Storychart: A Character Interaction Chart for Visualizing the Activities Flow

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***Abstract*— Event-predicate-based storyline extraction results in a chronologically ordered activity journal. The extraction results contain complex human activities, so the activity journal requires a visualization model to describe the interactions between actors. This paper proposes a chart to visualize the flow of activities to describe the interactions between characters in an activity journal. This chart is called a storychart. Storycharts have an actor channel that can accept single entities or teams. The actor channel allows changing the type from single to a team or vice versa and moving members to other teams. The activity channel serves as a connector to accommodate interactions between actors. The activity channel provides a visual space for the elements of what, where, and when. Event predicates are the core of what. Therefore, the storychart visualizes the event predicate using glyphs to attract the reader's attention. The main contribution of this paper is to introduce a team channel that can visualize the identity of team members and an activity channel that can visualize the details of events. We invited participants to discover the reader's perception of the ease of team recognition and the integrity of the meaning of the narrative visualized by the storychart. Participants involved in the evaluation were filtered by literacy score. Evaluation of storychart reading showed that readers could easily distinguish teams from single actors, and storycharts could convey the story in the activity journal with little reduction in meaning.**

***Keywords*—Information Visualization; Text Visualization; Story Visualization.**

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I. INTRODUCTION

A biography is a non-fiction story that describes the real life of a famous subject (character) [1]. Biographies tell the social interactions between the main character and other characters. To get a complete picture of a main character, biographers need facts about the activities of the main character from the past to the present [2], [3], then biographers compile these facts into an activity journal [4]. The activity journal contains data on interactions between the main character and other characters in chronological order. The activity journal helps observe the flow of interactions between characters. In general, activity journals are text sequences, so biographers need tools to help observe the flow of interactions between actors [5].

Several diagrams and charts have been developed to visualize interactions between characters [6]–[8]. Munroe was the first to introduce Movie Narrative Charts (MNC) on the XKCD website [7]. MNC is a line diagram to depict the flow of interactions. Each line has a color attribute and a name label to identify the actor. The actor's activity starts from the beginning to the end of the line. The series of actor activities are mapped horizontally. The width of the map indicates the duration of the story. Adjacent lines indicate interactions between actors. The area is marked with a bubble if the interaction indicates an important event. The bubble is brightly colored and labeled with the event's or location's name.

The Metro map is a topological diagram that depicts transportation routes [9]. Metro map simplifies routes using straight lines. The station symbol and transfer point indicate a stopping point. The unique color becomes the identity code for each route. Kraak transformed Minard's travel map for the Napoleonic army from Moscow to Kowno into a Metro Map [6]. The colored line represents the troops moving toward Moscow and back to Kowno. Shahaf et al. visualize the relationship between documents using a metro map [10]–[12]. Stations denote events or topics of a document. The relationship is symbolized as a path that connects several stations. Lines form a travel route from one station to the next. In addition to using news articles, Shahaf et al. have used metro maps to visualize relations between science documents [13].

Shelley developed an activity flow diagram to narrate an autobiography [8]. Shelley explained the flow of activities that

she did from birth to 2006. Shelley grouped activities based on similar topics. Each topic is made of a curve that looks like a river. The river topic narrows and widens according to the amount of activity. A topic river can boil down to a more important topic and branch into several sub-topics. The topic river contains a series of activities in chronological order. Activities occupy the location column, where the location column is arranged horizontally to coincide with the time channel. Some locations appear more than once at different times. Location repetition occurs because the actor changes residence and returns to the actor's place of origin.

Shelley's Biography [8] is designed to visualize the flow of single-actor activity. The advantage of Shelley's Biography is that activity channels can be branched and merged. MNC [7] and Metro Map [10]–[12] were developed to narrate multi-actor stories. Both model diagrams visualize the flow of interaction between actors. In general, an actor's channel represents a single character. Both diagrams have channels for the team, but team members are fixed from the beginning to the end of the narrative, so team members cannot increase or decrease. In addition, the Team can be identified from the adjoining lines, which is confusing with the visualization of the interacting actors.

Previous visualization techniques lacked team and activity channels. Teams are characterized by lines that are close to each other. Teams are ambiguous between several people interacting individually (e.g., meetings, fights, or transactions) or a team doing activities (several people doing activities on behalf of the team). Both are visualized with lines that are close together, making it difficult for readers to distinguish between a team and several people interacting. In addition, activities only appear on important events visualized with event-name labels, so the details of the activities are not visible. Meanwhile, biography visualization must convey the elements of *who*, *what*, *where*, and *when* in detail [5].

This paper proposes a chart design for narrating the flow of interactions between characters over time to address the problem above. This chart is named storychart. The development of the storychart refers to line-based storyline visualization [6], [7], [11]. The novelty of our proposed storychart is :

- Storycharts have a dynamic actor channel. A single actor can join and leave a team through activities. The team channel preserves member identities. We combine member identities into a unique team identity. Single actors are visualized with colored solid lines. The team is visualized with a dashed-line, where the member's color becomes the strip color of the unique dashed-line. The unique team identity aims to make it easier for readers to recognize team members.
- Storycharts have activity channels to give visual space to story elements other than actors (who). The activity channel can hold information about the action (what), location (where), event-names (what), and activity-results (what). Storycharts visualize actions with a glyph for easy reading by the reader. The location, event-name, activity-result elements are visualized with text labels.

We invited participants to read stories narrated with storycharts. Storycharts were evaluated to assess the ease of recognition of team members and the reduction of story meaning. The evaluation used perceptions from participants that were filtered using participants' literacy scores. The filter aimed to ensure that perceptions came from participants who could read the storychart. The evaluation results showed that : a) Visualization of teams using dashed lines makes it easier to recognize teams and their members, and b) Activity channels can help minimize meaning reduction compared to interaction flows narrated with text.

The rest of the paper is organized into four sections. The second section examines the materials and methods in the design of the storyline visualization. The third section presents the results and discussion. The fourth section describes the conclusions.

II. MATERIALS AND METHOD

This subsection discusses the design, experimental implementation, and assessment of storycharts. The storychart design describes the channels to visualize story elements. Based on the design, a storychart was applied to visualize a sportsman activity journal. The applied test produces a visualization of the storyline, which is then used to measure the reader's perception of the storyline.

A. Design Goal

Charts or diagrams were used to visualize data flows in the seventeenth century [14], [15]. Data flow visualization is grouped into three flow categories: quantities, visits, and activity flow [16]. Activity flow is the only category that can be used to visualize the flow of interactions between characters. We designed an "activity flow" genre storychart because storycharts are useful for visualizing data about actor interactions. This work was inspired by a storyline composed of a predicate event extracted from a text document [17]. The storyline is a flow of activities ordered by time. Each activity contains *4W* elements, namely the actor (*who*), event (*what*), time (*when*), location (*where*), and the results achieved by the action (*what*). The main activity elements are actors and events, while other elements are complementary. Because the constituent elements of the activity are fixed, the activity can be formed into structured data.

Storychart are developed based on the visualization of the activity flow [7], [8], [10], [11], [18]–[20]. Previous visualization techniques used solid lines as actor channels without distinguishing between single actors or teams. We added a particular channel for teams as a dashed line. We also added connectors to visualize activity details. Connectors provide space to visualize interaction information between actors.

We developed a storychart with two goals:

- **The first goal is coding team members in a single line** (G1). Since team members are a single entity, the team needs to be visualized in a single line. The team is encoded with a dashed line to distinguish it from a single actor, whereas the single actor is encoded with a solid line. The identity of team members can be identified through the strip's color in the dashed line. Visualizing teams with a single line aims to avoid the dual meaning of lines that are close to each other, making it easier to identify team members.
- **The second goal is to encode activities in a connector** (G2). Each activity should contain an actor and an action

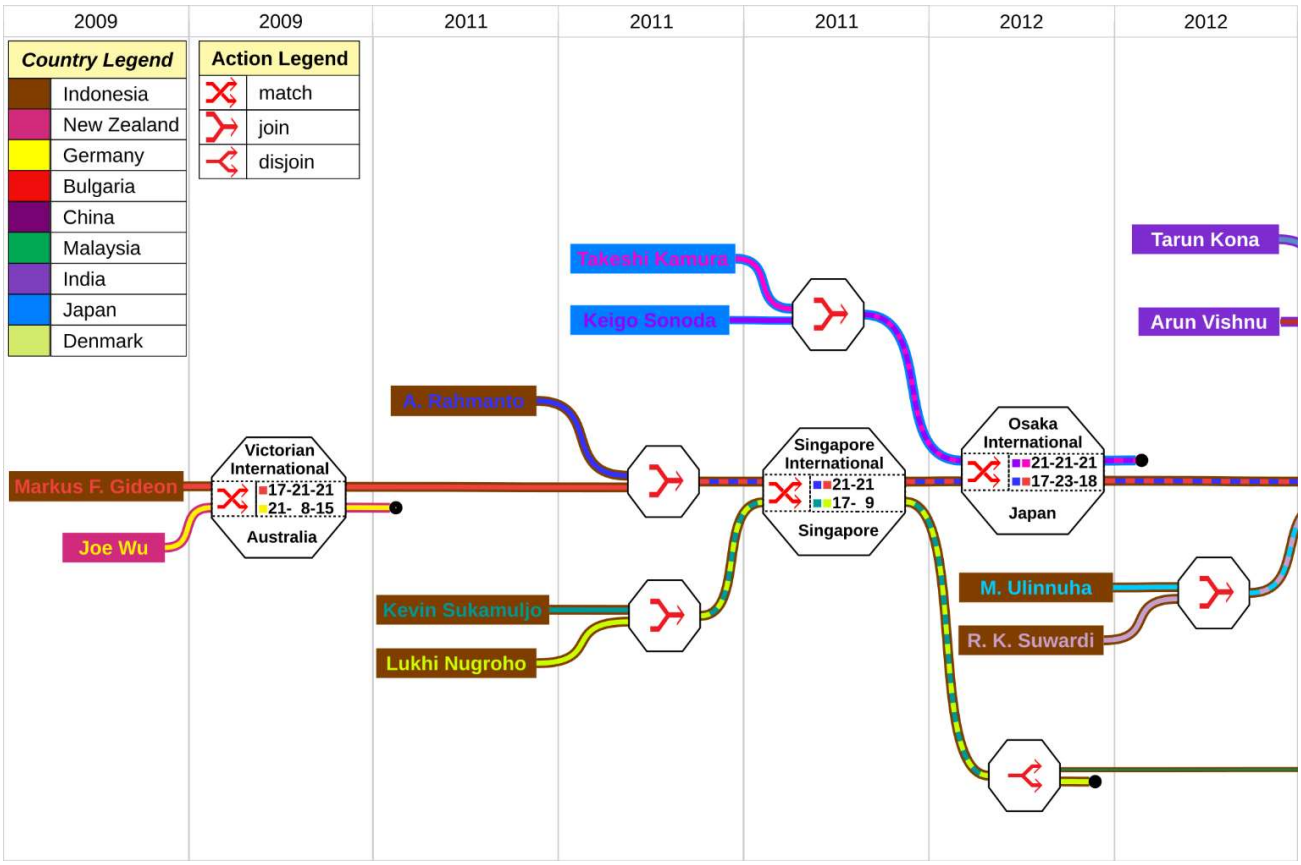


Fig. 1. Storychart narrates the story of the encounter between the Markus F. Gideon team from 2009 to 2012. The storychart is displayed in detail mode. Interaction connectors are displayed with complete information. Interaction connectors that do not have complementary data are displayed with a simple model.

(predicate). The completeness of the elements in each interaction can make understanding the meaning of the activity flow easier. We added connectors to visualize the activity elements. The lines connected to the connector indicate the interacting actors. If only one line is connected to the connector, it indicates that only one person performs the activity. The main element of activity is action (predicate), so actions are visualized with glyphs. Glyphs are more conspicuous than other elements so they will be the center of the reader's attention.

Based on the above goals, we define two tasks:

- **The reader can identify the team** (T1). The reader is given two storycharts. Each storychart has a different type of actor channel. Readers are asked to choose an actor channel that can facilitate team identification.
- **The series of connectors can narrate the storyline by minimizing the meaning reduction** (T2). Readers are asked to read two story narratives: storycharts and comparative narratives. The reader compares the two narratives' fitness of meaning and completeness of storyline elements.

B. *Storychart Design*

A storychart is a chart to visualize the connectedness of activities between actors. Storycharts are designed in the genre of flowcharts [21]. Storychart consists of lines (actors) and connectors (activities). Connectors resemble nodes in an event graph [22], [23]. Colored lines connect each connectors to the next. Octagonal planes are used to depict activities. Connectors contain actions as well as additional information. Glyphs are used to represent actions. Text labels are used to represent additional information. This subsection discusses the design of the storychart, which consists of channels: actors, activity, action, and time.

1) *Actor Channel*

We use colored lines to symbolize the movement of characters from one activity to another. The use of lines was inspired by MNC [7] dan Metro Map [10]. MNC and Metro Map use solid lines for single actor and team channels, so the actor channel has a double meaning. Actors can be visualized with solid and dashed lines [24]. Therefore, the storychart distinguishes between single-actor and team channels. The solid line symbolizes a single actor, and the dashed line represents a team. In addition, the line is added with a border to show the character's affiliation. The line extends to the right as the activity progresses. Fig. 1 visualizes teams with dashed lines and borders representing affiliation.

Start and End of Activity Flow. MNC and Shelley mark the beginning of the character's activity with a name tag at the beginning of the line [7], [8]. Name labels indicate identity but do not make it easy to observe, especially if the actor starts the activity in the middle of a very long story [8]. Metro Map emphasizes the name label with a rectangle with background color as the identity color [11]. The storychart marks the beginning of the activity using a rectangle with a background

color indicating the identity of the actor's affiliation. Name tags are colored with actor identity color, and name tags are embedded in a rectangular symbol. The start symbol refers to the event and decoration model of iStoryline [24].

The line is drawn from the start symbol to the first activity, to the next activity, and ends at the activity end symbol. The end of an activity is symbolized by a round black shape. The symbol end of an activity adopts the model from MNC [7] and iStoryline [24]. In Fig. 1, Joe Wu interacts with Markus F. Gideon, then the activity flow of Joe Wu is completed. The black circle symbol at the end of the yellow line means that the activity of Joe Wu has been completed, which means that the actor Joe Wu will not appear again in the next series of activities.

Single Actor Channel. The channel model for the single actors was adopted from MNC [7], Metro Map [10], dan iStoryline [24]. Solid lines represent activity shifts for a single actor (see Fig. 2a). Each line is assigned a unique color that serves as the actor's identity. Identity colors aid in actor recognition when actors have been active for a long time or are far from the start symbol.

Channel to Visualize Team. The use of lines to symbolize the flow of activity has been developed in several studies [25]–[29], but they do not have symbols for teams, so teams are visualized as blocks of lines flowing together. The storychart simplifies the team's visualization as a dashed line [24] (see Fig. 2b). The color of each stripe represents the identity of the team members.

Fig. 2. Symbols for character activity flow, a) single character in action, b) team in action, c) single character out of action d) team out of action

The number of colors indicates the number of team members so that readers can identify team members from the strip's color. Fig. 1, column 5, narrates the interactions between the Markus F. Gideon/A. Rahmanto with the team Kevin Sukamulyo/Lukhi Nugroho. Two join activities in column 4 precede the interaction. First, Markus F. Gideon (red line) joins A. Rahmanto (blue line) to become a team. The joining of the two actors is visualized with a connector containing the join action. Join interaction produces a dashed line with red and blue stripes. In the second activity, the characters Kevin Sukamulyo and Lukhi Nugroho joined to become a team with the identity of green and light green.

Channel to Visualize Affiliate. Sometimes, a actor represents his institution, such as a sportsman representing his country or a CEO representing his company. We accommodate the actor's institution or organization as an Affiliation. Affiliation members are present at various events in series or parallel [29]. Affiliations can accommodate the appearance of single actors and team members in parallel. The affiliation channel uses the edge color of the actor's channel (see Fig. 2). The use of affiliates can be seen through the activities of affiliate members. Fig. 1 and Fig. 3 narrates the activities of the four affiliates (Indonesia, New Zealand, Japan, and India). The affiliated

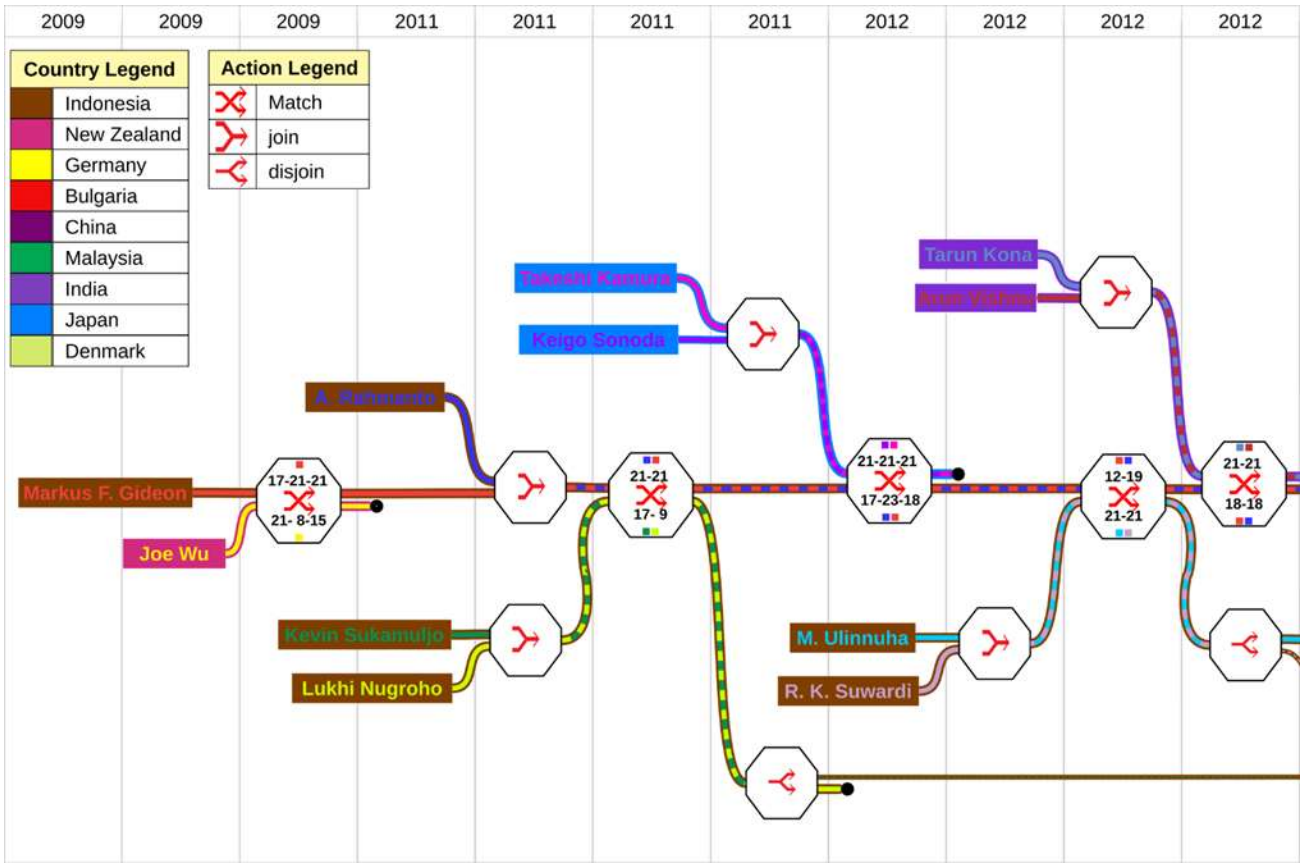


Fig. 3. Storychart narrates the story of the encounter between the Markus F. Gideon team from 2009 to 2012. The storychart is displayed in simple mode. Connectors only communicate actions, and result elements with low priority are not displayed.

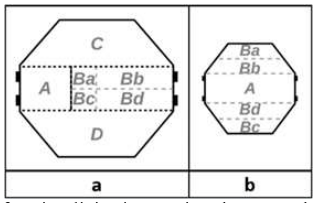


Fig. 4 Templates for visualizing interactions between characters, a) detailed mode template, b) simple mode template.

color is attached to the start symbol and the actor's channel border. Affiliates flow in parallel through each affiliate member actor channel. The affiliate starts from the start symbol, visualized through the background color of the start symbol.

We use affiliation colors to add uniqueness to the actor's identity. If the story involves many characters, it will require many identity colors. The identity colors should contrast with each other for easy visual distinction. On the other hand, getting many colors that contrast with each other is very difficult. Therefore, we combined the colors of the affiliation and the character to make a character identity. This combination requires the color of each affiliation to be unique. The member identity color is unique within the affiliate (locally unique), and the member identity color cannot be the same as the affiliate color. The combined uniqueness of affiliate and actor identities can increase the number of identity color variations.

Actor not in Action. Sometimes an actor is not active for a while, and then the actor does the activity again. The previous visualization technique did not distinguish the actor's inactivity [7], [8], [10], [11], [18]. The unavailability of symbols to describe actors who are not in action impacts the reading of the story because actors who are not in action look like they are in action. Therefore, storycharts create symbols that can distinguish actors in action or not in action. We depict an actor who is not in action with a thin line one-third the width of the thickness of the symbol in action. Fig. 2 is a symbol variation for an actor's activity flow. Flow symbols for actors in action using bold lines (Fig. 2a and Fig. 2b). Fig. 2a is a symbol for a single actor, and Fig. 2b symbolizes a team. Fig. 2c and Fig. 2d are symbols for inactive actors. The lines in Fig. 2c and Fig. 2d are thinner than those in Fig. 2a and Fig. 2c.

2) *Activity Channel*

The Storychart depicts an activity with an octagonal connector. Connectors provide space for action (*predicate*) elements and supporting elements (*where*, *when*, *what*). The connector has four visualization spaces from *spaces A* to *D* (see Fig. 4). *Spaces A* and *B* are assigned to elements of middle priority, and *spaces C* and *D* to low priority elements. The connected line on the left side of the connector indicates the actor that will act. The connected line to the right of the connector represents a completed activity, then continues to the next connector. The meeting of several lines on a connector indicates the interaction between actors. A single line connected to the connector indicates progress or single activity in an actor's journey.

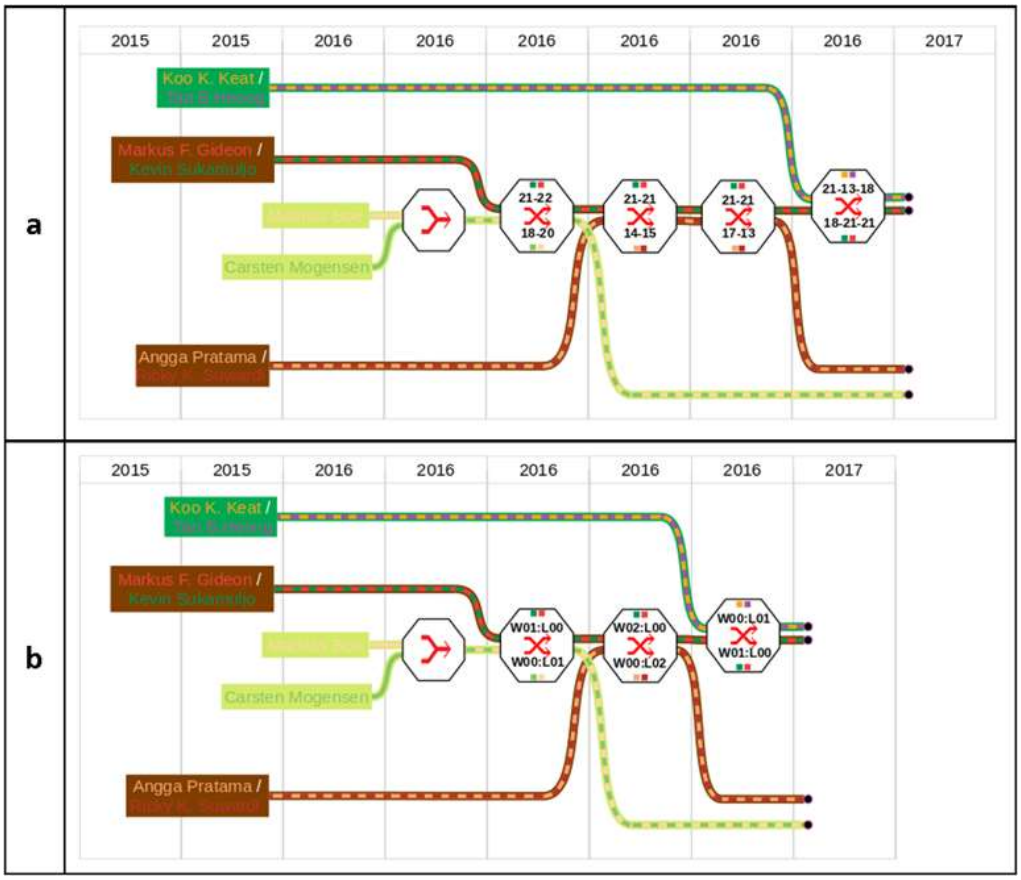


Fig. 5. Comparison of simple and summary modes. Sub storychart narrating the story of Markus F. Gideon in 2016, a) Diagram displayed in simple mode, b) Diagram displayed in summary mode.

The connector has three models: detailed, simple, and summary model. The detailed model provides visualization space for middle and low priority data. The simple model displays only middle priority data. Summary mode visualizes the data accumulation from the activities of the same character.

Conector in Detail Mode. The detail mode connector is divided into four visual spaces (Fig. 4a). The middle is divided into *space A* (left side) and *space B* (right side). *Spaces A* and *B* to put medium priority data. Low priority data is placed in *spaces C* and *D*. This paper uses detail connectors to visualize the elements: *action*, *result*, *event name*, and *location*. *Subspace A* is for displaying actions, and *subspace B* is used to display the *result*. *Ba* is the space for the first actor's identity, and the *result* owned by the first actor is placed in *space Bb*. *Space Bc* is used to place the identity of the second actor, and the *result* is placed in space *Bd*. The event name occupies *space C*. The location name occupies *space D*. Fig. 1 narrates the storyline using the detailed mode connector. This storychart can display the complete story elements.

Conector in Simple Mode. Detailed mode can only display a small number of connectors in one panel. Meanwhile, storyline observation sometimes requires observing a long series of activities. Therefore, connectors with a smaller size are needed to display more activities in one panel. Although small, these connectors are designed to display the essence of the activity. The simple mode uses activities with high and middle priority elements. The connector size becomes two-thirds of the detailed mode due to the reduced elements displayed. Fig. 4b illustrates the spatial division of the simple mode connector.

The connector displays only the action and result elements. The glyph of the action element is shown in the center (*space A*). The top and bottom sections display the result of an actor's activity. The top section displays the identifying element (*Ba*) followed by the result element (*Bb*) of the first actor. Likewise, for the lower space, the lower space displays the result of the activity (*Bd*) followed by the identity of the second actor (*Bc*). Fig. 3 uses a simple mode to narrate the story of Mark F. Gideon, as shown in Fig. 1. If Fig. 3 is compared to Fig. 1, Fig. 3 can contain more activities than Fig. 1. Fig. 1 only shows three activity data, while Fig. 3 can display five activity data.

Conector in Summary Mode. Summary mode displays multiple activities in a single activity summary. The summary mode connector uses the simple mode connector (Fig. 4b), but the summary mode replaces the contents of the result channel with the accumulation of the result channel. Accumulation is only applied to the activity sequence of the same actor interaction. The position of the action element and actor identity in summary mode is the same as in simple mode.

This paper summarizes activities by accumulating the results of a sequence of activities performed by the same actor. The accumulation forms the number of wins and losses. The accumulation is presented from the point of view of each actor. We write the accumulated results using the *Wx*:*Ly* format, where *x* is for the number of wins, and *y* for losses. Capital letter W as a sign for the accumulated winnings. The letter *L* is a marker of accumulated defeat (substitute *W*). A colon is used as a separator between winning and losing data.

Fig. 5 shows a chart that narrates the Markus F. Gideon sub-story in 2016. Fig. 5a narrates the sub-story in summary mode, while Fig. 5b shows the sub-story in simple mode. There are two sequences of interactions between the couple Markus F. Gideon/Kevin Sukamulyo and Angga Pratama/Ricky K. Suwandi in the sub-story. When viewed from the first pair, the accumulation is two wins, so it is written as *W02:L00*. From the side of the second pair, the accumulation shows a loss, so it is written as *W00:L02*.

Table 1
ACTION GLYPHS TO DEPICT INTERACTIONS BETWEEN CHARACTERS

No.	Symbol	Action
a		*Match*
b		*Join*
c		*disjoin*
d		*Progress*
d		*Gathering*

3) *Action Channel*

Storycharts make the action the core of the activity. Based on a survey conducted in iStoryline, meaningful images can describe activities [24]. Therefore, the storychart highlights the action with glyphs because the glyphs are easily recognizable to the reader [30]. Glyphs are colored red because red denotes action and attracts attention [31]. Red Glyphs assists readers in identifying actor activity. This paper divides actions into *interaction*, *merger*, and *progress*. *Interaction* consists of the *match* and *gathering* actions. *Match* represents a gathering of people from opposing groups to compete against each other. A *gathering* describes a gathering of people who come together to achieve a goal. *Merger* consists of *join* and *disjoin*. *Join* describes the joining of someone in a team, and *disjoin* vice versa. *Progress* for individual activities without involving other people.

We designed simple *glyphs* to represent the three groups of actions. The *glyphs* representing these actions can be seen in Table 1. Two crossed lines represent a *glyph match*. The crossed lines are extracted from the actions of competing athletes (Table 1a). Athletes attack each other, defend and swap places. *Glyph gathering* is formed from the two directional lines connected in a circle (Table 1e). The direction of the two lines is inspired by the exchange of opinions in a discussion. Mergers are developed based on the team development process. Teams are built by combining several people. *Glyph join* is formed from two lines that meet, which symbolize the joining of team members (Table 1b). *Disjoin glyphs* are depicted by branching lines which signify the member who broke away from the team (Table 1c). Glyph *Progress* is represented by three straight lines parallel to the right (Table 1d). *Glyph progress* shows the development of future activities.

Fig. 6 narrates Markus F. Gideon and Kevin Sukamuljo attending a meeting to cancel their participation in the Asian B. C. 2018 tournament. *Glyphs gathering* is used to describe meeting and marriage. Marriage begins with the disjoint

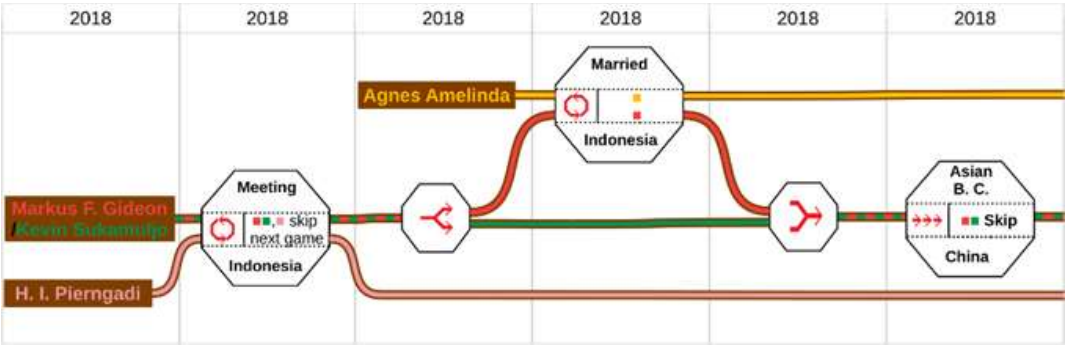


Fig. 6. The storychart narrates the meeting before Markus F. Gideon's wedding to Agnes Amelinda. Meeting and married activities are visualized using the gathering glyph. The tournament cancellation activity is visualized with the progress glyph.

activity of the team because marriage is an individual activity. After getting married, Markus returns to work with the team, symbolized by the *join*. Cancellation of the team's participation in the competition Asian B.C. visualized with glyph progress.

4) *Time Channel*

Time is fundamental for sequencing activities into a chronological story [17], [32], [33]. Storychart pins the time in column headers along the pane. The column model refers to the MNC [7]. Storycharts have non-uniform time columns. The number of columns per period adjusts the number of events. The column width matches the width of the connector.

C. Experiment

We implemented a storychart design to visualize the activity data of a famous person. The data set is converted into an activity journal. The conversion helps change the format and add supporting data. The journal is assembled into a graph to form an activity flow, where each actor and activity becomes a node. The graph becomes the basis for visualizing the flow of activities using storycharts. The flow of visualization stages using a storychart is depicted in Fig. 7.

1) *Dataset*

We implement storycharts using events about badminton matches. Selecting a famous athlete as the main character. We collect data related to the main character's matches, especially the final matches in each tournament. We collected Markus F. Gideon match data from 2009 to early 2018. We chose badminton because the Badminton World Federation hosts many tournaments every year so that we can get a series of events in a short period. Second, badminton has singles and doubles. An athlete is allowed to compete at several parties in a tournament. He can play multiple roles as singles and doubles athletes in one tournament. It can be used to analogize the activities of individuals or teams, shifts from one team to another, and changes from individuals to team members or vice versa. Some tournaments hold matches between groups. The group is affiliated with a country where several athletes represent the country. Athlete affiliation is used to analogize the individuals activities who represent an institution.

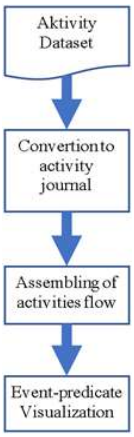


Fig. 7. Experimental stages of using storycharts for activity data visualization.

We get five data elements: player, action, score, tournament, location, and time. Table 2 contains a part of the dataset. The player consists of the main character (*actor01*) and the opposing player (*actor02*). Scores (*activity result*) are written in an *xx-yy* format, where *xx* is the main player's score, and *yy* is the opposing player's. The setting of an occurrence consists of the *event name*, *location*, and *time*.

Each element was given a visualization priority. Priority is given based on the importance of the data element. Elements with high priority will always be displayed in the visualization space. *Time* and *actor* elements are given high priority. *Time* is always displayed because it is used as the narration time. Likewise, *actors* are always displayed in the visualization space because actors are the actors of the activity. *Middle priority* is assigned to *actions* and *results* elements. *Event name* and *location* elements are categorized under low priority. Connectors display the middle and low priorities. Elements with low priority will be hidden when the storychart is in simple mode.

2) *Convert to Activity Journal*

The data obtained tend to show match activity without supporting data (see Table 2). Supporting data is challenging to find because the mass media rarely expose this information. Storycharts need data about the time anchored in the activity (such as team formation, members leaving the team, and the beginning and end of the activity). We added a join activity for the new team to meet the lack of supporting data. The join is inserted before the first activity of the new team. The joining time equals to the time of the team's first activity.

Storychart adds disjoint activities to accommodate team members moving to other teams or leaving the team to become a single actor. The disjoint activity is pinned between the old and new teams (teams or singles). The time label is taken from the new activity after the split. We added start-activity as a marker that an actor is active the first time. The start time is adjusted to the time of the first match. Added end-activity as a

Table 2
ELEMENTS OF ACTIVITY JOURNALS IN STRUCTURED DATA FOR STORYLINE PREPARATION MATERIA

Actor01	Actor02	Score	Event Name	Location	Time
Marcus F. Gideon	Joe Wu	17–21, 21–8, 21–15	Victorian International	Australia	2009
Marcus F. Gideon / Agripina P. Rahmanto	Lukhi A. Nugroho / Kevin S. Sukamuljo	21–17, 21–9	Singapore International	Singapore	2011
Marcus F. Gideon / Agripina P. Rahmanto	Takeshi Kamura / Keigo Sonoda	17–21, 23–21, 18–21	Osaka International	Japan	2012
Marcus F. Gideon / Agripina P. Rahmanto	Ricky K. Suwardi / Muhammad Ulinnuha	12–21, 19–21	Vietnam International	Vietnam	2012
Marcus F. Gideon / Agripina P. Rahmanto	Tarun Kona / Arun Vishnu	21–18, 21–18	Iran Fajr International	Iran	2012
Marcus F. Gideon / Markis Kido	Koo Kien Keat / Tan Boon Heong	21–16, 21–18	French Open	French	2013
Marcus F. Gideon / Markis Kido	Selvanus Geh / Kevin S. Sukamuljo	21–17, 20–22, 21–14	Indonesia Masters	Indonesia	2014
Marcus F. Gideon / Gabriela Stoeva	Jones Rafli Jansen / Cisita Joity Jansen	21–17, 17–21, 12–21	Turkey International	Turkey	2014

Table 3
ELEMENTS OF ACTIVITY JOURNALS IN STRUCTURED DATA FOR STORYLINE PREPARATION MATERIA

Actor	Action	Time	Result	Event Name	Location
[Marcus F. Gideon]	Start	2009			
[Joe Wu]	Start	2009			
[Marcus F. Gideon] # [Joe Wu]	Match	2009	17–21, 21–8, 21–15	Victorian International	Australia
[Agripina P. Rahmanto]	Start	2009			
[Joe Wu]	End	2009			
[Lukhi A. Nugroho]	Start	2009			
[Kevin S. Sukamuljo]	Start	2009			
[Marcus F. Gideon] # [Agripina P. Rahmanto]	Join	2011			
[Lukhi A. Nugroho] # [Kevin S. Sukamuljo]	Join	2011			
[Marcus F. Gideon / Agripina P. Rahmanto] # [Lukhi A. Nugroho / Kevin S. Sukamuljo]	Match	2011	21–17, 21–9	Singapore International	Singapore
[Takeshi Kamura]	Start	2011			
[Keigo Sonoda]	Start	2011			
[Takeshi Kamura] # [Keigo Sonoda]	Join	2011			
[Lukhi A. Nugroho / Kevin S. Sukamuljo]	Disjoin	2011			
[Marcus F. Gideon / Agripina P. Rahmanto] # [Takeshi Kamura / Keigo Sonoda]	Match	2012	17-21, 23–21,18-21	Osaka International	Japan
[Lukhi A. Nugroho]	End	2012			
[Takeshi Kamura / Keigo Sonoda]	End	2012			
[Ricky K. Suwardi]	Start	2012			
[Muhammad Ulinnuha]	Start	2012			
[Ricky K. Suwardi] # [Muhammad Ulinnuha]	Join	2012			
[Marcus F. Gideon / Agripina P. Rahmanto] # [Ricky K. Suwardi / Muhammad Ulinnuha]	Match	2012	12–21, 19–21	Vietnam International	Vietnam
[Tarun Kona]	Start	2012			
[Arun Vishnu]	Start	2012			
[Tarun Kona] # [Arun Vishnu]	Join	2012			
[Marcus F. Gideon / Agripina P. Rahmanto] # [Tarun Kona / Arun Vishnu]	Match	2012	21–18, 21–18	Iran Fajr International	Iran

marker that an actor is no longer active. The time to end is equal to the time of the last activities of an actor. The addition of supporting data is called normalization. Table 3 is the activity journal after normalization. Rows with a gray background indicate the original data, and white means additional data from normalization.

Algorithm 1 describes the normalization process. Normalization begins with initializing global variables (*groups*, *starts*, *ends*, *activities*, and *logs*) with an empty set (line 2). Global variables are repositories for storing similar activities (variable activity) and entities (*group*, *start*, *end*). All activities and entities function as nodes that are assembled into a graph.

Algorithm 1: Storyline Normalization

```
   Data: Data list of interaction tuples
   Result: graph of storyline
1  begin
2      set variable groups, starts, ends, activities, log to
         empty list
3      foreach tuple of Data do
4          newGroups ←read groups from tuple
5          newActors ←read actors from tuple
6          type ←read Type from tuple
7          newInteraction ←create interaction with type
8          if newActor is team then
9              CreateJoinInteraction
10         else
11             CreateSingleInteraction
```

The special log contains the status of each entity. After initialization, the process reads all tuples (line 3), extracts each activity element (lines 4-7), then normalizes as a single actor or team (lines 9-13).

Algorithm 2 describes the data normalization process for a single factor. The first step is to verify the presence of the group in groups. A new *group* and *actor* are created if the group never existed, connecting the actors with the interaction (lines 3-6). The actor's activity is recorded in ActiveActor (line 7). If the group is already available, make sure the actor has become a group member (line 10). If the actor is not already a group member, create a new actor in the group, connect the actor to the interaction, and record the actor in the ActiveActor log

Algorithm 2: CreateSingleInteraction

```
   input : GroupName, ActorName, interaction
1  begin
2      group ← lookup GroupName in groups
3      if group not found then // create new group
         and new actor
4          group ← groups.add(GroupName)
5          newActor ←
             createNewActor(group, ActorName)
6          set connection new actor for
             newActor, interaction
7          logging newActor in ActiveActor
8      else
9          actor ←lookup actor in group by ActorName
10         if actor ∉ group then
11             newActor ←
                 createNewActor(group, ActorName)
12             set Connection new actor for
                 newActor, interaction
13             logging newActor in ActiveActor
14         else
15             apActor ← log.searchPassiveActor(actor)
16             if apActor ∉ PassiveActor then
17                 insertInteraction(actor, interaction)
18             else
19                 oldTeam ← apActor.getChild()
20                 newDisjoin ← createDisJoin()
21                 addInteraction(newDisjoin)
22                 set connection between oldTeam to
                     newDisjoin
23                 set connection between newActor on
                     newDisjoin to interaction
24                 set connection between member oldTeam
                     except newActor on newDisjoin to
                     newEnd
25                 log.delActiveActor(oldTeam)
26                 ends.remove(endofoldTeam)
27                 log.ActiveActor(memberexceptnewActor)
28                 ends.add(allnewEnd)
29             log.ActiveActor(newActor)
```

(lines 11 to 13). If the actor has become a group member and is still active, connect the actor directly to the interaction (line 17). If the actor is inactive, this condition indicates that he has become a team member. For this, actors must be removed from the team with scenes: insert disjoints, connect the team with disjoints, connect actors from disjoint to interaction, and connect the other team members from the disjoin with the end node (lines 19-24). Lines 25-26 are the step of registering members on ActiveActor.

Algorithm 3 normalizes a team's data. Algorithm 3 is the same as Algorithm 2, but there are a few additional steps. First, insert a join-interaction for creating a new team (lines 6-8, 14-16, and 24-26). Rows 28-30 are moving members who have been on another team. Lines 31-34 connect newTeam with interaction, then newTeam is logged in ActiveActor.

3) *Activity Flow Assembly*

Assembly is the process of building a storychart chart. The process is executed from the start node of the first sequence stored in the global variable starts. The start node is given the current actor's starting coordinates and color identity. After the start node is complete, the process reads the next pointer on the start node for reference to move forward to the next node. If the Assembly is the process of building a storychart chart. The process is executed from the start node of the first sequence

Algorithm 3: CreateJoinInteraction

```
   input : GroupName, Members, interaction
1  begin
2      group ← lookup GroupName in groups
3      if group ∉ groups then
4          group ← add new group with (GroupName) to
             groups
5          newTeam ← createNewTeam
             (group, Members)
6          newJoin ← create new join interaction of
             newTeam
7          newJoin.when ← interaction.when
8          addInteraction(newjoin)
9          addInteraction(interaction)
10     else
11         newTeam ←lookup team in group by Members
12         if newTeam ∉ group then
13             newTeam ← createNewTeam
                 (group, Members)
14             newJoin ← create new join interaction of
                 newTeam
15             newJoin.when ← interaction.when
16             addInteraction(newjoin)
17             addInteraction(interaction)
18         else
19             activityActive ←
                 log.searchActivelog(Members)
20             if activityActive ∈ Activelog then
21                 insertInteraction(newTeam, interaction)
22                 addInteraction(interaction)
23             else
24                 newJoin ← create new join interaction
25                 newJoin.when ← interaction.when
26                 addInteraction(join)
27                 addInteraction(interaction)
28                 foreach actorName ∈ Members do
29                     Change actorName to newTeam
                         with group, newjoin
30                 set connection between newTeam to
                     interaction
31                 endTeam ← create End
32                 set connection between interaction to
                     endTeam
33                 log.ActiveActor(newTeam)
```

stored in the global variable starts. The start node is given the current actor's starting coordinates and color identity. After the start node is complete, the process reads the next pointer on the start node for reference to move forward to the next node.

4) *Visualization*

The storychart in Fig. 1 is organized using the data from rows one through four of Table 2. Markus F. Gideon and Joe Wu face off in singles. The second activity was the match between the Markus F. Gideon/Agripina Rahmanto team against the Kevin Sukamuljo/Lukhi Nugroho team. Since both are new teams, the normalization process inserts the join-activity before the match-activity. Join activity only has an action element without supporting information because the join activity is obtained from the normalization process. The join activity results in the change of an individual actor into a team symbolized by a dashed line. The color of the solid line becomes the color of the strip on the dashed line.

D. Quality Assessment of Activity Flow Visualization

This section presents the storychart quality assessment. This paper assesses the quality from the reader's perception of the ease of recognizing team members and changes in meaning between modes. For the assessment, we developed two closed questionnaires:

- a questionnaire to assess the quality of team member channels.
- a questionnaire to assess meaning reduction between modes.

Both questionnaires were distributed through parallel surveys after being validated by colleagues. Each questionnaire consisted of filter and perception sections. The filter section contained questions about the reader's understanding of the story narrated by the storychart. The perception assessment section contained questions to receive participants' opinions.

1) *Score to Filter Perception*

The questions in the filter section were used to obtain participants' literacy assessment of the story narrated with storycharts. The questions related to the story of *Markus F. Gedion's career journey* are narrated using storycharts. Each question provides storychart fragments as reading media to help participants find answers. The question's preparation in the filter section refers to the visual literacy model [34], [35].

Literacy score is used as a threshold value to eliminate participants. This paper uses the average literacy score as the threshold value. We use the mean as a threshold because the mean can be used to differentiate group members [36]. The perception assessment only involves perceptions from participants who passed the threshold. We assume that participants who pass the threshold can read the storychart and understand the content. This filter ensures that perceptions are obtained from people who can read the stories in the storycharts.

$$CS = R - \frac{W}{C-1} \quad (1)$$

$$NS = \frac{CS}{N} \times 100 \quad (2)$$

The literacy score (*CS*) is obtained from the number of correct answers (*R*) corrected by possible guessed answers. The correct score is obtained from the number of wrong answers (*W*) divided by the number of wrong answer options in each question [37]. Formula 1 to get the literacy score. A normalized score (*NS*) is the scaling of literacy scores to a range of 0 to 100. Normalized scores are obtained using Formula 2, where *N* is the number of questions.

2) *Perceptions of Team Identification Ease*

The ease of team identification was assessed by comparing two storycharts. The first storychart uses a uniquely colored solid line to visualize single actors and teams (old channel). The second storychart uses a solid line to visualize a single actor and a dashed line to visualize the team (proposed channel). The identity of the team members is combined into a stripe color within the dashed line.

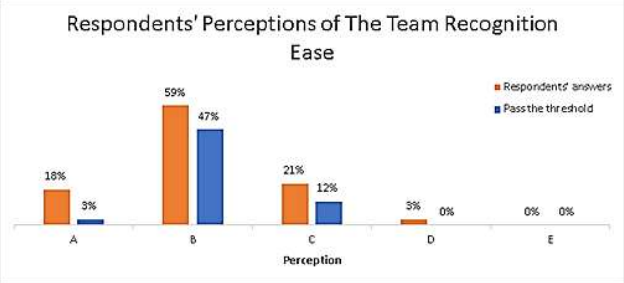
The perception section contained questions to compare the two actor channel models (single and team). The perception questions were accompanied by two storycharts (old and proposed channels). The questions asked for participants' opinions regarding the ease of team recognition. Each question provided five answers, of which four answers were about comparison perceptions, and one answer was "*no choice that matches my perception*". The four perception options consisted of: *both equally easy*, *both equally difficult*, *solid line easier for team detection*, and *dashed line easier for team detection*. The fifth option allowed participants whose perceptions did not match the four options. The ease of identifying teams was assessed through the percentage of participants' perceptions.

The filter section contained pairs of questions asking about the same story elements. Each pair contained: one question accompanied by a storychart with a solid line team channel (old channel) and another question accompanied by a dashed line team channel storychart (proposed channel). The storychart in each of questions narrates the same story fragment.

3) *Perception of Meaning Reduction*

The where, when, and what elements are visualized with connectors. The translation of story elements into visualization channels will experience a reduction in meaning. Therefore, we measure the reduction in the meaning of the stories narrated by storycharts. Two comparisons measure changes in meaning. The first comparison compares the detailed mode storychart with the story narrated with the text. Second, compare the detailed mode storychart with the simple and summary mode storychart.

The perception section contains 10 questions to assess meaning reduction. Comparison of storychart detail mode with modes: simple (4 questions), summary (3 questions), and text narration (3 questions). Questions are accompanied by a detailed storychart mode and comparison mode, where both storycharts narrate the same story. Each question provides 5 answer choices consisting of 4 choices about meaning reduction, and the answer *"no choice is the same as my perception*". The answers to meaning reduction consist of the following: *the two storycharts have the same meaning*, *the meaning of the two storycharts is the same even though the story's details are reduced*, *the two storycharts have different meanings*, and *the two storycharts do not narrate the same*



A) a solid line makes teams easier to identify than a dashed one.
B) a dashed line makes it simpler to recognize teams than a solid line.
C) solid and dashed lines make teams simple to identify.
D) solid and dashed lines make it difficult to distinguish between teams.
E) No comments.

Fig. 8. Comparison of participants' perceptions of ease of team channel identification.

story. The fifth answer is a space for respondents whose perceptions are not in the available choices.

The filter section contains 12 single-channel questions and 8 activity analysis questions. Single-channel questions ask for information within a channel, while analysis questions ask for information about the interactions of multiple actors. Each question had five answers: *one correct answer*, *three incorrect answers*, and the answer "*did not find the answer from the diagram*". The questionnaire provided a fifth answer to allow space for participants who could not find the answer in the fragment that accompanied a question. The fifth answer is helpful to avoid participants choosing answers randomly.

III. Result and Discussion

Participants in the first and second surveys had never been familiar with storycharts. Participants got to know the storychart through the introduction to the questionnaire in the storychart reading instructions section. Participants from various professions have experience in using diagrams, making diagrams, and writing stories or news. The majority of participants are between 26 to 45 years old. The perception survey to determine the model of the team channel involved 34 participants, while the survey to assess meaning reduction involved 83 participants.

A. Ease of Team Identification

Most participants for team identification can understand the story narrated with the storychart. Participants obtained a mean control score of 81.62 (σ=27.86), where the control score was calculated using formula 2. The control score achievement shows that participants can read storycharts that use dash lines and solid lines for team channels. A total of 62% of participants were able to achieve a control score above the mean and first quartile. 6% of participants achieved a control score of 6.25, where the rparticipant's score deviated from that of most other participants. Additionally, 6% of participants got the minimum control score (37.50). These participants achieved a meager control score. They may have limitations in reading visual media, or participants were reluctant to complete the questionnaire.

Based on the control score, the threshold for selecting the team channel form was 81.62. Participants who passed the threshold were 62%. The selection of the team channel form

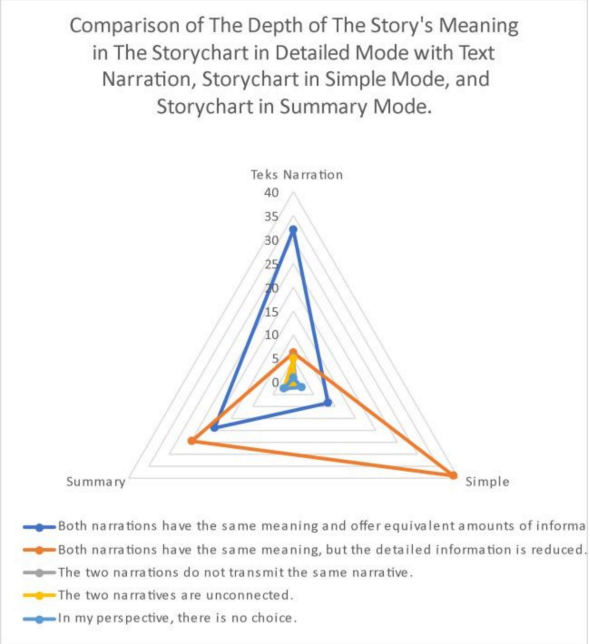


Fig. 9. Comparison of perceptions of meaning reduction between detailed mode storycharts, with text narration, simple mode storycharts, and summary mode storycharts.

only considers the perceptions of participants who pass the threshold. Fig. 8 shows the comparison between the overall participants' answers and the answers that pass the threshold. The following are the perceptions of participants who are selected by the threshold limit:

- Solid lines make it easier to identify teams (*perception A*) was selected by 6 participants, but only 1 passed the threshold. The interview results showed that participants wanted a simple diagram.
- Dash lines facilitate team identification (*perception B*) was chosen by 20 participants. 16 of those 20 participants passed the threshold. The different types of actor channels make it easier for participants to identify teams or not.
- Solid lines and dash lines make team identification easy (*perception C*) was chosen by 7 participants. 4 of these participants passed the threshold. For these participants, the shape and color of the channel did not make it difficult to identify either a team or a single actor.
- Solid line and dash line make team identification difficult (*perception D*) was only selected by 1 participant. However, this participant did not pass the threshold.
- No participants expressed no comment (*perception E*).

Participants with high visual ability could identify teams with dash lines and solid lines (perception C). Therefore, a complete picture of the team channel can be seen from the combined number of participants who chose perceptions A and B with the number of participants who chose perception C. The dashed line makes it easier to identify the team indicated by the dashed line selected by 59% of participants. In comparison, the solid line was selected by 15% of participants.

B. Reduction of Meaning

The control score for assessing meaning reduction reached a mean of 66.57 (σ=20.57). 47% of respondents scored between

the lower and upper quartile, and 28% of participants achieved more than the upper quartile. However, some participants scored less than the lower quartile. 18% of the participants scored between the minimum score (25.00) and the lower quartile (56.25). In addition, there were 7% of participants scored outside the norm. Participants who scored below the lower quartile may be due to their limited visual abilities.

A total of 60% of the participants scored above the mean. These participants passed the threshold to be included in the meaning reduction assessment. Participants generally believed there was a reduction in the meaning of the detailed mode storychart compared to the simple and summary modes. The detailed mode storychart did not experience any reduction in substance when compared to the text-narrated story. Fig. 9 compares meaning reduction between detailed mode storycharts with text narration, simple mode storycharts, and summary mode storycharts.

1) *Narrative Text versus Storychart in Detail Mode*

The detailed mode storychart can visualize the complete actor interaction. A total of 64% of participants stated that the stories visualized with the detailed mode storychart did not experience a reduction in the stories narrated with text. 13% think that the storyline in the detailed mode storychart has the same meaning as the story narrative in the text. However, the detailed mode storychart experiences a slight reduction in information. On the other hand, 11% of participants said they both narrated the same story but on different topics. 10% of the participants thought they were narrating different stories. 2% of participants chose not to express an opinion.

2) *Storychart in Detail Mode Versus Simple*

in story elements from the storyline, which is visualized in detail mode. 78% of participants said there was a reduction in story elements, but 17% thought there was no reduction. Beyond that, 1% of participants said the two told different topics. None of the participants chose the two visualizations to narrate different stories. 4% of participants said they did not have an opinion.

3) *Storychart in Detail Mode Versus Summary*

The summary mode storychart has many missing story elements compared to the detailed mode. Although 38% of participants thought there was no reduction in meaning, 49% of participants stated that there were missing story elements. The loss of story elements indicates that the story's meaning is reduced in the summary mode of storycharts. Not only were story elements missing, but participants thought the two storycharts told different stories. 3% of participants said they both told stories about different topics. 5% of those polled thought they told two different stories. 5% chose not to have an opinion.

C. Channal Comparision

We compared the storychart channels with Metro Map and MNC to determine the capabilities of each visualization model. We replicated the storychart narrating the story of Markus F. Gideon (in Fig. 1 and Fig. 3) on the storyline visualization with Metro Map (Fig. 10) and MNC (Fig. 11). Both comparisons are used to compare the visualization capabilities of each channel head-to-head. All three visualizations can visualize both single actors and teams. The actor channel in both comparisons is passive. Actors cannot change from single to team and vice versa. The join action does not cause the merging of the two actors and the disjoin action does not change the shape of the actor channel. Teams are only marked with two actor lines that are close to each other. The team marker is ambiguous with actors who interact with each other over a long period of time. Meanwhile, the join action on the storychart changes two single actor channels (solid lines) into one team channel (one dashed line).

Metro Map uses circles to represent actions. All actions are always symbolized with a circle which is why the metro map only has a few types of actions. Likewise for MNC, MNC only uses shaded circles to represent actions. The action of both comparisons can only be expanded by changing the circle to an oval or adding shading in the circle. The similarity of the shape of the action makes it difficult for readers to identify the type of action. The action can be clarified through text labels without changing the shape of the action channel. Meanwhile, storycharts use glyphs to visualize actions. The diversity of glyphs can be developed to represent various actions needed in storyline visualization.

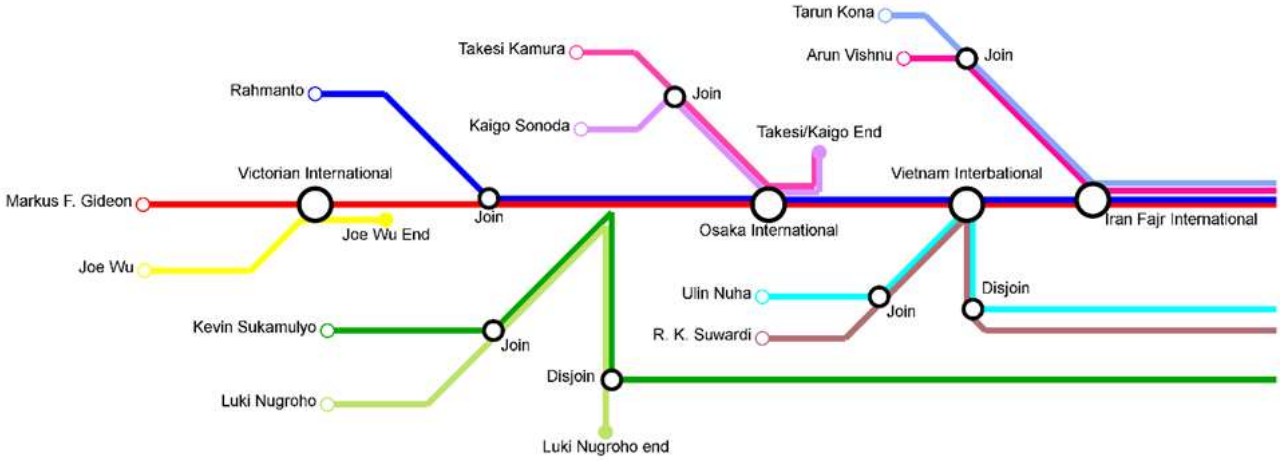


Fig. 10. Metro Map is used to visualize Markus F. Gideon's career story from 2009 to 2012.

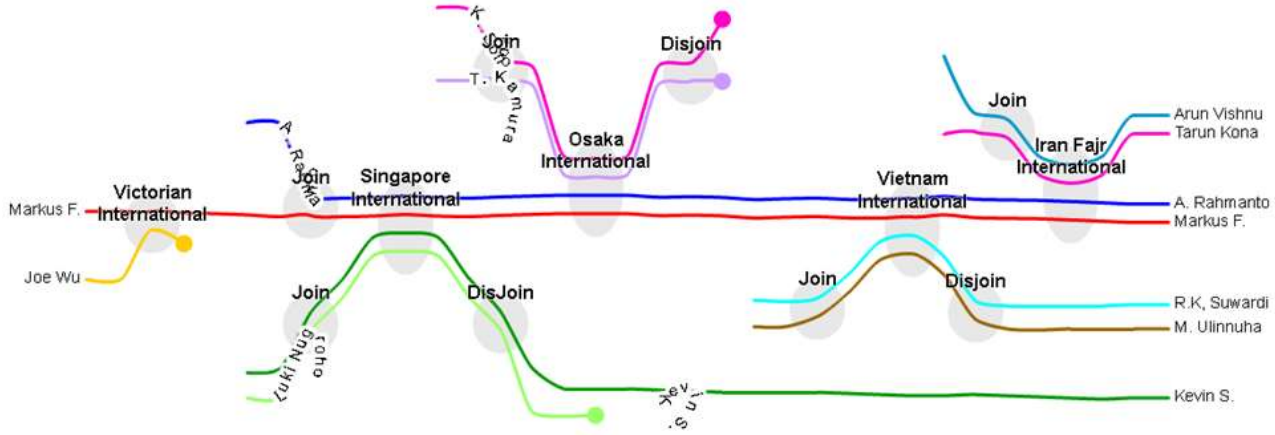


Fig. 11.. Markus F. Gideon's career story from 2009 to 2012 visualized using Movie Narrative Chart (MNC).

In addition to actions, activities in storycharts can be equipped with event-names, locations, and results. All three attributes are embedded in the activity channel with text. Especially for the simple mode storychart, it is similar to the visualization in the two comparators, but the storychart has a dynamic actor channel and actions in the form of glyphs. The simple mode storychart is easier to read than the two comparators because the action is visualized with glyphs. A summary of the comparison can be seen in Table 4.

IV. Conclusion

Storycharts visualize single actors with solid lines, and dashed lines are used to visualize teams. Storycharts add connectors to visualize activities. Both channels have successfully delivered stories to participants. The ability of the storychart is indicated by the story reading score achieved by the participants. Most participants scored above average in their ability to read the story. Participants' scores show readers can quickly identify the actor and activity channels.

We selected team channels and assessed the content of the storycharts based on the perceptions of participants with above-average reading scores. Dashed lines have made it easy to recognize teams, and dashed lines have even made it easier to identify team members. Readers can identify team members from the strip's color on the dashed line. On the content side, storycharts can tell the reader the flow of activities. The detailed mode storychart can narrate the story with the same meaning as the story narrated with text, although some readers found less activity detail. Simple mode storycharts can tell the flow of interactions between characters. Simple mode storycharts experienced a reduction in meaning compared to detailed mode storychat. We see potential in using detailed and simple modes as zooms based on data aggregation.

Storycharts can narrate the story of an activity journal, but there are some areas for improvement. Dashed-line needs to be developed to visualize multiple actors and affiliations. Storycharts do not allow characters to switch affiliations. The ability to switch affiliations will be a development focus in future research. Connectors have been able to convey activity details to the reader. However, the storychart decreases quality if the connector is simplified by reducing supporting information. Future work summarizes the content of the connector into a single glyph to make the connector more informative and straightforward.

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Table 4
Visualization Ability Comparison

Channel		Metro Map	Movie Narrative Chart	Storychart Detail	Storychart Simple
Actor	**Single**	Passive	Passive	Dynamic	Dynamic
	Team	Passive	Passive	Dynamic	Dynamic
Activity	**Action**	Circle	Circle	*Glyph*	*Glyph*
	Event	-	-	Text	-
	Location	-	-	Text	-
	Result	-	-	Text	-

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