HydroGIS Tool Structure: Neogeography Application Model

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Abstract— *The basic two interesting areas of the GIS are community based GIS application developments and complex process automations. The HydroGIS tool development laid on the complex process automation research side as it based on the complex hydrological models. The community based GIS application or Neogeographic application is the most used GIS applications which frequently upload spatial information such as hotels, shops etc. by the general public, today. Therefore, always a large amount of spatial data is generated effortlessly, but due to credibility and accuracy issues, these data are in a lower suitability to be used in complex GIS processes.*

The present work attempted to develop a model to verify and use of such for complex GIS process. The proposed model consists three sub modules namely Presentation, GIS and Confirmation Modules. Basically the presentation module described about the user-side interface and its behaviour. The GIS module is the complex GIS Process Automation, which is totally depend on the individual GIS model used in processing. The most interest part of the model is Confirmation Module, which purifies the inputs of users and forwards to use in complex GIS processes. Within the Confirmation Module, there is a structured mechanism to analysis the user behaviour. Further this algorithm evaluates the users' credibility & reliability and then index him/her accordingly (c&r index). Then each data captured from the users are evaluated based on c&r index which the algorithm resulted.

The scenario considered in the present work is flash flood forecast based on the visually estimated rainfall. However, as the rainfall can be observed by naked eye, its relatively easy to ensure the accuracy. Presently this scenario is under development to verify the model.

Keywords— **Neogeography, Visually Estimated Rainfall, Accuracy evaluation**

I. INTRODUCTION

A. Geographic Information System

Since few decades Geographic Information System (GIS) researches and hydrologist have identified the lack of sophisticated analytical and modelling capability as the major deficiency of the GIS technology. As most of the engineering works are with the spatial context, GIS used to be a tool, which used in analysing critical processes and assisted in spatial decision-making. Hence, most of the engineering related researches attempted to solve the problematic areas of GIS technology.

But with the mobile application popularity, community GIS applications ; which help layman to make spatial decisions and understand the spatial relations such as path fining, finding nearest place for facilities; grab the attention of the general public. With these developments, GIS became a day-to-day tool. Basically these applications are used by non-GIS-expert users. However, without knowingly they execute geographic techniques and tools for personal and community purposes. This is called as "Neogeography" or "new geography" (Turner, 2006)

Nevertheless, the important part in the development relates to the scientific researches. Various researches develop the skills of GIS to analysis more and more powerful logics on automation of various models available for engineering calculations in order to simplify the complex process and achieve the highest accuracy.

B. Hydrology Modelling

Hydrological model automation is also an important area in GIS. Unlike most other environmental models, hydrology models follows well established standards and practises. Those are widely accepted by hydrologists and hydraulic engineers (Sui and Maggio, 1999) For decades GIS is used to hydrological modelling due to the maturity of the technology using in GIS. Further it considered GIS as a very suitable tool for hydrology modelling as it always closely related to the spatial variation.(Maidment, 1992).

When consider the incorporation of hydrological models with the GIS technology there is common barrier. That is, GIS based on the spatial context whilst the hydrology models are concern the temporal context. Hence, it has to develop number of map layers to incorporate temporal context and manage temporal information using programming language supported by the GIS software.

It has identified four types of integration of GIS with hydrological models (Figure 1). Due to highly technical environment in the GIS, the best practises at the present are embedding hydrological models in GIS and loose coupling.(Sui and Maggio, 1999)

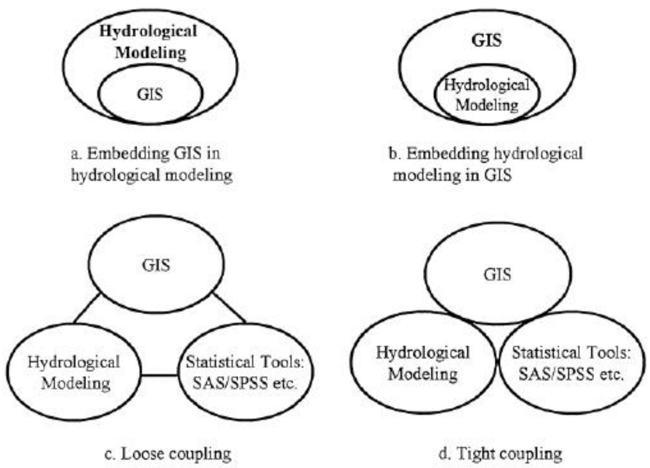


Figure 1. Integrating GIS with Hydrological modelling
Source: Sui and Maggio (1999)

There are dozens of GIS tools and hydrology tools, but most of these perform either hydrological calculations or map based manipulations. To fill the gap Pradeep and Wijesekara (2012) have developed a Hydro-GIS tool to assist non-technical persons to perform map based activities and hydrological calculations to make easy decision making on urban flash flood management options. They have practised the "Embedding hydrological modelling in GIS" type of the Sui and Maggio(1999). Further this work introduced the word "Hydro-GIS" which explaining the fully automated hydrological modelling in Geographic Information System (GIS). Nevertheless, usability became a major difficulty, when handover the GIS tool to laymen.

Al-Sabhan et al.,(2003) has identified the usability difficulties of the GIS software as difficult Interface, knowledge of GIS, platform dependency, requirement of Computer and programming knowledge, difficult in Customisation, limited accessibility for data, requirement of rectifications in analysis, limited collaboration and costly real-time data acquisition and communication. However, due to the neogeography most of the difficulties start to be disappeared.

C. Indigenous Rainfall Estimation

Historically, rain is the remarkable event of the life of people whose main income is farming. Hence, farmers had a good sense and much accurate knowledge in predication of rain and its repercussions. (Fabiyi and Oloukoi, 2013; Okonya and Kroschel, 2013; Raj, 2006; UNEP, 2007; Zuma-Netshiukhwi et al., 2013). One such knowledge utilised by the Sri Lankan farmers for predict rain, intensity and consequences though natural indicators are shown in the Table 1. (Berger et al., 2009)

Table 1. Traditional forecasting indicators

Observation	Prediction
Large termites start breeding during a dry period.	Rain will come soon.
Ants appear with their eggs and move to a new nest	Rain will start within 24 hours.
Small termites start breeding during a rainy period.	Rain will stop soon.
A noise is heard emanating from the sea.	Rain will come within seven hours and last for seven days.
Off-season trees such as tamarind and wood apple give good yields	Good future rainy season – farmers cultivate large areas.
Dogs and cattle make unusual sounds.	Destructive rainy season leading to disasters is anticipated

Source: (Berger et al., 2009)

However, this knowledge is disappearing with the changing of the economy and agricultural technologies. Therefore, the present study required an acceptable method to capture the precipitation intensities through naked eye to standardize the data capturing. Nevertheless, most of the literatures found on the same subject, are not directly related to the work's objective. Estimating the rainfall intensity through the viper speed of a moving car is one such example, which interested to the work (Rabiei et al., 2013). Then the work able to find a guideline which used as a starting point as shown in the Figure 2.

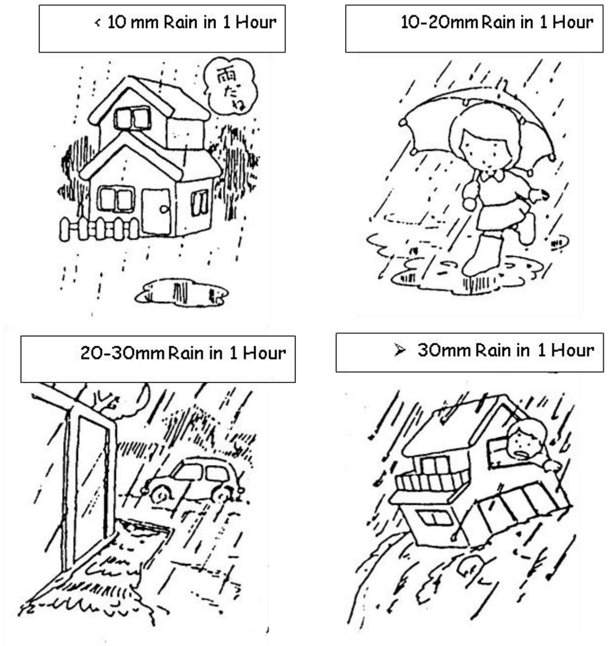


Figure 2. Naked eye precipitation guideline

C. Web GIS and Web 2.0

As well with the popularity of the internet as a service (IaaS) oriented architecture, web-GIS is getting popular due to its inherent characteristics such as ability to global reach, handling large number of users, better cross-platform capability, low cost, easy to use for end users, unified update capability and ability of diverse applications. As well Web 2.0 describes the new version of the World Wide Web. However, Web 2.0 is not a technical specification, but it refers to software developers and end users behaviour's change the use of the Web. Equation 1.0 shows the short summary of Web 2.0 (Fu and Sun, 2010).

Equation 1. Web 2.0 explanation

$$\begin{aligned} \boldsymbol{web\ 2.0} = \boldsymbol{user generated\ content} \\ + \boldsymbol{web\ as\ a\ platform} \\ + \boldsymbol{rich\ user\ experiance} \end{aligned}$$

D. The Problem

However one of the difficulties which describes by Al-Sabhan et al.,(2003) remains unchanged. That is "costly real-time data acquisition". The hydrological models which are utilised in the prediction, required real-time data. For that, there are different techniques such as sensor networks, mobile applications and etc. are used (Al-sabhan, 2010; Baker and Gaspard, 2008). As well the present work studied that neogeography applications are generating big amount of real-time spatial information, but with low credibility and reliability (c&r). Nevertheless, if there is mechanism to increase the credibility and reliability, these data become a low cost and powerful input to real-time GIS processes. Hence there is a requirement to development of a mechanism to confirm the c&r of the neogeographical data to be used in the Hydro-GIS modelling due to at the present no literature to be found.

E. Objective

Therefore the main objective of the present work is to develop a general model to utilise neogeographic data in real life GIS analysis.

II. METHODOLOGY

A. Model Development

The present work main work is to develop a model to capture and use community based GIS (neographical) data to analysis and provide the results. A general model was formulated but further the work formulates a mechanism to capture the real-time precipitation information from the general public and use those as a parameter to hydrological model which can predict a flash-flood.

Flash-flood prediction is a common research area in the flood forecasting, hence the present study is not focusing to develop or utilize any model of such, but considered only to provide precipitation input to the model. The work assumes precipitation input is the main dynamic input to flood forecasting model.

B. Model

The proposed model consists of three sub-modules namely GIS, Presentation and Confirmation modules and users and administrators. The model is shown in the Figure 3.

1) Presentation Module: This is the place where the users add data to the system or the GIS data layers and view the results. Such data sharing may be places of interests such as hotels, site to see, garages, dispensaries, shops and etc. But the proposed model described to capture more explanatory data, such as user feeling on the precipitation events such as drizzling, small rain, rainstorm, cloudburst, cool, very hot and etc. through application interface.

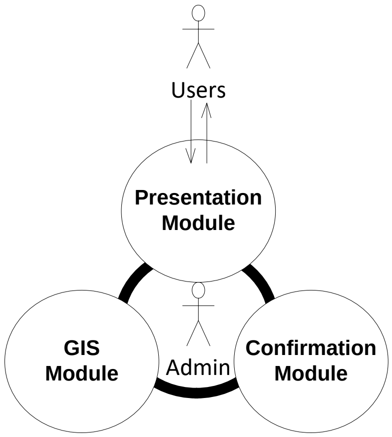


Figure 3. HydroGIS-Neogeography Model

2) GIS Module: The GIS module runs the required GIS operations to generate the requited results. The GIS models are incorporated with the GIS module and all the GIS functions can be automated or can run under the observation of the system administrator.

3) Confirmation Module: This is the intelligent part of the model, and employs an information purification activity before acceptance of the data. The model proposed to capture the certified information from the direct source and evaluate the user's c&r. Further model suggested weighting the users accordance with the level of c&r .

III. TOOL DEVELOPMENT

A. Hypothetical Tool

For a better description, the proposed model is described using a hypothetical tool, which proposed a mobile application that capture the rainfall information from users in a user-friendly way and process the data to predict local flood events in a backend cloud GIS server as shown in the Figure 4. Further, the tool provides an online updated weather map of the user interested area with the history flash flood event locations. The local weather, which affects the user, is shown in text and iconic format at the bottom of the GUI. Further, nearby users are displayed (if they permitted) in the right bottom of the GUI. Through these features, the tool expects to align with the Web 2.0 standard as shown in the Equation 1.

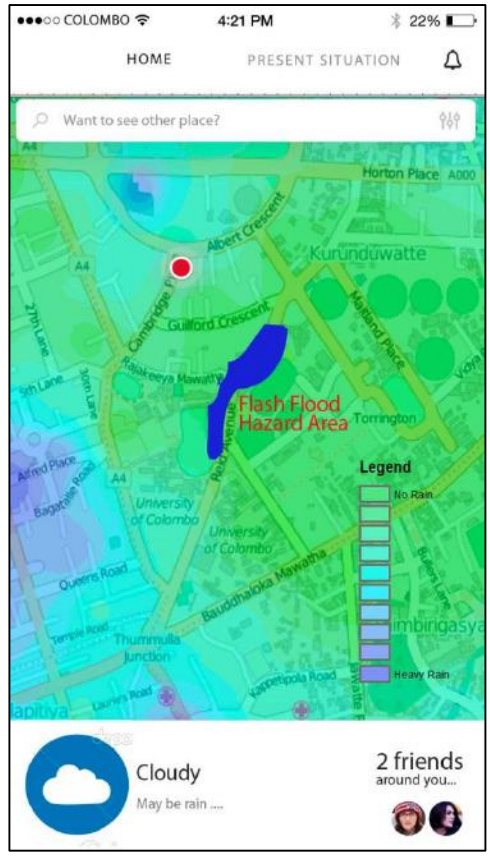


Figure 4. Proposed main GUI

B. Presentation Module

The tool required user account registration. The users are agreed to provide the weather and location information when inquire by the tool. The tool should capture the location information by accessing the GPS module of the mobile equipment whilst the weather information are captured from the users in a different occasions such as once a fixed time period, or when user needs or when tool backend realised a interesting local precipitation event through other users' data entry.

1) Triggers for data captures: The model has identified three different occasions, which users are to update / provide information. The first occasion is user input precipitation information by him/herself when a remarkable event. The second occasion is fixed time inquiry which the mobile application inquiry the user for precipitation situation in user agreed frequency. The third occasion is the much important occasion. If one or more users spatially around a single user are reporting a precipitation event, the server sends an inquiry to the single user and gets the confirmation of the precipitation event (Figure 5Figure **5**). Through this, the model expects to capture the real time situation of a precipitation event spread across the local spatial area.

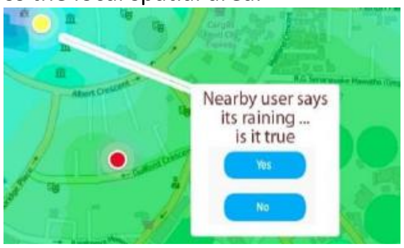


Figure 5. Confirmation of other user Input

2) User Interfaces: The development of the UI is out of the focus of the model, but the capturing of the precipitation event in a more standard and generalise format is interested. As described, the available guideline shows in the Figure 2. can be summarised as shown in Table 1.

Table 1. Estimated precipitation levels

Observation	Estimated Precipitation
Drizzling with puddles	< 10 mm for 1 hour
Walk with umbrella	10 -20 mm for 1 hour
Rain with flushed drains	20-30 mm for 1 hour
Torrential rain with remarkable damages	>30 mm for 1 hour

Utilizing the knowledge, users' observations are to be captured and then analysed and recorded in the backend. Hence the GUI should capture this information directly from the user as shown in the Figure 6.

Then proposed outputs to the users are included online precipitation local map with past flash flood events as shown in Figure 4. (based on accepted users' inputs and real data) and flash flood warning with a local hazard map. The term "local map/area" is referred to the area where the user is presently located. The extent can be specified by the user.

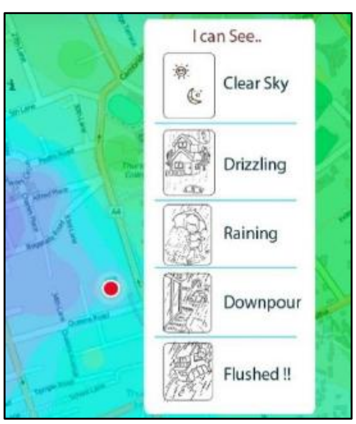


Figure 6. User Precipitation Data Input GUI

C. *GIS Module*

GIS module is basically for the flash flood forecast, which is a trial and error process that based on actual flash flood events (which can observed by naked eye) and precipitation information (which users observed by naked eye) correlations. The present work suggested to capture the precipitation information from the users who is named as human rain gauge (hRG). Importantly, as these users are movable, the hRGs are dynamic. Then a single hRG may update multiple data inputs for different geographical places. Hence, the study considers the rain gauges are based on the geographical location, but if a two different users update data from a same location it consider as two rain gauges. Outline of the GIS module is shown in the Figure 7.

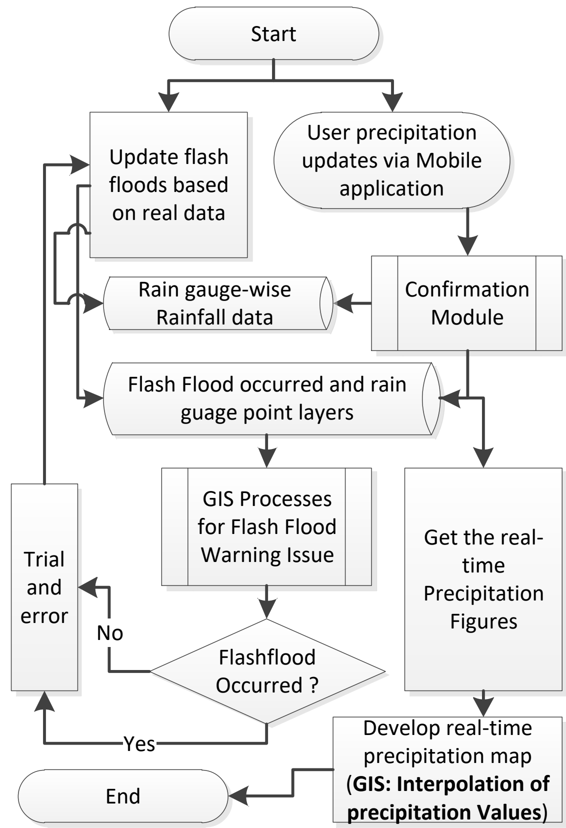


Figure 7. GIS Processes of the Model

1) GIS Inputs: As shown on the Figure 7, there are two main inputs to the GIS module which are; (1) Data about actual flash flood events by the administrator and (2) Real-time precipitation data of the users. Real-time user data are subjected to confirmation to be used in the GIS processes. This Confirmation process is described under the Confirmation Module (Under Part III . Section D.)

2) GIS Processes: Conceptually, basic delineation area for the process should be the catchment of the each flash flood, based on the contours. Nevertheless, the proposed model expects to develop catchment for each recorded flash flood either located within the same watershed. The rain gauge located within the considered catchment and warning level rainfalls of each rainfall gauge (sample warning level rainfall related to one gauge shown in the Figure 8), should be used in flash flood warning issue.

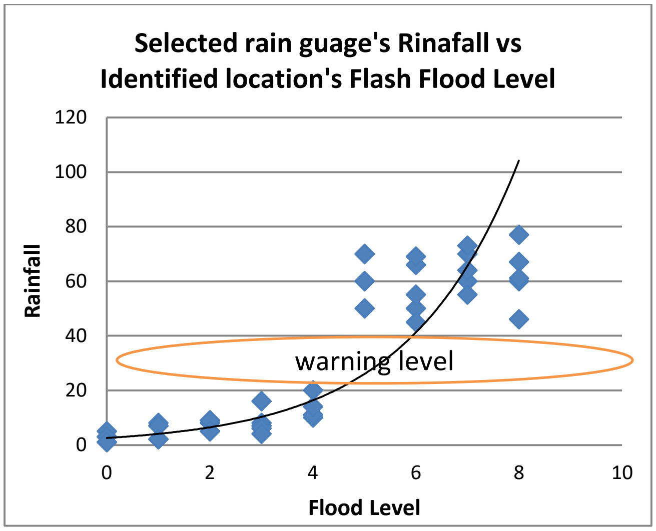
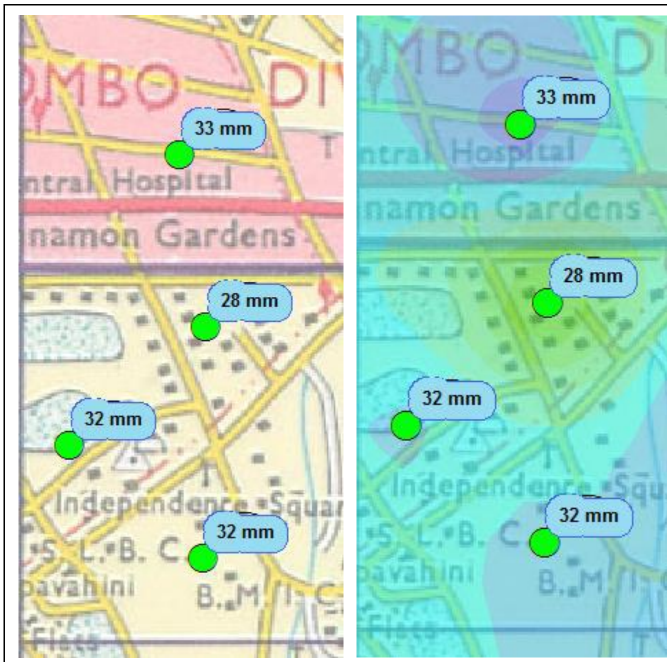


Figure 8 Correlation between a single Rain gauge and flood level

3) Real-time precipitation map development: Real-time precipitation map is being developed using all available real-time precipitation data in the spatial/relational databases as shown in the Figure 7. All the confirmed precipitation data points are marked on the map and then interpolate the precipitation values to develop the real-time precipitation map (Figure 9.)



Precipitation marked on the map

After Interpolation

Figure 9. Real-time Precipitation map Development

4) GIS Process for Flash Flood Warning Issue: Flash Flood warning issuing GIS processes are trail and error process, which always should be researchable. As a starting point, the Model suggested a GIS model as shown in the Figure 10.

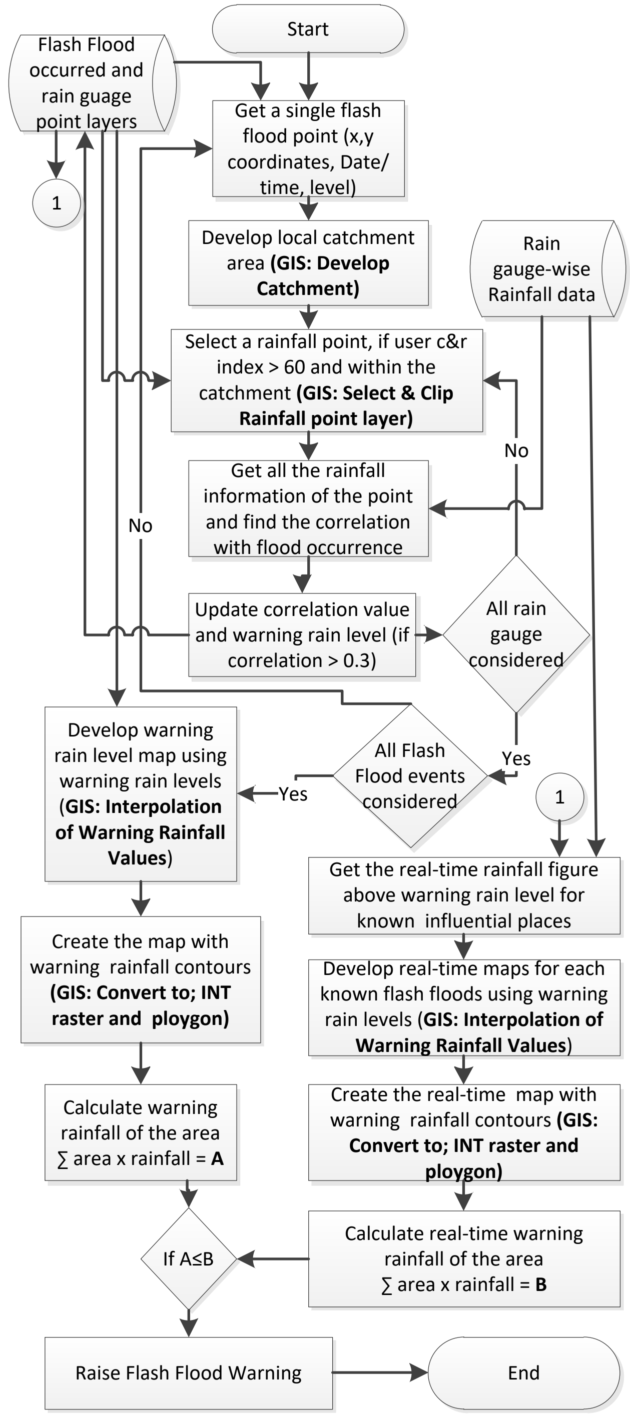


Figure 10. Proposed GIS Process for Flash Flood Warning Issue

In the proposed GIS model, initial step is, develop the catchment area for each and every known flash flood. Then

consider the influences of the level of rainfall of each rain gauge spread over the catchment (Figure 8).
Using these rainfall levels, model proposes to develop rainfall contours of warning level using GIS operation (interpolation), convert to Integer raster and convert raster to polygon.
For warning issue, the starting signal is reporting of warning rainfall of an influential location. Then, it follows the same process using the real-time user inputs instead of history rainfall data; and known catchments, which develop previously for history flash floods. After develop real-time rainfall contours for warning rainfall levels, then catchment area's total rainfall value match with the actual flash flood situation's total rainfall value (in figure 10., B and A values respectively). IF the A < B, it shows the flash flood warning rainfall is occurring in the catchment area. Then model propose to issue a warning order.

D. Confirmation Module

The important algorithm development is placed in this module. As the individual person is behaving as a data entry point, the accuracy of the input data must be very high. For that the model suggested a Confirmation module, which is a trial and error accuracy evaluating model for each and every user. Steps of the confirmation module are shown in the **Error! Reference source not found.**.

1) c&r Index: At the initial stage, all the users are in a same confidence level. The confidence level of the user is named **c&r index** which denote the individual user's data accuracy over the actual rainfall data and nearby users' inputs.

2) Level of accuracy over real event: The reporting of individual precipitation event should match with actual rainfall data. In this context, the person may generate number of inputs for different geographical locations; hence, the information should match with the actual rainfall data for each place. Then the formula used to calculate level of accuracy over real event *(W_Actual*) is shown in the Figure 11.
Some times the physical rain gauge may not record the rain but the users may record a rain, or vice-versa. However, this accuracy checking is not a real time operation.

3) Level of accuracy over nearby inputs: Apart from that, confirmation module suggests two methods to verify the accuracy over nearby user's inputs. As described in the Presentation Module, when a user is generated a precipitation event, the system searches nearby users and get a confirmation of the event. Decide the search radius distance is a trial and error process. Then the formula used to calculate level of accuracy over nearby inputs (*W_Update*) is shown in the Figure 11.

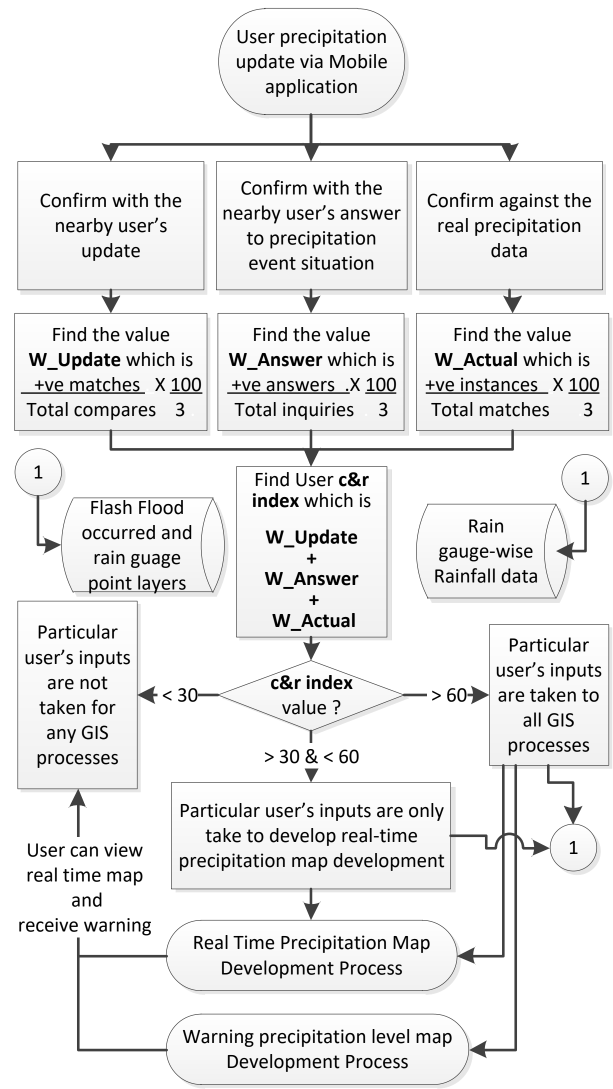


Figure 11. Confirmation Module Processes

4) Level of accuracy confirmation from the nearby users: The other method is invoking a message through the mobile application and getting confirmation by the nearby users when a single user informs an event, but available users around the user do not reporting any information. Then the formula used to calculate level of accuracy confirmation from the nearby users (*W_Answer*) is shown in the Figure 11.

5) Calculation of c&r Index: In this initial proposal, c&r index is a summation of equal weighted *W_Actual, W_Update* and *W_Answer, which* the values *are* varying from zero to 100. However, it excepts that the further studies to be done with real data, which generate through the real deployment of the tool.

6) Influence of c&r Index: Further, it is suggested to categorise the user into three groups based on the c&r index. First group is index value less than 30 users. The overall confidence of these group is less than 1/3 of the total, hence it suggested to not to use their inputs for any GIS process, such as real-time weather map development or any other advance GIS operations. But, user inputs are considered for further calculations of his/her c&r index.

The next group is index value between 30 and 60, who represent the middle class of the variation. In this initial stage, it suggested to use their information for real time precipitation map development but not for advanced GIS process.

Other group is highly confidence users who scored more than 60. Their inputs are used in real-time precipitation map development and find the correlation between flash flood and precipitation distribution within the watershed. As well, it hopes to re-demarcate the boundary values of the groups whilst the further studies.

IV. RESULTS & DISCUSSION

The present study has identified main three different functions to be included in the neogeography HydroGIS tool as shown in the table 3.

Table 3. Basic Components of a Neogeography HydroGIS Tool

Function	Description
User Interface	The user interface of the neogeography application
Input accuracy Confirmation	The mechanism for accuracy verify of the user inputs
Backend	This is the mechanism for GIS process and other database processing which is under the administrator control.

The flash flood forecasting is an observation based prediction model, which should increase the accuracy through trial and error process.

For the proposed model, it is not important to have accurate rainfall levels as the model suggested to find the correlation between naked eye rainfall estimation and flash flood event.

This model results a localized real-time precipitation map, which is presently not available to general public. This demonstrates practical usages of the community GIS / neogeography applications for the day-to-day decision making of the people.

The present model uses the information generated by the non-GIS / non-hydrology specialist to advanced HydroGIS calculations. This breakthrough suggests to re-evaluate the high cost spatial data collection mechanisms.

The model proposes a categorization of users based on the reliability and accuracy of inputs which is presently highly urging requirement for develop HydroGIS tools which need neogeographical data.

IV. CONCLUSION

Neogeographic data inputs are indicating the characteristics to be develop as BIG data. Hence a considerable attention to be required on the developing analysis of neogeographic data.

There is a requirement to hydrological analysis the traditional knowledge on weather forecasting. This observation-based knowledge can be established as a natural theory in weather forecasting and the observations are gathered through neogeographic inputs.

The present model is under the development and the tool construction is on progress. The main attention is being paid to identify the main areas and those responsibilities. The present work attempted to highlight the requirement of backend mechanism to use the user-generate information in geospatial context to actual analysis.

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