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INVITED COMMENTARY

Water sensor network applications: Time to move beyond the technical?

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1 INTRODUCTION

We have observed a dramatic increase recently in the range and diversity of hydrological and water resources projects using low-cost sensor networks to collect data across space-time. By reviewing the latest sensing and wireless communication technologies and their applications, and our recent experience of implementing hydrological sensors in low- and middle-income countries (Mountain-EVO, 2017), we argue here that the research frontier for sensor networks has to move beyond purely technical considerations. This is because the scope of available low-cost modules (such as Arduino, Raspberry Pi, and Xbee) and inexpensive sensors now enables rapid development of robust sensor networks that are highly effective and easily assembled rather than having to be built from scratch. With a wide variety of functions and features, these modules can support customisation of hydrological monitoring networks for users that have widely different goals and aspirations.

"Non-technical challenges" concern how the implementation of sensing, information, and communication technologies can be transformed into applications that meet contemporary societal challenges, such as water resources management (Aqeel-Ur-Rehman, Islam, & Shaikh, 2014), disaster resilience building (Mao et al., 2017), and sustainable development (Buytaert et al., 2014). It is increasingly evident that these societal challenges should play a more important role than technological considerations in evaluating successful applications of information and communication technologies (ICTs). Nonetheless, these non-technical aspects continue to be largely overlooked by hydrologists and sensor network developers.

In this commentary, we gather current views from the hydrological sciences community on water sensor network applications and distil-out the key technical and non-technical challenges, from which we contest that successful applications of hydrological sensors require further research, not only on technology itself but also on sociocultural and governance aspects.

2 CURRENT PERSPECTIVES @AGU2017

To bring these issues to the attention of the hydrological community, and to improve our understanding of current prevailing attitudes and opinions to the development and use of sensor networks in the water sector, we presented an interactive poster on this theme at the 2017 American Geophysical Union (AGU) Fall Meeting. The AGU is the largest conference in the Earth and space sciences, regularly attracting more than 20,000 attendees from around the world (AGU, 2017).

The poster was scheduled in the MacGyver Session on December 14, 2017, an annual poster event for promoting innovative environmental data acquisition and transmission solutions (Hut et al., 2016). As well as being listed in the AGU's official programme website and mobile app, we also advertised the poster before the presentation through our Twitter account (@freshwaterflows), inviting conference attendees to join the presentation and conversation. The poster was set up at 8 a.m. The presenter (F. Mao) introduced the study and discussed its implications with the audience from 8 to 11 a.m. The poster remained on display until 6 p.m. when the afternoon session...
ended. A summary of technical and non-technical challenges was presented interactively: The audience was encouraged to place round stickers next to the issues or challenges they felt were most important, or to leave comments and feedback using post-it notes (see Figure 1).

3 | EMERGENT TECHNICAL AND NON-TECHNICAL CHALLENGES

Based on the feedback from the AGU community, challenges for water sensor network applications were identified. Interestingly, although the poster focused on “neglected non-technical perspectives,” most of the comments were about the technology itself. Conventional technical features and challenges included low-cost, battery life, and power efficiency; wireless connections; real-time data acquisition and processing, precision and accuracy; robustness and reliability; physical and information security, and sensor network optimisation. The non-technical challenges that were flagged are summarised in Table 1 along with posted example questions.

Feedback showed that all the technical features were deemed important, with wireless communication being the most popular. However, in practice, there are always trade-offs and compromises in choosing the features for sensor network design. One participant commented that finding a “silver bullet” technological solution addressing multiple technical challenges was highly unlikely—that is, one that could be simultaneously power efficient, cheap to obtain, and have wireless communication. With limited resources (e.g., funds and human capacity), certain features tend to be selected to maximise the overall performance of sensor networks. For example, the low-cost sensor is usually regarded as an alternative solution to collect environmental data in an affordable way, while compromising data precision and accuracy. Compared with the conventional and professional sensor stations, the low-cost solution can significantly increase the coverage area of monitoring or the number/density of sensor nodes (Hart & Martinez, 2006). However, the size, number, and density can also depend on the expected duration of monitoring activities. One audience member noted that long-term monitoring with fewer nodes could be more valuable and useful than short-term monitoring with a wider coverage in some situations.

Ultimately, these trade-offs and compromises are determined by the goals and sociotechnical contexts of end-users. For example, early warning systems may have higher demand on technical functions such as real-time data processing and communication than other applications such as scientific data collection or water resources management in general. In addition, analysing user demands is clearly essential. For example, one comment pointed out that the understanding of “low-
TABLE 1 Non-technical challenges and example questions

| Application scenarios | Stakeholders and partnerships | Table 1 Non-technical challenges and example questions |
|-----------------------|-----------------------------|------------------------------------------------------|
| ● What do we need low-cost sensor networks for? | ● Who is involved in operating sensor networks and for what purpose? | ● How can we define and evaluate ‘successful’ sensor network applications? |
|                       | ● How and why do these stakeholders collaborate? What are their collaborative roles? | ● How can we create pathways to achieve long-term societal impact through sensor network applications? |
|                       | Citizen science and public participation | Decision and policy-making |
|                       | ● How can citizen scientists be involved? | ● How can collected data feed into decision and policy making at different levels? |
|                       | ● What incentives are there for public participation in sensor networks? | Finance and operational mechanism |
|                       | Context | ● How should sensor networks be funded? |
|                       | ● How can sensor networks be adapted to different physical, socio-economic and sociotechnical contexts? | ● How can sensor networks be made more financially and politically sustainable? |

4 MOVING BEYOND THE TECHNICAL

We believe that successful applications of hydrological and water resource sensors require further research not only on technical but also crucially on sociocultural and governance factors. Our poster study offered a means of testing this proposition among the scientific community, while drawing people’s attention to this neglected issue. Addressing this issue comprehensively now requires sensor network researchers and developers to work closely with a broader range of stakeholders than they are accustomed to, including policy makers, NGOs, local community members, and private sector representatives to identify practical real-world challenges and demands that the academy may not yet be aware of. Furthermore, it is likely that hydrologists and sensor engineers will need the support of social scientists in fields such as environmental governance, international development, public policy, and socioeconomics to broaden their grasp of the importance of sociocultural contexts and sociotechnical regimes to sensor network development. Interdisciplinary studies that are nourished by these knowledge domains will be in a better position to provide solutions to non-technical problems, and answer questions such as how ICT applications can help and support poor and marginalised communities and social groups (Heeks, 2008).

This discussion on non-technical aspects of water sensor network applications will be continued in such events as the International Tech4Dev Conference in Lausanne, Switzerland in June 2018 (EPFL, 2017). We hope this commentary will stimulate some debate within and beyond the hydrological community on neglected non-technical perspectives on sensor networks.

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