives

The notion of supporting African languages was not new in 1995. A Conference of Education Ministers took place in Tehran in 1965, at the peak of the independence movement, which stipulated the use of local languages to enact national literacy programs. Subsequent summits focused on specific tasks intended to equip languages as instruments of social development and governance. Yet, the development of language resources held low priority in most countries. Tanzania was the notable leader, with a highly successful Swahili literacy campaign in the 1970s, conducted by an army of passionate teachers armed with a few roughly-printed instructional texts. Yet even the story of Swahili mostly left out Tanzania's other 120 languages. Mali began a school reform in 1962 that was intended to join four "national" languages with French as languages of instruction, expanded to 10 in 1982 and 13 by 1993, with print resources emerging such as dictionaries, technical terminologies, and translations of important documents (Houssouba 2007). Were education ministers to have had technologies available for their nations' languages in 1995, many would assuredly have worked for their adoption.

There was no home-grown technology industry, however, outside of South Africa and Egypt. Africans who could gain training opportunities in IT abroad tended to stay abroad. Without a grand vision of African language technology as something that could be instigated locally, efforts were left to random academic research centers, volunteers, and corporations operating in the interest of short-term altruism and long-term profit.

Osborn (2010) presents a full overview of the projects that grew after 1995. Much of the work from that time centered on the enabling environment: creating fonts and standardizing characters in Unicode, restoring unusual diacritics in text recognition for languages such as Gĩkũyũ, software for keyboard input, detailing language parameters for the Common Locales Data Repository, and, through the African Network for Localisation (ANLoc), convening technologists and policy planners to promote ongoing development (Sinha and Hyma 2013).[5] Another strand has been the localization of web services (notably by Google and Facebook) and software (particularly by Mozilla and Microsoft) for select languages, including the creation of proposed ICT terminologies,[6] assisting the production of African language content. A third theme has been work on language data, including building lexicons and corpora (Badenhorst et al 2011, Chiarcos et al 2011, Bosch 2014), and methods for data extraction and analysis such as part-of-speech tagging (De Pauw et al 2012), named entity recognition, morphological analysis (Katushemererwe 2013, Littell et al 2014), and efforts toward machine translation (Gasser 2012). Some work has been done on acoustic models (Gelas et al 2011), with advances by the Meraka Institute for automatic speech recognition for the official South African languages, likely to play a central role in human/machine interaction in the next twenty years, that illuminate both the possibilities of more complex NLP applications that tailor extant technologies to African languages, and their paucity for most of the continent (Barnard et al 2010).

3.! Analysis: successes, failures, and reasons for both

The various projects above have often succeeded in their own terms, but have collectively done little to normalize African language use within technological domains.[7] Experiences with Swahili provide some insight.[8]

[5] ANLoc was supported by the Canadian International Development Research Centre through 2013. It is now inactive, with the website offline.

[6] "ANLoc ICT Terminology Available to Download: Completed Terminology Sets", https://kamusi.org/content/anloc-ict-terminology-available-download, accessed 10/9/15!

[7] The situation in South Africa is well-discussed in Grover et al (2011). They find that, "whilst there is a considerable level of HLT activity in South Africa, there are significant differences in the amount of activity across the eleven languages, and in general the language resources and applications currently available are of a very basic nature (p. 282).

[8] A parallel discussion of Mali could not be included for space constraints. Very briefly, localized products for Malian languages are mostly the fruit of volunteer initiatives: Firefox in Songhay, completed by a Malian team, is the only browser available for a national language, and the MAKDAS association has produced word-processing software with embedded keyboards for ten local languages (bataki.org). Currently, the leading telecom company is partnering with Mozilla to localize Firefox OS for smartphones into Bambara, the country's main language, by the end of 2015. Mali recently issued two policy documents: Mali Ministry of Education (2014) to promote ICT tools and digital content in national languages, and Mali Ministry of Digital Economy (2014) to use HLT to enact universal access, especially by bridging the gap between rural and urban areas. However, the ambitious "Plan Mali numérique 2020" designed to spearhead this revolution has not moved off the starting blocks as of

Swahili, with a potential market of 100 million consumers in several countries and well-established government and research support, has been at the forefront of digitization (Besha 2009). The Kamusi Project initiated a collaborative online dictionary in 1995, and the TshwaneDJe dictionary came online a decade later. The Helsinki Corpus of Swahili opened for research purposes in 2004. Google began volunteer localization of its services to Swahili in about 2003, with a professional department opened in Nairobi some years later; more recently, Google Translate has offered buyer-beware conversions between Swahili and English, and ostensibly to other languages. Microsoft-prepared Swahili language packs for Windows and Office beginning late in the last decade. In 2009, Mozilla worked with volunteer teams to localize Firefox through version 3.5; currently at Firefox 40, Swahili has long since slipped the net. Similarly, an OpenOffice localization completed by Kilinux in 2006 is now generations out of date. Though not strictly a technology project in itself, the Swahili Wikipedia has nearly 30,000 entries (recently overtaken by Afrikaans, Yoruba, and the almost completely bot-generated Malagasy) that present a corpus open for mining. Facebook, which has made itself free in Tanzania to users of the Tigo network, has since 2009 had about two thirds of its growing string set localized to Swahili by volunteers.

With these resources available for Swahili, the question arises whether people in East Africa have the expectation that technology will be available to them in the major regional language, now or in the future. Unfortunately, usage statistics are not available for Google or Facebook. In our subjective evaluation, Google provides a mostly satisfying user interface in Swahili (this paper was comfortably edited on one side in the Swahili version of Google Docs), although Google Translate, which deserves a separate article, produces output that would get a professional translator fired. Facebook is localized piecemeal by volunteers who have the ability to contribute some suggestions (some strings are locked, some strings cannot be opened in certain contexts, some submission boxes do not have "submit" options) that are sometimes incorporated. The basic Facebook concept of "Like" is a tangle of untranslated strings and confused journeys through the Swahili verb to indicate what is pleasing to whom. The result is an interface that mixes questionable Swahili with default English (see figure 1; "18 wamependezwa" translates as "18 people have been liked"). In our unscientific poll of Swahili-speaking contacts on Facebook, top-heavy with language professionals, most reported that they typically use English as their interface for Google and Facebook. Firefox and OpenOffice had very low uptake when they were functional, unsurprising due to their distribution solely as downloads to PCs in an era when modems were slow and expensive and most people with computers were educated professionals who knew how to navigate in English. Microsoft products are also available in Swahili only for computers (not the feature phones, smartphones or tablets held by most people), and only for licensed users.

Figure 1: Detail from Facebook Swahili localization

For an indication of engagement between Swahili technology users and resources, we analyzed the historical record of the Swahili Wikipedia.[9] Though opened in 2003, the project had only 56 articles until the first prolific contributor joined in February 2005; by the end of 2006, sw.wikipedia.org had nearly 3000 articles.[10] Among the top 27 logged-in contributors, about 145,000 edits, including about 60,000 semi-robotic, have been by people who did not learn the language before becoming adults, versus about 12,000 from native speakers or childhood learners (one with nearly 10,000 edits). About 225 people have edited more than ten but fewer than 250 articles, 400 people have edited from 3 to 10, nearly 1500 have made one or two edits, and almost 20,000 have registered[11] but never contributed.[12] Thus, during the past decade, an average of 200 people per year have edited one or more page - roughly one new person trying an edit every second day. Three quarters of those never came back, while about 10% of those who ever edited could be considered as occasionally active participants, and 1% as committed in principle (although only 15 of the power users have edited in the past two years). Some of the moderate participants are people who joined specially organized events, contributed to a few articles at the time, and have never returned. Overall, the project is clearly the output of a handful of individuals who are extremely passionate about producing a resource for their fellow tens of millions of Swahili speakers. In 2015, the landing page has been viewed as many as 28,000 times in a single late 2015. Altogether a wide gap persists between visionary policy statement and active implementation.

[9] Data from "Wikipedia Statistics Swahili", http://stats.wikimedia.org/EN/TablesWikipediaSW.htm#wikipedians, accessed 2/9/2015, user biographies from their talk pages, and page edit histories.

[10] Data from the Internet Archive Wayback Machine, https://web.archive.org/web/*/http://sw.wikipedia.org, accessed 16/9/2015.

[11] Most are likely automatic subscriptions from Wikimedians who once clicked a Swahili page.

[12] Additionally, nearly 12,000 edits were made by anonymous users. This could range from a single person to 12,000 different individuals, or be associated with bots. Registered Wikipedians sometimes forget to log in, or choose to edit anonymously in certain circumstances.

month,[13] with normal traffic in the vicinity of 700 visits per day, including both new and returning users. Many people certainly land elsewhere on the site via search engines or other links, but the landing page is the entry point for intentional searching for Swahili encyclopedia entries. The engagement between the Swahili world and its Wikipedia, orders of magnitude lower than the circulation of major Swahili newspapers, cannot be seen as notable. Reasons for the low uptake rates might include: (1) content still being too thin to be useful, as a substantial percentage of the articles are about locally irrelevant topics; (2) a lack of knowledge that the resource exists, as Wikimedia has done very little publicity, and no education ministry has worked to promote its use or production as part of the curriculum; (3) low access - students using one of the few computers in a school (if there are any at all) are not at leisure to peruse an online knowledge base, and few homes in East Africa have permanent network subscriptions; (4) people have not adopted the habit of going online to seek information in any language, which will undoubtedly change for some in the next few years; (5) the information that is available on the English Wikipedia is much more extensive, and the Kenyans and Tanzanians who are educated enough to be using a technology resource are likely to have the ability to read English at some level. Reasons for low editorship could include all of the above, added to the lack of awareness that Wikipedia can be edited, poor roadmaps to editing features, or frustrating experiences with the system.[14] To that, one must add motivation: it is the rare user who donates content creation in any language, such as contributing a user review on TripAdvisor, because most people feel their time is better spent doing things other than providing bits of information to others.

A common thread among the efforts mentioned above is that they have been shipped without much attention (except to the extent that Google offers users the option to switch to Swahili when they log in from East Africa) to engaging the end user on their own terms. For example, Firefox could have been distributed on CDs that vendors would be encouraged to "pirate", rather than quietly announced as available for download. Instead, the projects generally focus on the technical work, and leave consumer uptake to the wind. This is a matter of both the focus of the teams involved, and that the limited budgets of the projects dry up by the point of product delivery. Given that the potential market is largely unaware of the existence of the products, much less how to acquire and make use of them, it should not be too surprising that they have not become widely popular.

4. Future work - caught in the past or future shaping?

With twenty years of experience to guide us, we propose a new direction for African language technology. The first element should be, in fact, to have a twenty-year view toward what technical facilities will be available in Africa twenty years from now, and what is required starting now to make those functional for African languages. This view should have an assertive focus toward language equity; average consumers should expect to use their technology in their language, whether in Seattle or Soweto. Voice commands in Bambara for smart home technology, for example, should be considered a requirement, not a fantasy - if a product works in English and Chinese but not Akan or Malagasy, it is broken and not fit for sale in Ghana or Madagascar.

Such a declaration is, of course, much easier to state than to accomplish, involving both political commitment, financial investment, and concerted technological development. By and large, African states have rarely led the charge. The intergovernmental institution, ACALAN, has a small budget and a limited voice. Thus, ACALAN articulates goals for technological milestones[15] that it may not be in a position to implement unless it can garner influential support from politics and civil society. In this regard, corporations, philanthropies, and international agencies should be brought into the conversation. To date, most organizations that should recognize language equity as a key to reaching economic and social goals hold, at best, to the notion that some tools can be localized to a few major African languages. Thus, Facebook's founder can go to India and assert that language is important in reaching billions of potential subscribers in developing countries,[16] but leave that work to unpaid volunteers while investing billions in such technologies as virtual reality gaming.[17] International organizations, meanwhile, do not have language on their agenda, because that falls out of the scope usually considered important for successful activities in fields such as health or environmental conservation. Involving bilateral, multilateral and non-governmental organizations in the production of

[13] "Wikipedia Article Traffic Statistics", http://stats.grok.se/sw/201505/Mwanzo, accessed 16/9/2015.

[14] The new WYSIWYG editing tool is much more user-friendly than learning wiki markup, but still involves a substantial amount of learning, without evident tutorials, that would intimidate most novices.

[15] Project on African Languages and Cyberspace, http://www.acalan.org/eng/projects/cyberspace.php

[16] Mark Zuckerberg Facebook post, 9 October 2014, https://www.facebook.com/zuck/posts/10101687201975511

[17] African language game interfaces, much less games tailored to African consumers, are not within the visual horizon of the industry. "What languages to localize your game into", http://gamasutra.com/blogs/JacobStempniewicz/20150619/244998/What_languages_to_localize_your_game_into.php, 19 June 2015.

language tools that may be of use to their communications or their beneficiaries can raise their awareness of the aid proper language technology can provide for their missions, as well as raising the needed funds.

The most effective way to institute this general call will be through specific actions. To this end, kamusi.org and songhay.org are embarking on new directions in response to the experiences of the past two decades. As with the other projects discussed above, these two digital lexicography initiatives have not yet lived up to their potential, either in terms of usage of published resources or contributions to their growth. In part, this stems from chronic financial shortfalls that make it difficult to maintain existing systems, much less invest in new development. Kamusi faces the particular technical challenge of Big Data, with now tens of millions of internal links that must be computed and available to search engine indexing without bringing down its underpowered server.[18] The projects have also neglected publicity, on the dubious assumption that speakers will find their way to web resources for their languages; with Africa engaging the digital sphere with handheld devices, projects designed around the wired web do not find the audience where they reside. They have also been weak in encouraging their users to contribute. While Kamusi especially has always made it clear that data is open to editing, the project has not been aggressive about recruiting the public to contribute. Moreover, the editing interface is a web form that asks for a lot of different types of lexical information[19]; while no more difficult than booking a hotel room online, experience training college students in Burundi shows that the platform is intimidating, and too bulky given the slow connection speeds and frequent power outages many Africans confront. Consequently, the two dictionary projects have come together and are completely revising their approach to public interactions. Because most Africans engage through Facebook and mobile devices (Rivron 2012), software development is now focusing on those platforms. Rather than ask for masses of data about each word, participants are asked highly targeted questions about particular linguistic elements. A lot of attention will be given to fostering language communities, including diasporic populations who have good connectivity and the desire to give something back to the people in their homeland, with kasahorow.org organizing online user groups beginning with two dozen languages. Through intensive and repetitive public outreach, the project seeks to make the idea of contributing to and accessing linguistic data normative for currently less-resourced languages.

[18] The Kamusi Big Data Beta, https://kamusi.org/big_data_beta

[19] How Kamusi Works, https://kamusi.org/how-kamusi-works

On the other side, partnerships are needed between African language specialists and other technologists who are developing tools for the deployment of linguistic data. For example, linguistic data from one group can be used for morphological analysis by another, which can be the basis for computer assisted translation from a third that supplies live chat services from a fourth. Much NLP technology is rooted in European languages for three reasons: (1) that is where the funding is, (2) that is where the researchers are comfortable, and (3) that is where data is available. By resolving the third issue, African languages become attractive to researchers as an under-explored opportunity to make impactful advances. By resolving the second issue, showing that high-quality African language data can be produced at low cost and implemented within cutting technology by leading research groups, the idea of African languages as full participants in the technology sphere shifts from esoteric fantasy to evident fundability. The challenge now is to implement these optimistic plans in a financial and policy environment where African language equity does not factor as a realistic goal, despite a technically viable roadmap to success.

A review of academic presentations at international conferences regarding language technology shows that a small number of groups are hard at work on a few important topics for a few African languages, principally Arabic, Swahili, Yoruba, Amharic, Gikuyu, and several languages in South Africa. Using conference participation as a proxy for research support, the number of attendees focused on African languages is notably low, whether the conference topic is Computational Linguistics, Language Resources, or Language Documentation.[20] Frequently, African languages are best represented at such events by a few attendees in workshops for under-resourced or endangered languages. The major biennial meeting that focuses on African language technology is AfLaT (aflat.org), with numbers that showcase how small the research community is. Without a large cadre of researchers and institutions pushing forward on a number of topics and languages, it is hard to see a significant change in the status quo.

[20] Examples of proceedings from relevant events include: 52nd Annual Meeting of the Association for Computational Linguistics (2014), http://acl2014.org/acl2014/mainconferenceprogram.html; 9th International Conference on Language Resources and Evaluation (2014), http://www.lrec-conf.org/proceedings/lrec2014/index.html; 4th International Conference on Language Documentation and Conservation (2015), http://scholarspace.manoa.hawaii.edu/handle/10125/35354

Can African language technology emerge from the shallows? The past twenty years have largely missed preparing for the present - most Africans have no expectation of ever seeing the sorts of services in their languages that are routinely available today to most Europeans. The task is akin to designing urban light rail; plans must be in motion today to have an effective system two decades hence. If technologists continue with modest projects that address limited current objectives, we will find ourselves twenty years from now with African language technology that conquers some of the pressing issues of 2015. To address the needs of 2035 requires an insistent vision of a future where technology helps erase the language barriers it currently embeds. By stating the broad goal of technology for African languages reaching parity with where better-resourced languages in Europe and Asia will be twenty years hence, we can see the target. If this vision can be converted to policy and funding support for the development of linguistic data and tools throughout the continent, then perhaps we can not just see the target, but actually reach it.

References

Badenhorst, J., Van Heerden C., Davel M. H., and Barnard E. (2011). "Collecting and evaluating speech recognition corpora for 11 South African languages", In: *Language Resources and Evaluation*, (45) 3, 289-309.

Barnard, E., Davel, M., Van Huyssteen, G. (2010). "Speech technology for information access: a South African case study". AAAI Symposium on Artificial Intelligence, AAAI Spring Symposium Series, Stanford University, USA.

Bearth. Th., Bonato, J., Geitlinger, K., Coray-Dapretto, L., Möhlig, W.J.G. and Olver, Th. (Eds.) (2009). *African Languages in Global Society*. Cologne: Rüdiger Köppe.

Besha R., (2009). "Regional and local languages as resources of human development in the age of globalization," in Bearth et al. (1-13).

Bosch, S. (2014). "Towards an Integrated E-Dictionary Application – The Case of an English to Zulu Dictionary of Possessives", In: *Proceedings of the XVI EURALEX International Congress: The User in Focus*, Bolzano (Italy), 739-748.

Chiarcos, C., Fiedler, I., Grubic, M., Hartmann, K., Ritz, J., Schwarz, A., Zeldes, A., and Zimmermann, M. (2011). "Information structure in African languages: corpora and tools", In: *Language Resources and Evaluation*, (45) 3, 361-374.

De Pauw, G., de Schryver G., and van de Loo, J., (2012). "Resource-Light Bantu Part-of-Speech Tagging, Proceedings of the workshop on Language technology for normalisation of less-resourced languages", In: *Proceedings of the Workshop on Language Technology for Normalisation of Less-Resourced Languages*, Istanbul, Turkey, 85-92.

Diki-Kidiri, M. (2007). *Comment assurer la présence d'une langue dans le cybersspace*. Paris: UNESCO.

Gasser, M. (2012). "Toward a Rule-Based System for English-Amharic Translation", In "*Proceedings of the Workshop on Language Technology for Normalisation of Less-Resourced Languages*, Istanbul, Turkey, 41-46.

Gelas H., Abate S.T., Besacier L. and Pellegrino F. (2011). Evaluation of crowdsourcing transcriptions for African languages. In: *HLTD 2011*.

Grover, A., van Huyssteen, G.B., and Pretorius, M. (2011). "The South African Human Language Technology Audit", in *Language Resources and Evaluation*, (45) 3, 271-288.

HLTD (2011). *Proceedings of the Conference of Human Language Technology for Development* (2011). Alexandria: Bibliotheca Alexandrina.

Katushemererwe, F. (2013). *Computational Morphology and Bantu Language Learning: An Implementation for Runyakitara*, Ph.D. Thesis, Groningen University, Netherlands.

Littell, P., Price, K., and Levin, L. (2014), "Morphological Parsing of Swahili using Crowdsourced Lexical Resources", In: Proceedings of the Ninth International Conference on Language Resources and Evaluation, Reykjavik (Iceland).

Mali Ministry of Digital Economy (2014). "Plan Mali numérique 2020: Stratégie nationale de l'économie numérique". Bamako: Ministère de l'Économie Numérique, de l'Information et de la Communication. (Approved by Government 21 May, 2015).

Mali Ministry of Education (2014). "Document de politique linguistique du Mali". Bamako: Ministère de l'Éducation Nationale. (Approved by Government 3 December, 2014).

Mohomodou Houssouba (2007), "La concomitance du français et des langues nationales au Mali" in Françoise Argot-Dutard, ed, *Le français: des mots de chacun, une langue pour tous*. (3e Lyriades). Rennes: Presses universitaires de Rennes.

Osborn, O. (2010). *African Languages in a Digital Age: Challenges and opportunities for indigenous language computing*. Cape Town: HSRC Press.

Rivron, V, (2012). "The Use of Facebook by the Eton of Cameroon," In: *NET.LANG: Toward a Multilingual Cyberspace,* 160-165.

Sinha, C. and Hyma, R. (2013). ICTs and Social Inclusion. In: Elder, L. et al (Eds), *Connecting ICTs to Development: The IDRC Experience*. London: Anthem.

Vannini L. and Le Crosnier, H. (2012). *NET.LANG: Toward a Multilingual Cyberspace*. Caen: C&F Éditions and MAAYA Network.